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IN AN INDUSTRIALIZED PORTION OF THE OTTAWA RIVER NEAR OTTAWA AND HULL, CANADA

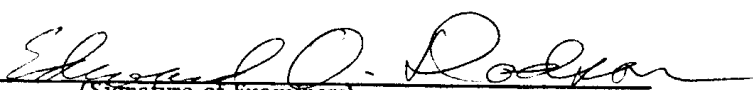
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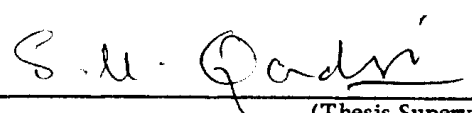
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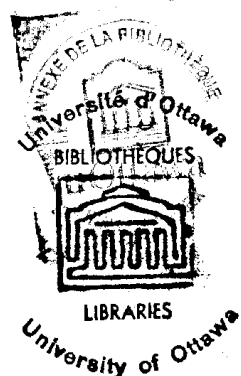
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SOME ASPECTS OF THE DISTRIBUTION AND ECOLOGY OF
MACROBENTHOS IN AN INDUSTRIALIZED PORTION OF THE
OTTAWA RIVER NEAR OTTAWA AND HULL, CANADA

by

Gerald L. Mackie

A thesis submitted in partial fulfilment of the requirements
for the degree of Master of Science at the University of
Ottawa, School of Graduate Studies.



July 1971

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The Ontario Water Resources Commission made the water chemistry determinations in 1968, Mrs. Kennedy of the Ontario Public Health Laboratories at Bells Corners made the bacteriological determinations and the Federal Inland Waters Branch supplied the data on water stages and flows of the Ottawa River. Dr. I. Ahmad of the Department of Cybernetics, University of Ottawa, gave advice and supervised the statistical treatment of the data.

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ABSTRACT

A limnological study of the Ottawa River near the cities of Ottawa and Hull was carried out in the summers of 1968 and 1969 to determine some aspects of the distribution, abundance, and ecology of macrobenthos. Stations were located in clean and polluted waters. The 672 and 514 Ekman dredge samples taken in 1968 and 1969 respectively, were complemented with chemical, physical, and bacteriological determinations of the water at each of the seven stations.

On the basis of the biochemical oxygen demand (B.O.D.), one station (Brewery Creek) was subpolluted and another (the Gatineau shores Below Canadian International Paper Co.) was grossly polluted. Of the seven stations, only Britannia Bay was not grossly polluted with coliform bacteria. There is evidence that pollution of the Ottawa River has been aggravated since 1954.

More than 150 macrobenthic species occurred in the study area. Of these, 29 are discussed with respect to their distribution between stations, their seasonal distribution during the summer, and their depth (of water) distribution.

Species which had significantly larger populations in cleaner waters than in polluted waters were the platyhelminth, Hydrolimax grisea, the oligochaetes, Pelosclex n. sp., Uncinais uncinata, and Arcteonais lomondi, the amphipod, Gammarus fasciatus, the chironomids, Pseudochironomus and Dicrotendipes, the gastropods, Amnicola limosa, Valvata tricarinata, Lymnaea catascopium, Goniobasis livescens, and Campeloma decisum, and the pelecypods, Sphaerium striatinum, Sphaerium securis, Pisidium lilljeborgi, and Pisidium

casertanum.

The subpolluted waters of Brewery Creek had significantly larger populations of the platyhelminth , Dugesia tigrina, the oligochaetes, Limnodrilus hoffmeisteri, Stylaria fossularis, Stylaria lacustris, and Dero nivea, the isopods, and the chironomids, Phaenopsectra, Chironomus, and Procladius, than had the cleaner waters. Populations of the amphipod, Hyaella azteca were similar to those in Britannia Bay. The presence of aquatic vegetation in Brewery Creek was probably most responsible for the large populations of many of these organisms.

The grossly polluted waters below Canadian International Paper Co. were inhabited only by L. hoffmeisteri and Chironomus.

Such factors as the nature of the substratum, water movement, shore morphometry, abundance of aquatic vegetation, and food and predation also probably affected the distribution of the animals. Populations of many species were temporally and spatially separated.

RESUME .

Une étude limnologique de la rivière Outaouais en amont et en aval des cités d'Ottawa et de Hull fut entreprise à l'été de 1968 et terminée à la fin de l'été de 1969 afin d'effectuer un relevé sur la distribution et l'abondance ainsi que l'écologie des invertébrés de fond. Les sept postes d'échantillonnage correspondaient à des régions d'eau polluée et non polluée; les échantillons, recueillis au moyen d'une drague Ekman (modèle 672 et 514), furent aussi soumis à des expertises chimiques, physiques et bactériologiques.

A partir des critères de la demande biochimique d'oxygène (D.B.O.), le degré de pollution du poste "Ruisseau de la Brasserie" était peu élevé tandis que le poste dans le canton de Gatineau en aval de la compagnie "Canadian International Paper Co." était très élevé. Des sept postes d'échantillonnage, seules les eaux de la baie de Britannia offraient un compte de bactéries coliformes acceptable. Il semble que le degré de pollution de la rivière des Outaouais a sensiblement augmenté depuis 1954.

Plus de 150 espèces d'invertébrés de fond ont été identifiées; la distribution de vingt-neuf de ces espèces a été étudiée en fonction des divers postes d'échantillonnage, de la profondeur d'eau et des variations saisonnières.

La densité de population des espèces suivant provenant d'eau peu polluée était de beaucoup supérieure à la densité des

mêmes espèces provenant d'eau polluée c'est à dire le plathelminthe Hydroilimax grisea, les oligochètes, Peloscolex n.sp., Uncinais uncinata, et Arcteonais lomondi, l'amphipode, Gammarus fasciatus, les chironomides, Pseudochironomus et Dicrotendipes, les gastropodes Amnicola limosa, Valvata tricarinata, Lymnaea catascopium, Goniobasis livescens, et Campeloma decusum, et les pélécy-podes, Sphaerium striatinum, Sphaerium securis, Pisidium lilljeborgi, et Pisidium casertanum.

Les populations des plathelminthes Dugesia tigrina, des oligochètes, Limnodrilus hoffmeisteri, Stylaria fossularis, Stylaria lacustris, et Dero nivea, étaient beaucoup plus élevés dans les eaux polluées du ruisseau de la Brasserie que dans des eaux moins polluées. La densité de population de l'amphipode, Hyaella azteca étaient semblable à celle de la baie de Britannia. La présence d'une végétation aquatique dans le ruisseau de la Brasserie est probablement la cause principale de la forte densité de population de plusieurs de ces organismes.

L. hoffmeisteri et Chironomus étaient les seuls organismes présents dans les échantillons provenant des eaux hautement polluées en aval de la "Canadian International Paper Co."

La composition du lit de la rivière, les courants la morphométrie des rivages, l'abondance de la végétation aquatique, les diverses sources de nourriture ainsi que le phénomène de prédation ont probablement tous joué dans la distribution des ces organismes. Des variations saisonnières et territoriales ont été notées chez les population de plusieurs espèces.

INTRODUCTION

The Ottawa River is one of the largest fresh water rivers in Canada and serves as the interprovincial boundary between Ontario and Quebec. It begins as the principal drainage system of Lake Timiskaming and forms a 1113 km (696 miles) tributary of the St. Lawrence River. Piché (1954) has estimated that the Ottawa River has a watershed of some 128,000 sq km (50,000 sq mi), about one third of which is located between Ottawa and Montreal. The particular area under investigation was that 26 km stretch between Britannia Bay (Lat. 45° 22'N and Long. 75° 53'W) and the Township of Gatineau (Lat. 45° 24'N and Long. 75° 35'W). The Ottawa River flows through sedimentary deposits of limestone, sandstone and shale, all of which are superimposed on ancient Precambrian rock (Wilson, 1956).

Several investigations have been carried out on the Ottawa River (Thomas, 1952; Piché, 1954; Le Sauter, 1965; Barrens, 1961). Most of these were oriented towards the chemical assessment of pollution by measuring dissolved oxygen, biochemical oxygen demand (B.O.D.) suspended solids, and/or ammonia. As is usual in the chemical assessment of pollution, they took no particular account of the details of biological effects which are probably a better measure of pollution. To quote Hynes (1960), "Chemical analyses are at best an indirect measure of the basic biological properties of the water." Moreover, an assessment of biological communities is more representative of prevailing conditions than are chemical measurements which reflect only the instantaneous conditions. A chemist may sample the water during discharge of an effluent

or he may miss the discharge altogether. Thus prevailing conditions would not be truly represented.

To alleviate this lack of data on the biological effects of pollution in the Ottawa River, a program was initiated under the supervision of Dr. S. U. Qadri. Because two pulp and paper plants (E. B. Eddy Co., and Canadian International Paper Co.,) are close to Ottawa, the program was restricted to this immediate area. There are also slaughter house (Canada Packers Ltd.) outfalls in Hull, and several raw sewage outfalls from Hull, Gatineau Pointe, Gatineau Township, and Ottawa which would permit a comparison of the biological effects of three types of pollutants. The first study to be completed under this program was a study of the effect of pollution on the growth of perch, Perca flavescens (Stobo, M S. 1971). The effects of pollution on the abundance and growth of other fish species are presently being evaluated.

I chose to study the distribution, abundance and ecology of the macrobenthos of the Ottawa River because the macroinvertebrate fauna of the area of the Ottawa River is not well known, and undescribed species and range extensions of certain species exist.

Also, the abundance and distribution of the macroinvertebrates is not known. Quantitative data on macrobenthos are needed for any biological assessment of pollution using bottom organisms and it also provides useful material to the taxonomist who is interested in obtaining enough specimens for a statistical analysis.

A third reason for a benthological survey was to provide some ecological data that were desperately wanting for many invertebrate species. An understanding of the seasonal and depth distributions of the

benthos is essential for correctly interpreting the pollution status of an aquatic system. Such environmental factors as the chemistry and physics of the water and the nature of the substratum must also be evaluated to understand better the structure and function of the aquatic ecosystem.

Fourth it is desirable to establish a guideline for future benthic studies in evaluating the deterioration (or recovery) of the macrobenthic communities. In benthic studies, the guideline should ideally be represented by the benthic communities that prevailed prior to the introduction of a pollutant. More often than not, however, the ecosystem has suffered environmental deterioration long before the natural communities have been assessed. In this case the biologist can examine the communities immediately upstream of the outfalls if the environmental conditions are the same as they were downstream prior to pollution. If no such biotope (as used by Macan, 1964) exists he must accept the communities of existing conditions as his guideline.

Lastly, certain benthic organisms are valuable indices in assessing pollution as Richardson (1921, 1929), Gauffin and Tarzwell (1952, 1955), Wurtz (1955), Brinkhurst (1965), and several European workers, have clearly demonstrated. The widespread use of benthic organisms in assessing pollution is probably due to the ease with which they are collected and identified. Such attributes cannot be demonstrated for fish, algae or periphyton. There are certain disadvantages in using benthic organism; Hynes (1960), for example, argues that there are only a very few species that can tolerate gross organic pollution and that if a suitable substratum is not available, they do not appear. Periphyton, on the other hand, can be provided with

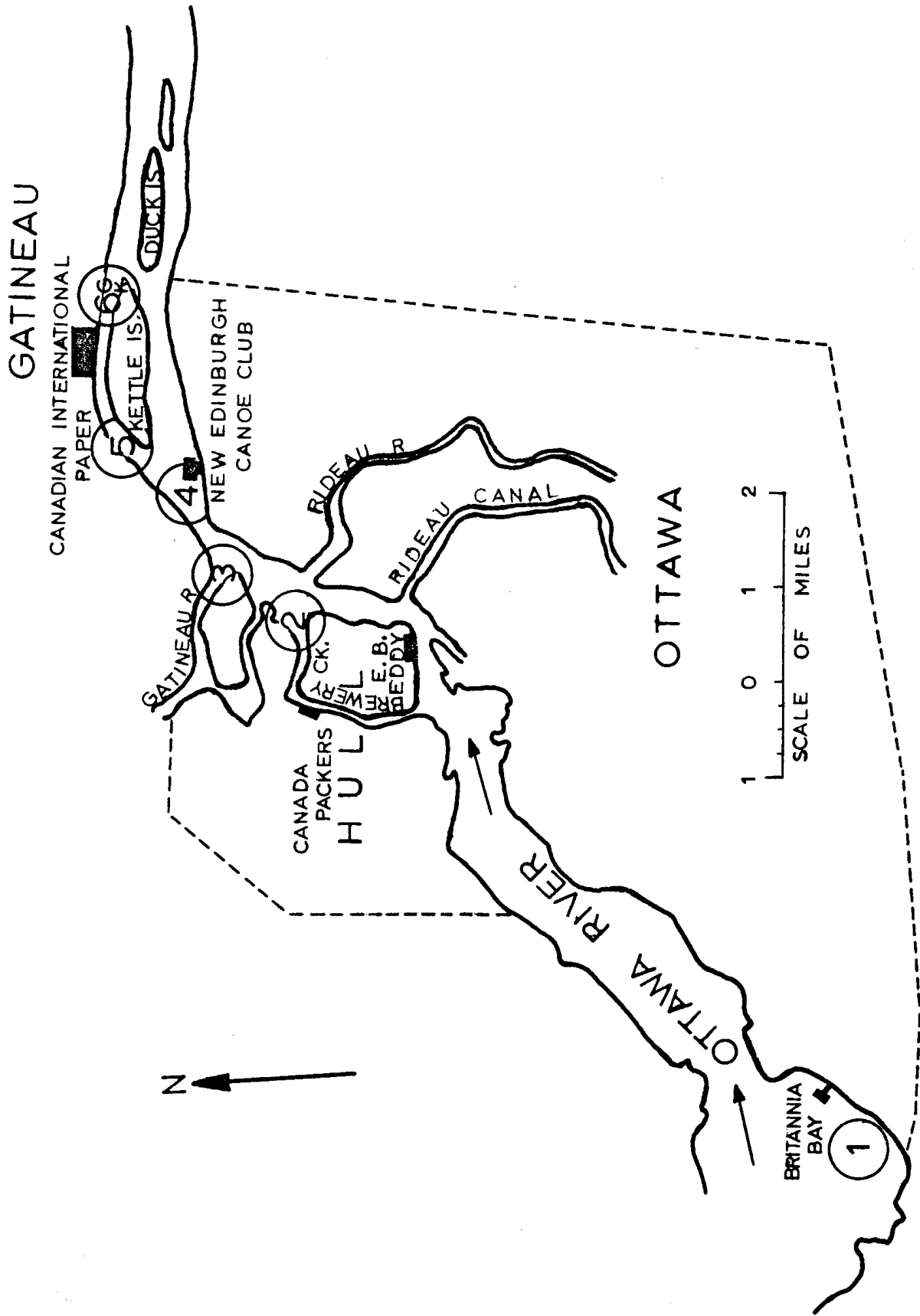
a variety of substrates (Sladeckova, 1962).

MATERIALS AND METHODS

Organization

Most of the materials and methods are described below. The study area was sampled at six stations, as shown in Fig. 1. Station 1 was located on the Ontario side of Britannia Bay and was used as a control since it received no significant amounts of industrial or domestic waste. Station 2, in 1968, was situated at the downstream end of Brewery Creek and, in 1969, extended a distance of two kilometers from a point one km below Canada Packers outfalls to the Ottawa River. A riffle area did not permit sampling immediately below the Canada Packers outfalls. Station 3, located at the junction of the Gatineau and Ottawa Rivers, was selected to determine the effects of the Gatineau River on the benthos of the Ottawa River. Station 4, situated on the Ontario side of the Ottawa River in the vicinity of the New Edinburgh Canoe Club, was chosen to evaluate conditions on the Ontario shore. Station 5 extended from the western tip of Kettle Island to the Canadian International Paper Company (CIP) outfalls and included the channel between Kettle Island and the Quebec shores; it was selected to assess the benthic communities prior to their exposure to the CIP effluents of Station 6G. The channel between Kettle Island and the Gatineau shores below the CIP outfalls was divided into two substations; Station 6G was that area from midchannel to the Gatineau shore and Station 6K was that area between midchannel and the Kettle Island shore. Stations 6G and 6K, in 1968, extended from the CIP

Fig. 1.. The Ottawa River study area and the locations of the stations.



outfalls to the eastern tip of Kettle Island; in 1969; from the CIP outfalls to a point 8 km downstream. Since the effluents were restricted mainly to the Gatineau shore by the flow of the water through the CIP channel, only that shore was used to assess the effects of the CIP effluents on the benthic communities; this was achieved by comparing these communities with those of Stations 5 and 6K. Other characteristics of each station are given in Table 1.

Water Chemistry

Chemical analyses of the water at each station entailed either weekly, biweekly, or monthly determinations of twenty chemical parameters. The method of analysis and the sampling frequency for each parameter are described in Table 2. The pH, carbon dioxide, dissolved oxygen, and conductivity were determined directly at the site, the remaining parameters being determined at the laboratory. Measurements were made for both bottom and surface waters, the bottom being collected approximately 30 cm (one foot) above the substrate with a 4 litre Van Dorn water sampler. Four of the parameters (copper, zinc, manganese, and sulfides) frequently yielded negligible results and were discontinued in the 1969 analyses. As shown in Table 2, the Ontario Water Resources Commission made most of the chemical analyses in 1968. In 1969 a Direct Reading E. L. Hach Chemical Kit and the 4th edition instruction manual were used.

Water Physics

The physical parameters examined were temperature, water

Table 1. Some characteristics of each station in the Ottawa River study area. Frequency of aquatic plant species given as percent occurrence in Ekman dredge samples collected in 0 to 2 m depths.

Stations and morphometry	Substrate type	Frequency of submerged aquatic plants	Pollutants
1. Britannia Bay - Control (Ontario shore) Area = 2.4 km ² Mean depth = 1.7 m Shore slope = 0.3 m/15 m	Very fine sand.	<u>Potamogeton</u> spp. 70% <u>Elodea canadensis</u> 3 <u>Myriophyllum</u> sp. 2 <u>Vallisneria americana</u> 1	Relatively clean with few industrial effluents.
2. Brewery Creek ₂ Area = 0.2 km ² Mean depth = 2.0 m Shore slope = 1 m/15 m	Fine sand overlain with a thick layer of plant and animal detritus.	<u>E. canadensis</u> 46 <u>Myriophyllum heterophyllum</u> 2 <u>M. alterniflorum</u> 2 <u>V. americana</u> 2	Organic pollution from Canada Packers and untreated sewage from Hull.
3. Gatineau River Area = 0.3 km ² Mean depth = 2.7 m Shore slope = 1.3 m/15 m	Very fine to coarse sand overlain with a thin layer of plant debris.	<u>M. heterophyllum</u> 25	Bark from logbooming, wood-chips, and raw sewage from Gatineau Pointe.
4. New Edinburgh ₂ Canoe Club Area = 0.2 km ² Mean depth = 2.8 m Shore slope = 1.5 m/15 m	Mud to fine sand overlain with thick layers of woodchips and/or organic detritus.	<u>V. americana</u> 15 <u>E. canadensis</u> 10	Diluted sewage from Hull and Gatineau Pointe. Diluted effluents from Canada Packers.
5. Canadian International Paper (Above outfalls) Area = 0.3 km ² Mean depth = 3.5 m Shore slope = 2.5 m/15 m	Fine sand with little plant debris.	<u>V. americana</u> 25 <u>E. canadensis</u> 1	Diluted sewage from Hull and Gatineau Pointe. Diluted effluents from Canada Packers.
6. Canadian International Paper 6G. (Below outfalls). Gatineau shores. Area = 0.6 km ² Mean depth = 3.2 m 6K. Kettle Island shores Area = 0.3 km ² Mean depth (6G, 6K) = 3.2 m Shore slope = 1.5 m/15 m	Thick layer of wood- Fine sand with thick layer of woodchips and some woodfibers.	No plants. <u>V. americana</u>	Woodfibers and chemicals from Canadian International Paper. Untreated sewage from Gatineau Township. Dilution of pollutants in in Station 6G.

Table 2. Methods and frequencies of chemical analyses of the Ottawa River water during the summers of 1968, 1969.

Chemical parameters	Analytical methods		Sampling frequency	
	1968	1969	1968	1969
pH	Hach Chemistry Kit.	Hach Chemistry Kit.	Weekly	Weekly
Carbon dioxide			"	"
Dissolved oxygen	"	"	"	"
Conductivity	Ontario Water Resources Commission.	Beckman Cond. Meter.	Biweekly	"
B.O.D.		Hach B.O.D. Apparatus.	"	Monthly
Alkalinity	"	Direct Reading E.L.	"	Biweekly
Calcium	"	Hach Chemical Kit.	"	No chemicals
Chloride	"		"	Biweekly
Detergent	"	"	"	Discontinued
Hardness (Ca)	"	"	"	Biweekly
Iron	"	"	"	"
Nitrate Nitrogen	"	"	"	"
Nitrite Nitrogen	"	"	"	"
Phenols	"	"	"	Discontinued
Phosphates (Ortho)	"	"	"	Biweekly
Sulfates	"	"	"	"
Copper	"	Discontinued	"	Discontinued
Zinc	"	"	"	"
Manganese	"	"	"	"
Sulfide	"	"	"	"

velocity, turbidity, and direction of current flow. The temperature was determined weekly on both bottom and surface waters using a thermistor. Water stage and flow data, supplied by the Federal Inland Waters Branch, Department of Mines and Technical Surveys, Ottawa were used to compute average water velocity. Water turbidity was recorded as depth of light penetration, using a 20 cm Secchi disc, and as Jackson Turbidity Units, using the Direct Reading E. L. Hach Chemical Kit. The direction of current flow was determined by observing the path of three plastic bottles partially filled with sand and joined by three metres of rope.

Sediment Analyses

A K. B. Core sampler (from Wildlife Supply, Michigan), with an inside diameter of 5.1 cm, was used to take substrate samples for sediment analyses. Three random cores, each 10 cm deep, were taken of sediments in the 0 to 2 metre depths at each station. After separating the animals, each core sample was air dried and screened through a nest of seven mesh sizes viz., 4.0, 1.0, 0.5, 0.25, 0.125, 0.0625 and 0.0039 mm mesh openings. These mesh openings were selected to permit classifications of the particle sizes in Phi units, as recommended by Cummins (1962). The substrate particle size terminology and the Phi scale used are given in Table 3. Dry volumes and weights of each size class were then determined so that densities and percent particle sizes could be calculated.

Table 3. Terminology of particle sizes and the Phi scale classification

Substrate type	Particle size mm	Phi scale
Gravel	16.0-2.0	-3, -2, -1
Very coarse sand	1.0-2.-	0
Coarse sand	0.5-1.0	1
Medium sand	0.25-0.50	2
Fine sand	0.125-0.250	3
Very fine sand	0.0625-0.125	4
Silt	0.0625-0.0039	5, 6, 7, 8,
Clay	less than 0.0039	9

Bacteria

Bottom and surface water samples from each station were taken approximately every two weeks and sent to the Ontario Public Health Laboratories where the Most Probable Number (MPN) per 100cc of total coliform and total fecal coliform bacteria were determined.

Macrobenthos

In 1968 a stratified random sampling technique was used to sample as many habitats as possible, the criteria being the presence or absence of aquatic vegetation, distance from industrial outfalls, accessibility to each site by boat, the nature of the substratum, and water movement. Slower moving waters were selected because the Ekman dredge (discussed below) worked optimally under these conditions. The

depth distribution of the benthos was determined by sampling three zones at each site: a shore zone represented by the 0 to 2 meter depth, a middle zone by the 2 to 3 meter depth and an inner zone by depths greater than 3 meters. Usually three samples were taken from each zone (depth) and combined. A total of 672 Ekman dredge samples were taken in 1968.

The stratified random sampling technique (1968) was not conducive to seasonal nor depth distribution analyses of the various benthic species since different depths and sites were sampled each week. Seasonal and depth distribution analyses are more reliable when one samples only those habitats that are highly productive in the species being investigated. Consequently, only the two most productive sites from each station of 1968 were sampled in 1969. Because of the pollution in Stations 6G and 6K several sites were again sampled in 1969. Due to bad weather, one sampling period was missed at Stations 3 and 4 in 1969 so that seasonal data is incomplete for these stations. Since as many as eight different depths were sampled at any one site and date, the zone structure employed in 1968 was not strictly adhered to in 1969. Three Ekman dredge samples were taken at each depth and combined. A total of 514 samples were taken in 1969.

A 15 x 15 cm Ekman dredge, with a screen on top, was used to secure the bottom samples. The results of Sly (1969) and Flannagan et al (1969) were instrumental in the selection of the Ekman dredge used for this investigation. They found that the Ekman dredge was more efficient in soft sediments than the Ponar, Shipek, Petersen, Dietz Lafond, or the Franklin-Anderson grabs. Moreover, the Ekman dredge is light in weight, facilitating the acquisition of a greater number of

samples per unit time (Welch, 1948; Cochran, 1953), and is much easier to manipulate than the heavy Ponar, Shipek, or Petersen grabs. The results of Paterson (1969), Hudson (1970), and Flannagan (1970) also support the use of the Ekman dredge in soft sediments.

The combined sample was washed through a nest of two sieves, the lower sieve having mesh openings of 0.37 mm and the upper having mesh openings of 2.8 mm. A 0.20 mm mesh size, recommended by Jonasson (1955) for washing sediment samples, were not used because of the increase in time required to wash the samples, as shown by Reisch (1955). The procedure employed to wash the samples followed that outlined by Mackie and Qadri (1971 a). The washed samples were stored in either 16 or 164 oz jars and kept in a cold room at 5°C until ready for separation of the macroinvertebrates. Storage in the cold room varied from one to three days. The animals were hand-picked from the associated debris and preserved in 70% ethanol according to major taxonomic groups (Platyhelminthes, Oligochaeta, Polychaeta, Hirudinea, Isopoda, Amphipoda, Insecta, Hydracarina, Gastropoda, and Pelecypoda). Other techniques (Moon, 1935; Anderson, 1959; Slack, 1965; Whitehouse and Lewis, 1966; Hamilton 1969) for separating the benthos from the debris were not used because of their selectivity for certain invertebrate groups. All taxa were tentatively identified to genus and if taxonomic keys were available to species. Specimens of each species were sent to people listed in Table 4 for positive identification. The species of each sample were counted and dried for weighing. Soft bodied animals did not change in weight after 16 hours at 60°F and the shelled mollusks after 48 hours at 70°F. Weights were measured in milligrams to four decimal places on a Sartorius microbalance. The absolute number and weight of each species were divided

Table 4. Authorities who identified or verified identifications of various taxa collected from the Ottawa River and the taxonomic keys used by the author: 1, Pennak (1953); 2, Brinkhurst, (1964); 3, Brinkhurst (1965); Brinkhurst and Cook (1966); 5, Ward and Whipple (1966); 6, Bousfield (1958); 7, Williams (MS, 1968); 8, Usinger (1968); 9, Roback (1957), 10, Berry (1943); 11, Herrington (1962); 12, Clarke and Berg (1959).

GROUPS	SOURCE	AUTHORITY
Platyhelminthes	1	Mr. I. Ball, University of Waterloo, Department of Zoology, Waterloo, Ontario.
Oligochaeta	2, 3, 4	Dr. D. Cook, National Museum of Canada, Ottawa, Ontario.
Polychaeta	5	Dr. M. Pettibone, Smithsonian Institution, Division of Worms, Washington, D.C., 20560.
Hirudinea	1	Dr. D. Klemm, Museum of Zoology, Mollusk Division, The University of Michigan, Ann Arbor, Michigan 48104.
Amphipoda, Isopoda	1, 6, 7	Dr. E. L. Bousfield, National Museum of Canada, Ottawa, Ontario.
Ephemeroptera, Plecoptera Odonata, Megaloptera	8	Mr. J. E. H. Martin, Canada Department of Agriculture, Research Branch, Entomology Research Institute Ottawa, Ontario.
Lepidoptera	8	Dr. M. MacKay, Ibid.
Tricoptera	8	Dr. G. Wiggins, Royal Ontario Museum, Department of Entomology, Toronto, Ontario.

Table 4. Con't.

GROUPS	Source	AUTHORITY
Coleoptera	8	Dr. E. C. Becker, Canada Department of Agriculture, Research Branch, Entomology Institute, Ottawa, Ontario.
Diptera (except Chironomidae)	8	Dr. H. J. Teskey, Ibid.
Diptera (Chironomidae)	8	Dr. D. Oliver, Ibid.
Gastropoda	1, 10	Dr. A. H. Clarke, Jr., National Museum of Canada, Ottawa, Ontario.
Pelecypoda (Sphaeriidae)	11	Rev. H. B. Herrington, Westbrook, Ontario.
Pelecypoda (Unionidae)	12	Dr. A. H. Clarke, Jr., National Museum of Canada, Ottawa, Ontario.

by the number of dredges taken for the sample and then multiplied by 44.44 to express results as number (and/or milligrams) per square meter. Animal communities are expressed in terms of both weight and number per square meter because weights and numbers more accurately show wide variations in the sizes of the organisms than do weights alone as purported by Pennak and Van Gerpen (1947).

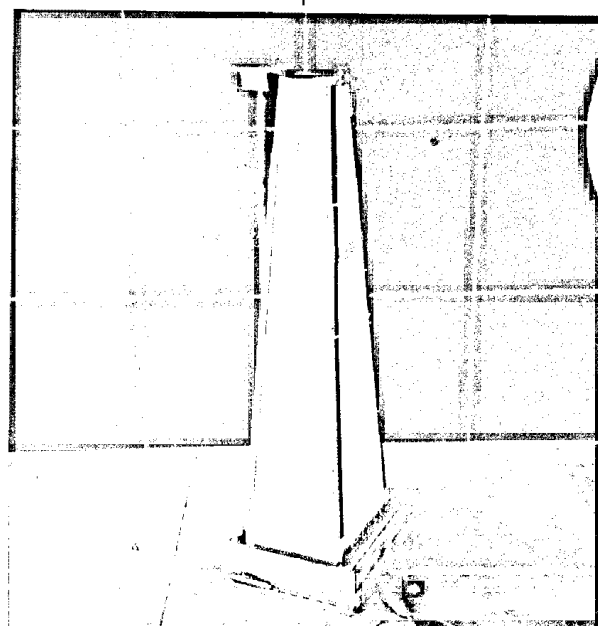
The results for analysis of benthos distribution are expressed qualitatively and quantitatively. Benthic data collected from both years were averaged for the qualitative results and considered separately for the quantitative results. The abundance of each species is expressed as percent of the total benthos at each station. Average standing crops are expressed in histograms and are used for the assessment of environmental conditions at each station. This is in accordance with Hynes (1960) who concluded that tabulations or histograms of numerical data show the effects of pollution more clearly than elaborate graphical methods (i.e. Bartsch and Churchill, 1949) which attempt to classify polluted streams into zones. Hynes (1960) also suggested that the classification of polluted streams into zones takes no account of such environmental factors as shallow and turbulent waters. In the midst of septic conditions, turbulent waters could temporarily restore oxygen levels, alter the animal communities and hence destroy the "hard-and-fast scheme" of zones. All depth and seasonal distribution studies are based entirely on the 1969 data. The habitat characteristics and the seasonal and depth maxima of the common benthic species discussed in the text, are summarized in tabular form in Appendix O.

The submerged aquatic plants in the Ekman dredge samples were identified to species according to taxonomic keys in Meunscher (1944) and the identifications were confirmed by Dr. W. Dore of the Canada Department

of Agriculture, Ottawa. The frequency with which aquatic plant species occurred at each station was determined by noting the number of times a plant species appeared in the Ekman dredge samples. To establish which macro-invertebrates dominated the aquatic plants, a sampler was constructed in such a manner that phytomacrofauna (defined by Gerking (1957) as those animals living on the plants) could be taken completely independent of the benthic macrofauna (Mackie and Qadri, in Press). The prototype is shown in Fig. 2. It consists of a tapered net that is detachable from a lower box containing cutter blades. With the blades in the open position, the sampler is quickly lowered over a bed of aquatic plants. A messenger is sent down a guide wire to release the tripping mechanism holding the blades. Stretched rubber tubing around the blades forces them to close and cut the plants with a shearing action. The sampler is taken from the water and the plants are removed through a trap door in the detachable net. For an evaluation of the efficiency of the sampler, duplicate samples of Myriophyllum spp., Elodea canadensis, and Vallisneria americana were taken with both the above phytomacrofauna sampler and the Ekman dredge. The number of macroinvertebrates on 100 cc of each aquatic plant species was then determined. To distinguish between those animals that dominated the aquatic plants and those that dominated the substrate, duplicate samples of the substrate in the vicinity of each plant species, were also taken. The species and the average number of animals in 100 cc of the substrate were then determined. All plant and substrate samples were taken from a small area in Station 3 that contained the three plant species.

Dr. I. Ahmad, of the Department of Cybernetics, University of Ottawa, gave advice and supervised the statistical treatment of the data.

Fig. 2. Prototype of the phytomacrofauna sampler designed by Mackie and Qadri (in press).



The statistical method used was the Students "t" test for small samples (Simpson et al, 1960, p 176). The statistical treatment of the data used in the text are shown in Appendices I-IX. All significant differences are considered at the 5% level but this level is not indicated in the text.

RESULTS AND DISCUSSION

Water Chemistry

Since the concentration of the chemicals between bottom and surface waters in either 1968 or 1969 did not appear to be different within any one site, Tables 5 and 6 express the results as average and range values. To assess the quality of the water with respect to each chemical entity, criteria as determined by the Ontario Water Resources Commission (1970) are also included. Particular attention should be paid to the Biochemical Oxygen Demand (B.O.D.) which is an arbitrary measure of the oxygen uptake after 5 days at 20°C by microorganisms in their breakdown of organic matter. The widely accepted criterion for polluted waters is a B.O.D. value of 4 ppm or greater.

The water from the Gatineau River differed from that in the Ottawa River in properties of alkalinity, calcium, hardness, phenols, sulfates and conductivity. The concentration of these were lower and the nitrates higher in the Gatineau River than in the Ottawa River (Tables 5 and 6). Station 2 had a higher phosphate content, probably from the domestic sewage of Hull, than the other stations. Larger B.O.D., sulfate, and some phenol contents were observed at Station 6G than the remaining stations. Station 6K had the largest phenol content. As discussed later under the various benthic taxa, (with the exception of B.O.D.), the differences did not seem to be of sufficient magnitude to have been determining factors in the distribution

Table 5. Results of chemical determinations made weekly at each station. Data from the summers of 1968 and 1969 and the bottom and surface values are averaged. Units are mg/l unless otherwise indicated. For each parameter and station, the range is followed by the mean and number of samples.

Chemical Parameters	Stations						Pollution Criteria ^a
	1	2	3	4	5	6K	
pH	6.4-7.5 7.2 36	6.4-7.5 6.9 38	6.5-7.5 6.8 40	6.6-7.5 6.9 38	6.7-7.0 6.9 36	6.3-7.0 6.8 20	6.7-7.0 6.8 16 6.5-8.5
Dissolved oxygen	7.0-12.0 9.4 37	7.0-12.0 8.2 38	6.0-10.0 8.4 40	6.0-12.0 8.3 36	6.0-12.0 8.0 33	6.0-10.0 7.7 21	7.0-11.0 8.4 14 > 5
Carbon dioxide	5.0-13.0 9.4 35	10.0-20.0 11.9 38	5.0-15.0 10.4 40	6.0-15.0 10.6 36	7.0-15.0 10.2 33	10.0-25.0 12.7 21	10.0-13.0 10.3 14 < 25
Conductivity micro- mhos/cm	43.0-97.0 68.3 21	58.0-90.0 77.2 24	36.0-50.0 41.6 20	58.0-104.0 71.8 22	45.2-83.0 64.3 20	31.0-76.0 54.4 14	35.0-86.0 59.0 6 No increase > 1/3 of natural state

a. As recommended for fish and wildlife by the Ontario Water Resources Commission (1970).

Table 6. Results of chemical determinations made biweekly at each station. Data from the summers of 1968 and 1969 and the bottom and surface values are averaged. Units are mg/l unless otherwise indicated. For each parameter and station, the range is followed by the mean and number of samples

Chemical Parameters	Stations						Pollution Criteria a
	1	2	3	4	5	6K	
Alkalinity	20.0-34.0 25.8 16	22.0-32.0 26.5 16	10.0-26.0 16.4 16	17.0-37.0 25.5 18	17.5-30.0 24.1 17	18.0-30.0 24.1 11	18.0-30.0 23.5 6 >20
B.O.D.	0.4-3.0 1.1 12	0.6-16.5 3.8 12	0.5-2.5 1.6 10	0.5-2.3 1.3 13	0.5-4.0 1.6 13	0.4-29.4 6.8 8	0.5-3.0 1.2 5 <4
Calcium	9.0-12.0 10.3 8	10.0-12.0 10.5 8	6.0-14.0 7.2 9	9.0-11.0 10.1 10	9.0-10.0 9.8 9	10.0-11.0 10.0 5	10.0-10.0 10.0 4 No criterion given
Chlorides	1.0-7.5 3.3 16	2.0-5.0 3.4 16	1.0-5.0 2.3 17	1.0-5.0 3.0 18	1.0-5.0 2.8 17	1.0-9.0 4.0 11	2.0-2.5 2.3 6 <250
Detergents ABS	0.00-0.05 0.03 8	0.00-0.07 0.03 10	0.00-0.07 0.02 11	0.02-0.10 0.03 10	0.00-0.09 0.03 11	0.00-0.08 0.03 7	0.02-0.05 0.04 2 <1/7 48 hr TLM b
Hardness (Ca)	20.5-30.0 24.9 8	20.0-32.0 28.1 10	10.0-20.0 16.9 10	20.0-35.0 27.5 10	20.0-32.0 27.7 10	20.0-55.0 38.5 8	20.0-20.0 20.0 2 Plant growths
Iron	0.11-0.92	0.02-0.70	0.10-0.70	0.00-0.90	0.00-0.80	0.18-0.74	0.14-0.50

Manganese	0.00-0.02 0.00 8	0.27 16	0.35 16	0.33 17	0.31 18	0.28 17	0.33 11	0.33 6	Should not cause nuisance
Nitrate Nitrogen	0.01-0.15 0.06 8	0.02-0.29 0.11 8	0.00-0.01 0.00 10	0.00-0.04 0.01 9	0.00-0.01 0.00 10	0.00-0.02 0.01 9	0.00-0.02 0.01 5	0.00-0.03 0.01 4	Should not cause nuisance
Nitrite Nitrogen	0.001-0.025 0.008 16	0.003-0.014 0.013 16	0.004-0.017 0.010 17	0.003-0.014 0.008 18	0.004-0.026 0.013 17	0.01-0.24 0.10 10	0.004-0.045 0.018 11	0.004-0.017 0.008 6	Should not cause nuisance
Phenols ppb	0.0-12.0 5.6 8	0.0-10.0 6.0 10	0.0-10.0 3.9 9	0.0-10.0 5.7 10	0.0-10.0 5.6 7	8.0-10.0 9.2 5	0.0-20.0 10.5 4	Should not cause nuisance	
Phosphates	0.05-0.32 0.12 16	0.19-4.00 0.60 16	0.04-0.30 0.11 17	0.02-0.38 0.15 18	0.07-0.26 0.14 17	0.02-0.27 0.14 11	0.06-0.30 0.16 6	Should not cause nuisance	
Sulfates	13.0-18.0 15.0 16	10.0-24.0 15.5 12	8.0-14.0 10.3 11	11.0-17.0 14.3 12	12.0-20.0 15.1 11	12.0-40.0 21.8 9	11.0-17.0 14.0 2	Should not cause nuisance	
Zinc	0 0 2	0 0 4	0 0 3	0.00-0.01 0 4	0 0 3	0 0 3	0 0 3	<1/100 96 hr TLM b	

a. As recommended for fish and wildlife by the Ontario Water Resources Commission (1970).

b. 48 hr nor 96 hr TLM's were investigated for any of the species in this report.

of the bottom organisms. However, I do recognize that the industries could have been emitting "slugs" of effluents which I could not detect without continuous monitoring.

The B.O.D. values suggest a degradation of the water quality at Brewery Creek (Station 2) and particularly below the outfalls of the Canadian International Paper Co. (Station 6G). Organic matter or woodfiber decomposition, or both, were probably major factors in causing the B.O.D. increments.

In practice large B.O.D. values usually coincide with a significant drop in dissolved oxygen. However, during early summer B.O.D. values of 3.4 and 12.4 ppm at Stations 2 and 6G were accompanied by dissolved oxygen contents of 8 and 6 ppm, respectively. It would appear that the water flow was so turbulent in the upper reaches of Station 2 and so fast-flowing through Station 6G that the water was being continually oxygenated. This mixing of bottom and surface waters by turbulence and flow restored oxygen to the lower strata where active decomposition of organic matter by microorganisms was occurring. During August, after the water flow had decreased, the B.O.D. values rose to 4.8 ppm at Station 2 and 29.4 ppm at Station 6G.

A comparison of our results with those of Thomas (1952) shows that concentrations of some chemicals had increased by 1968 and 1969. The average values at Station 1 increased for iron from 0.12 to 0.27 ppm, for sulfate from 11.9 to 15.0 ppm, and for chloride from 0 to 3.3 ppm. Similar increases of these properties were noticed at Stations 4 and 6G. No observations were made by Thomas (1952) for the other stations. Unfortunately, such chemical entities as dissolved oxygen, B.O.D., and carbon

dioxide were not examined in the 1952 survey for our study area. Piché (1954) showed that the water at Britannia Bay (Station 1) was of good quality (B.O.D. = 1.0 ppm and dissolved oxygen = 8.69-9.03 ppm) while that below Canadian International Paper was grossly polluted (B.O.D. = 1.5-30.0 ppm and dissolved oxygen = 6.9-8.0 ppm) in August, 1954. Barrens (1961) also indicated clean water at Britannia Bay (B.O.D. = 1.0-2.0) and gross pollution at Station 6G (B.O.D. = 2.7-37.0); the dissolved oxygen contents were not comparable since the study was done in November. Four years later, LeSauter (1965) concluded that the Ottawa River had undergone further deterioration in dissolved oxygen content with August readings of 7.9-9.3 ppm at Station 1 and 5.9-8.1 ppm at Station 6G. Although the B.O.D. at Station 1 (0.6-1.6) indicated further deterioration since 1954, LeSauter (1965) suggested that the B.O.D. values of 0.8-14.2 ppm at Station 6G were inconclusive. Our results also suggest further deterioration at Station 1 with B.O.D.'s of 0.4-3.0 ppm and in August dissolved oxygen content of 7.0 ppm. The B.O.D. and dissolved oxygen contents at 11 km downstream of the CIP outfalls, where the above authors took their samples, were 12.3 and 4.0 ppm, respectively, and also suggest further deterioration.

Water Physics

The physical characters of the water examined in the study area are shown in Table 7. Temperatures never varied more than 2°C between bottom and surface waters. There was some conflict between the Secchi disc readings and turbidity measurements, particularly between Stations 1 and 3.

Table 7. Physical characters of the water at each station. Data for 1968 and 1969 and the bottom and surface values are averaged. For each parameter and station, the range is followed by the mean and the number of samples.

Physical Characters	Stations						Pollution Criteria a
	1	2	3	4	5	6K	
Temperature °C	4.4-23.6 17.2 37	5.6-22.2 17.2 37	5.6-22.2 17.1 41	4.4-22.0 17.0 36	6.1-22.8 17.1 35	7.4-22.5 17.0 15	No artificial increase
Secchi disc m	1.2-2.4 2.2 7	1.0-1.7 1.4 10	0.6-2.3 1.7 10	0.9-1.9 1.5 7	0.9-1.8 1.6 9	no data	Not quantified
Turbidity JTU	10.0-24.0 17.4 16	15.0-21.0 31.7 18	5.0-21.0 15.0 17	10.0-28.0 18.3 18	5.0-26.0 18.6 17	20.0-22.0 21.0 6	No artificial increase > 25 JTU
Velocity m/sec	0.1-0.4	0.1-2.1	0.5-1.5	0.6-2.0	0.6-3.8	0.6-3.8	Not applicable

a. As recommended for fish and wildlife by the Ontario Water Resources Commission (1970).

The clearest waters using the Secchi disc are at Station 1. The turbidity measurements indicate that the waters at Station 3 were the clearest. These discrepancies can be attributed to the sampling of silt-laden water near the shores of Station 1 during rough weather on two occasions. Secchi disc readings on the other hand, were always taken at greater depths where waves did not disturb the bottom. Moreover, the Secchi disc readings are subject to greater degrees of error as indicated by Beeton (1957) and Tyler (1968). The type of turbidity was also an important factor. At Station 1 turbidity was primarily caused by silt and suspended matter not characteristic of Stations 2 and 6G where suspended organic debris and woodfibre caused turbid waters. Turbidity at Stations 2 and 6G were more a function of industrial effluents while turbidity at Station 1 was a function of natural phenomenon. The extent to which silt and organic matter occurred at Stations 3, 4, 5 and 6G is less clear because these stations were situated farther downstream or across from effluents so that the concentration of suspended matter would be somewhat diluted.

The water velocity values were calculated from stage and flow data which gives a less reliable measure than a current meter. This lack of reliability particularly applies to that stratum of water at the mud-water interface since it is this layer of water that directly affects the bottom organisms. Nevertheless, the seasonal minimum and maximum velocity values of Table 7 do indicate where the fastest waters occurred. The results can be summarized as follows: waters at Station 1 were essentially stagnant; waters were stagnant in the study area at Station 2 in 1968, but highly turbulent in the extended study area at this station in 1969; waters

were moderately fast flowing at Stations 3 and 4, and fast flowing at Stations 5, 6G and 6K.

Sediment Analyses

Figure 3 shows the percent particle size fractions and their mean densities of the sediments at the stations. The mean density of the particles is probably the most informative parameter since it describes the type of material in the sediments. Mean densities of ≥ 1.00 gm/cc are indicative of the heavier elements such as sand and stones while values ≤ 1.00 gm/cc generally indicate plant material. On the basis of Table 3 and Fig. 3 shores at Stations 1 and 3 consist primarily of very fine sand with some silt, Station 5 of fine sand and less silt, Station 2 of plant and animal debris, Station 6G of plant (woodfiber) debris and Stations 4 and 6K of plant debris with sand particles interspersed. The percent organic matter (as percent volatile solids) occurs with decreasing abundance at Stations 6G, 6K, 2, 4, 3, 5, and 1.

Bacteria

Table 8 shows the mean and ranges for total coliform and fecal coliform bacteria as MPN/100 ml at each station. The Ontario Water Resources Commission has set the maximum tolerance limit for recreationally used water at 1000 MPN/100 ml. On this basis all stations were polluted where Stations 2 and 6G were grossly polluted. However, the results at Station 1 were somewhat obscured by a single water sample taken at a point where Grahams Creek empties into Britannia Bay; the coliform count of this sample as 9300 MPN/100 ml. The total coliform counts of other sites in Britannia Bay were well below the criterion of 1000 MPN/100 ml. The

Fig. 3. Particle size fractions and organic matter as percent of total at each station. Density of particles in parentheses.

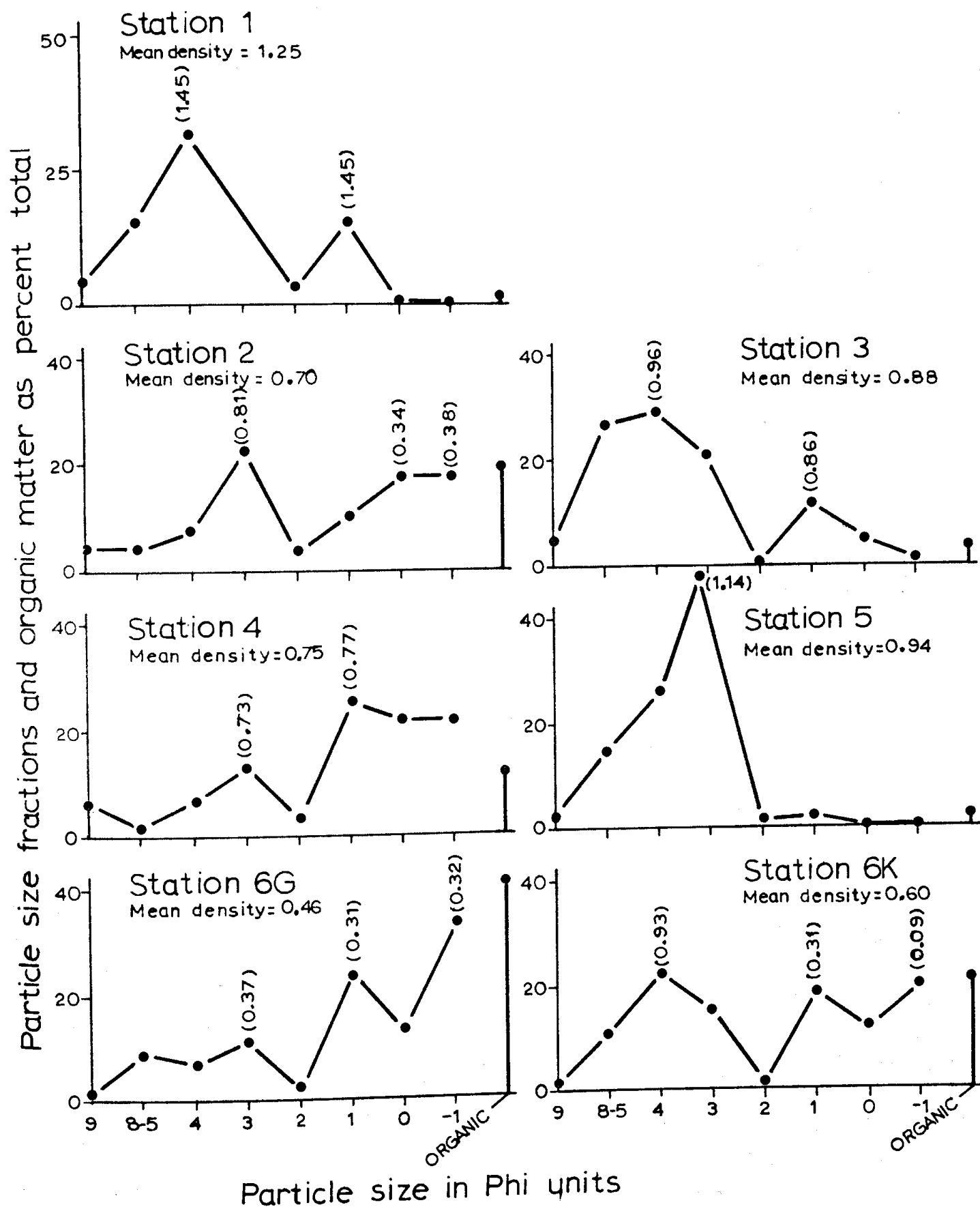


Table 8. Total coliform and fecal coliform bacteria (MPN/100 ml) for bottom and surface waters during the summers of 1968 and 1969.

Station No.	1968						1969					
	Bottom			Surface			Bottom			Surface		
	Mean	# Samp.	Range	Mean	# Samp.	Range	Mean	# Samp.	Range	Mean	# Samp.	Range
Station 1												
Total coliform	1676	8	21-9300	920	8	23-2300	237	2	43-430	182	3	23-430
Fecal coliform	214		0-930	253		0-1500	5		0-10	151		0-430
Station 2												
Total coliform	267800	5	11000-930000	207000	5	11000-430000	203333	3	150000-230000	610600	5	43000-2400000
Fecal coliform	96851		23-430000	66386		230-230000	85100		2300-230000	25300		2300-95000
Station 3												
Total coliform	32025	5	75-150000	8697	5	93-23000	16817	3	150-460000	14900	4	4300-23000
Fecal coliform	955		0-4600	3111		0-11000	2208		23-4300	5819		23-23000
Station 4												
Total coliform	15780	5	4300-23000	15720	5	2300-43000	23433	3	4300-43000	26000	4	15000-43000
Fecal coliform	1545		23-2300	6045		23-23000	8570		950-23000	1030		230-2300
Station 5												
Total coliform	5350	4	2300-9300	3800	4	2300-4300	12225	4	9300-21000	11780	5	6300-21000
Fecal coliform	2513		23-7500	2162		23-4300	1316		23-2300	2368		640-4300
Station 6 (6G, 6K)												
Total coliform	120357	6	5200-430000	342500	6	11000-1500000	439250	4	12000-1500000	466050	6	9300-2400000
Fecal coliform	10363		580-23000	160054		23-930000	291550		2300-930000	59972		230-230000

City of Hull and the Township of Gatineau contributed the greatest loads of raw sewage with Gatineau Pointe being third on the list. Bacterial pollution on the Ontario side above Britannia Bay was not excessive but near the City of Ottawa, at Station 4, the coliform values exceeded the criterion of 1000 MPN/100 ml. The percent contribution of coliform bacteria from Ottawa and Quebec at Station 4 was not known.

Piché (1954) in his survey of the Ottawa River, made bacteriological examinations of the water at Stations 1 and 6G in July-August of 1954 and found readings of 0-40 and more than 18,000 coliform bacteria per 100 ml, respectively. Barrens (1961), in using the membrane filter technique, found an average of 108 at Station 1, 200 at Station 2, and 15,400 coliform bacteria per 100 ml at Station 6G in the month of November. LeSauter (1965) found 200-1700 near Station 1 and 11-160,000 coliform bacteria per 100 ml at Station 6G in July-August. Our results showed that the total coliform counts were 93-2300 at Station 1 in July-August, 1968 and 430 at Station 1 and 43,000 at Station 2 during November 1969. Although we did not do bacterial analyses of the water at a point approximately 11 km downstream of the CIP outfalls (Station 6G) where Piché (1954), Barrens (1961), and LeSauter (1965) performed their analyses, there was an increase in the total coliform counts during July to September from 11,000-1,500,000 in 1968 to 9300-240,000 in 1969 at a point 3 km downstream of the CIP outfalls. Referring to the above results of Piché (1954), Barrens (1961), LeSauter (1965), and ours, it is apparent that the total coliform counts have been steadily increasing since 1954 at Stations 1, 2, and 6G. Since Stations 3, 4, 5, and 6K and/or the sampling periods did not correspond to those of previous studies,

the four years (1954, 1961, 1965, 1969) cannot be compared.

Animals on Aquatic Plants

In sampling the substrate to differentiate between macrobenthic fauna and phytomacrofauna, the best method would have been to take the plant sample and then to sample the bottom where the plants had been removed. However, without a special sampler, such as the Gerking (1957) sampler, one cannot be sure that animals from surrounding plants had not invaded the newly denuded area and there would be a great probability of trapping these animals as the dredge was being lowered. Substrate at the edge of the plants were sampled being careful not to include any plants.

The newly designed phytomacrofauna sampler is superior to the Ekman dredge for taking plant samples (Mackie and Qadri, 1971) and much more flexible, efficient and easier to apply than previous techniques, such as hand picking the plant specimens (Krecker, 1939 a) or using a dip net (Rosine, 1955), a zippered net (Andrews and Hasler, 1943) or other especially constructed instruments (Forsburg, 1959; Gillespie and Brown, 1966). When the animals on plants taken with the phytomacrofauna sampler were compared with those in the substrate taken with the Ekman dredge, (Table 9) two distinct groups of animals are seen: those that primarily inhabit the aquatic vegetation and those that inhabit the substrate. These two groups can be summarized as follows:

Table 9. A comparison of the average number of animals in the substrate taken with the Ekman dredge (3 samples) with that in paired samples of three submerged macrophytes taken with the phytomacrofauna sampler and Ekman dredge. Analyses based on 100 cc of plants and substrate.

Species	Phytomacrofauna sampler			Ekman dredge		
	<u>Myriophyllum</u>	<u>E. canadensis</u>	<u>V. americana</u>	<u>Myriophyllum</u>	<u>E. canadensis</u>	<u>V. americana</u> Substrate
<u>Hydrolimax grisea</u>	0	0	0	0	0	3.4
<u>Dugesia tigrina</u>	84	45	23	84	69	0.6
<u>Limnodrilus hoffmeisteri</u>	0	0	0	0	0	1.8
<u>Pelosclex n. sp.</u>	0	0	0	0	0	0.5
<u>Stylaria lacustris</u>	9	12	9	0	3	0
<u>Stylaria fossularis</u>	36	39	12	3	3	0
<u>Asellus sp.</u>	0	0	0	0	3	0
<u>Hyalella azteca</u>	1593	1029	131	867	483	8.9
<u>Gammarus fasciatus</u>	9	24	5	3	6	4.4
<u>Crangonyx pseudogracilis</u>	0	0	3	0	0	0.1
<u>Hydracarina</u>	3	8	3	3	3	0.2
<u>Ephemeroptera</u>	0	0	3	0	0	0
<u>Enallagma signatum</u>	78	57	11	14	8	0
<u>Lepidoptera</u>	0	0	0	0	0	0
<u>Tricoptera</u>	24	6	3	6	0	0.2
<u>Cricotopus sp.</u>	15	0	3	9	0	0
<u>Procladius sp.</u>	0	0	0	0	0	2.6
<u>Dicrotendipes sp.</u>	0	0	0	0	0	1.8
<u>Other Chironomidae</u>	0	0	0	0	0	2.0
<u>Ceratopogonidae</u>	0	0	0	0	0	0.3
<u>Cyraulius parvus</u>	18	30	14	15	9	0
<u>Cyraulius hirsutus</u>	0	3	0	0	0	0
<u>Cyraulius defleclus</u>	15	6	7	6	6	0
<u>Promenetus exacuus</u>	15	9	3	12	12	0
<u>Physa gyrina</u>	9	39	3	18	18	0.1
<u>Amnicola limosa</u>	36	78	19	21	21	0.3
<u>Ferrissia paralella</u>	0	0	9	0	0	0
<u>Campeloma decisum</u>	0	0	0	0	0	0.3
<u>Sphaeriidae</u>	0	0	0	0	0	2.6
Total	1944	1385	261	1070	644	30.1

Animals on Plants

Platyhelminthes

Dugesia tigrina

Oligochaeta

Stylaria fossularisStylaria lacustris

Amphipoda

Gammarus fasciatusHyaella aztecaCrangonyx pseudogracilis

Hydracarina

Insecta

Odonata

Ephemeroptera

Lepidoptera

Tricoptera

Chironomidae (Cricotopus sp.)

Gastropoda

Cyraulius parvusG. hirsutusG. deflectusPromenetus exacuusFerrissia paralellaPhysa gyrinaAmnicola limosa

Animals in Substrate

Platyhelminthes

Hydrolimax grisea

Oligochaeta

Limnodrilus hoffmeisteriPelosclex n. sp.

Isopoda

Asellus spp.

Insecta

Cryptochironomus sp.Polypedilum sp.Dicrotendipes sp.Procladius sp.Phaenopsectra sp.Ceratopogonidae sp.

Gastropoda

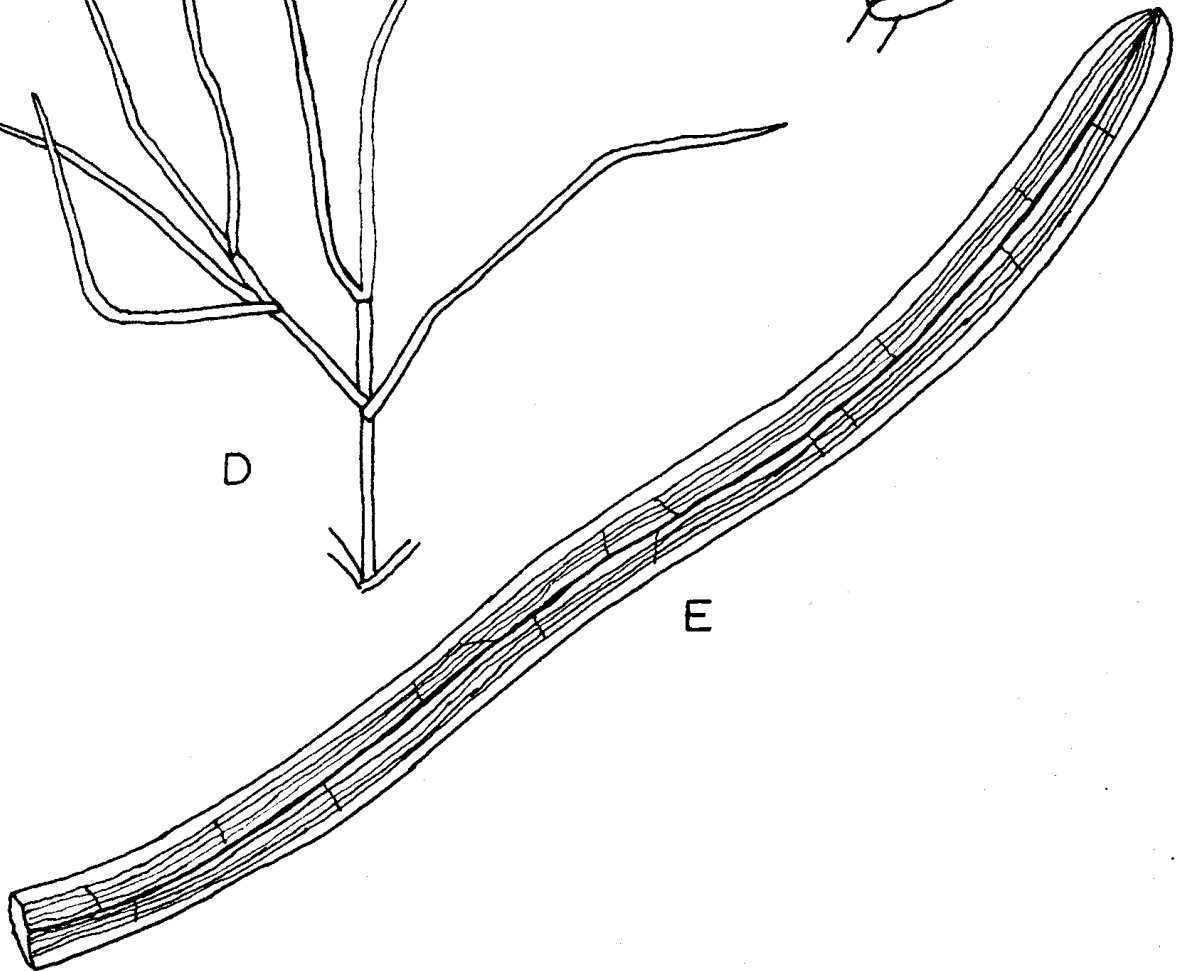
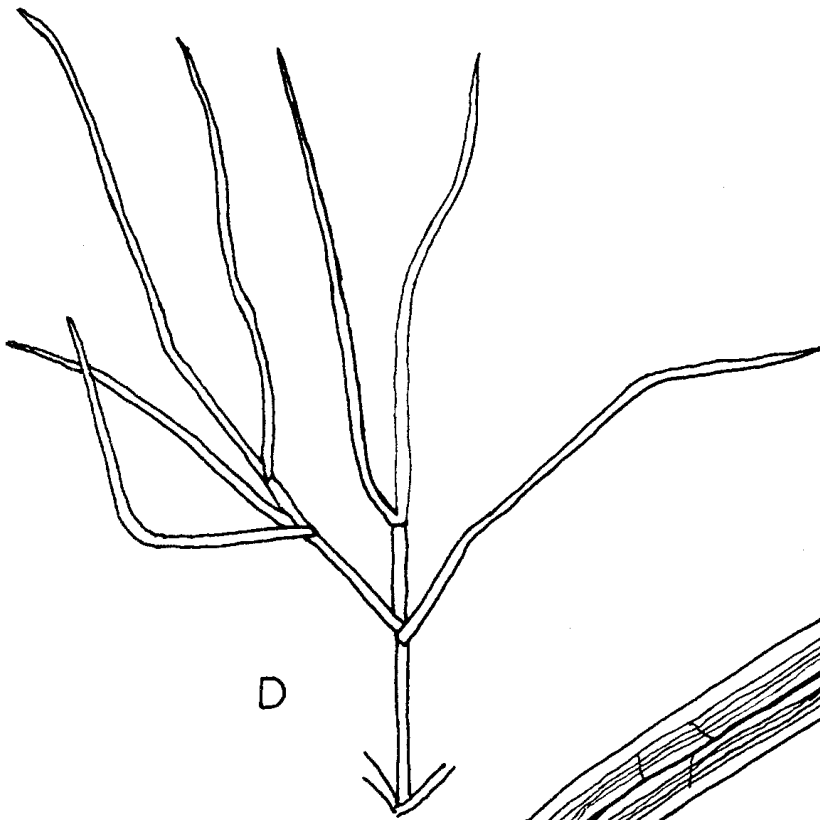
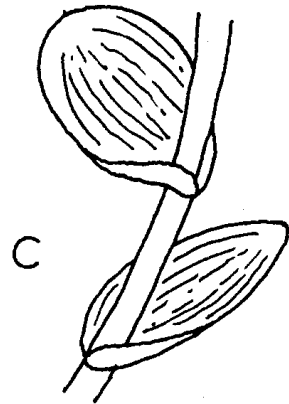
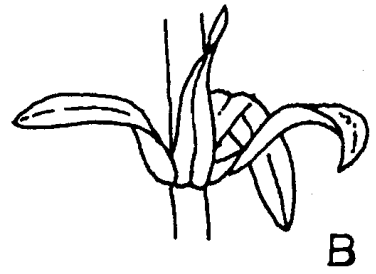
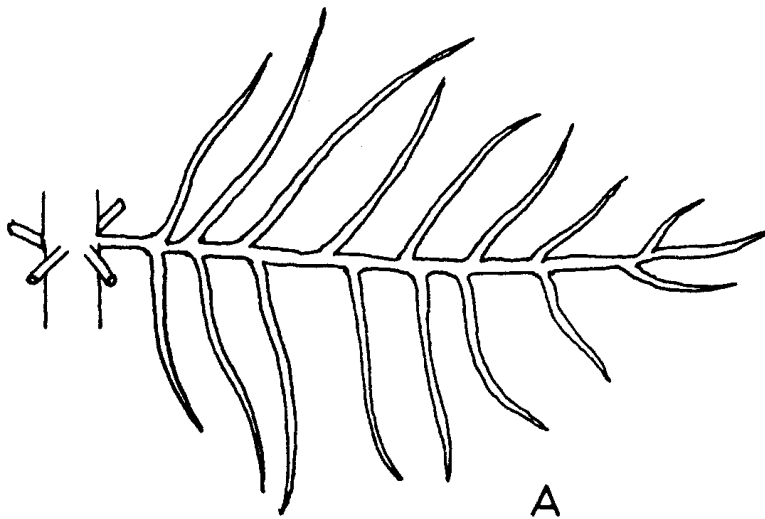
Campeloma decisum

Pelecypoda

Pisidium casertanumP. ferrugineumP. compressumP. nitidum

Since only a small area at Station 3 was sampled, the above results are not complete. Such species as Goniobasis liviscens and Lymnaea catascopium

Fig. 4. Types of leaves on submerged aquatic plants of the Ottawa River. A. Myriophyllum heterophyllum, an example of a dissected leaf. B. Elodea canadensis (4 leaves shown). C. Potamogeton perfoliatus (2 leaves shown). D. Potamogeton pectinatus, a habit sketch. E. Vallisneria americana, part of a single leaf.



were restricted to certain stations (i.e. Station 1) and would not appear in the above samples. Other species were possibly not common enough (i.e. Helobdella stagnalis) and their small numbers were not detected. Finally, other species may have been common but since all these samples were taken over a one week period, the seasonal maximum of the species may have been missed.

There has only been speculation as to why animals inhabit aquatic plants. Rawson (1930) suggested that plants primarily provide shelter and their value as oxygen producers is important only under stagnant conditions. Whitwer (1955) concluded that, as a source of oxygen, Myriophyllum spp. was not as important in well aerated moving water as it was in stagnant water. Whether or not plants provide support, shelter, food and/or oxygen, their complete removal is accompanied by the disappearance of associated animals.

The occurrence of large numbers of animals on plants that have highly dissected leaves (compare Fig. 4 and Table 9) is well documented (Krecker, 1939 a; Rosine, 1955; Andrews and Hasler, 1943) but why this should be so has not been conclusively established. Krecker (1939 a) suggests that Myriophyllum is a more suitable substratum for stylarians because they can curl their bodies around the needle-like leaves. Whitwer (1955) found that Myriophyllum photosynthesized at 1.3 times the rate of Vallisneria but suggested the difference was not significant enough to explain the value of Myriophyllum as a better oxygen producer in moving water. Berg (1949) showed that lepidopterans depended on plant tissue for food while others suggest that animals feed on the microfauna attached to

plants. Much work is needed in this respect but it is suspected that the value of plants varies for different species and under different environmental conditions.

Macrobenthos

The following section shows the qualitative and quantitative results of the benthic study. The quantitative results are discussed in three aspects; the horizontal distribution, the summer seasonal distribution, and the depth of water distribution of the benthos. Only species which formed at least 10% of the average standing crop of each major taxa are discussed with respect to the above aspects.

Five factors that appeared to influence the horizontal distribution of the benthos are: (1) the nature of the substratum, (2) water movement, (3) shore morphometry, (4) food and predation, and/or (5) pollution. Each of these factors is discussed as it correlates to the distribution of the benthos in the study area. Appendix O served as a guide to the discussion of the five factors.

The seasonal distribution of a species varies in response to reproduction, vertical and horizontal migrations, and/or mortality. Limited observations included notes on the breeding season, the size or weight of individuals during minimum and/or maximum numbers, seasonal differences in depth distributions, and/or reference to other investigations. For greater reliability of the data, only those stations which showed the largest average standing crops of the various taxa were considered for seasonal distribution studies. Preference is given to Stations 1, 2, 5,

and 6G since complete seasonal (and depth) data were obtained for these stations.

An analysis of the depth distribution of the benthos provided a greater insight into the associations among different species. For the same reasons given above, preference is given to those stations (1, 2, 5 and 6G) which showed the largest average standing crop for the taxa or species under consideration.

Platyhelminthes

Table 10 gives the four species of platyhelminthes and their abundance as percent of the average standing crop that occurred at each station. The two species, D. tigrina and H. grisea were the most widely distributed being present at all stations. Stations 4, 5, and 6G were the most diverse having four species while Stations 1 and 6K were represented by only two species. It is quite possible that a fifth species of platyhelminthes exists in the study area. This assumption is based on the findings of three dendrocoelid specimens which, because of their immature state, could not be identified beyond the Family Dendrocoelidae. Mr. Ian Ball, who identified the platyhelminthes, has suggested that these individuals were either immature specimens of P. fluviatilis or of another dendrocoelid species.

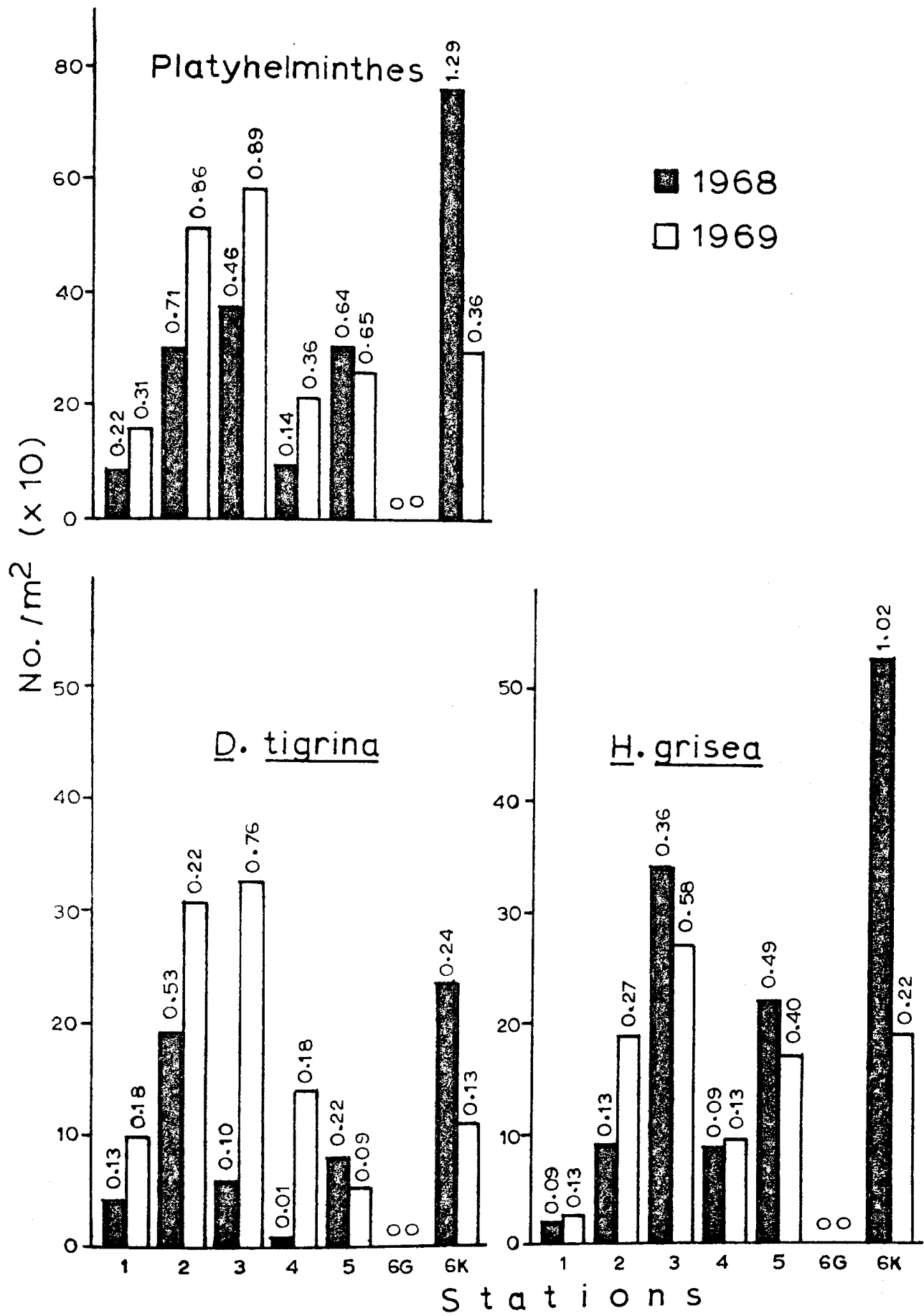
Horizontal Distribution

Populations of D. tigrina and H. grisea were significantly larger at Station 2 than at Station 1 (Fig. 5 and Appendices I.1 - I.3). A 5% level of significance is used here and throughout the thesis as mentioned earlier in the section on Material and Methods, page 17. The average standing crop of D. tigrina was significantly larger than

Table 10. Platyhelminthes species composition as percent of average standing crop ($\#/m^2$) at each station in the summers of 1968 and 1969.

Species	Stations													
	1		2		3		4		5		6G		6K	
	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969
Tricladida														
<u>Dugesia tigrina</u>	76.5	70.5	34.1	29.7	20.1	50.2	29.1	66.5	22.9	33.9	10.8	33.3	26.6	25.1
<u>Procotyla fluviatilis</u>	0	0	0.2	0	0.5	0.1	1.6	0	0.2	0.1	3.1	33.3	0	0
<u>Phagocata gracilis</u> <u>woodworthi</u>	0	0	0	0	0	0	3.1	4.1	0	0.4	6.2	0	0	0
Alloeocoela														
<u>Hydrolimax grisea</u>	23.5	29.5	65.7	70.3	79.4	49.7	62.2	29.4	76.9	60.2	79.9	33.3	0	0
Average #/m ²	41.8	26.8	387.3	264.7	169.9	246.5	144.0	170.8	210.1	544.4	28.9	11.9	384.5	80.6
Average wt. (mg/m ²)	0.12	0.26	0.73	0.50	0.25	0.66	0.33	0.30	0.43	0.58	0.06	0.13	0.57	0.08

Fig. 5. Average standing crop (No./m²) of Platyhelminthes, Dugesia tigrina, and Hydrolimax grisea at each station in the summers of 1968 and 1969. Average dry biomass (mg/m²) above histograms.



H. grisea at Station 2 and significantly smaller at Stations 3, 4, and 5 (Appendix I.4). No platyhelminthes occurred in the grossly polluted areas of Station 6G. As Table 9 shows, D. tigrina was a more common inhabitant of aquatic vegetation than of the bottom and H. grisea was more common on the bottom than on the plants. Although calcium and dissolved matter may be influential in the mere occurrence of platyhelminthes (Reynoldson, 1958) they were not determining factors in affecting their distribution between stations. This was best shown at Station 3 where the lowest average calcium content (7.2 ppm Table 6) supported larger populations of platyhelminthes than Stations 1 and 4 which had average calcium contents of 10.3 and 10.1 ppm, respectively.

There was an apparent correlation between the amount of organic matter in the substrate and the abundance of D. tigrina (Fig. 3, 5) where Station 2 with its high organic content, supported larger populations than Stations 1, 3, and 4. No correlation was observed between the abundance of D. tigrina and the abundance of aquatic plants, even though they were inhabitants of the plants. The association of D. tigrina with organic content was most probably related to food supply since they feed on living, dead, or crushed animal matter (Pennak, 1953). Such food staples were in ample supply at Station 2 which acted as a storage bin for the slaughter house wastes from Canada Packers. The amount of organic matter also appeared to influence the distribution of H. grisea but the correlation did not appear as strong as with D. tigrina. Kenk (1944), in a study of several Michigan lakes and rivers, considered the nature of the substratum as of secondary importance since planarians occurred on all types of substrates—sand, mud, stones, and organic material. He

considered the scarcity or absence of resting places as principle limiting factor; even though water chemistry, temperature, food and other variables were near optimum, planarians did not occur in abundance when shady resting places were absent.

Water movement could also have affected the distribution of platyhelminthes. D. tigrina dominated H. grisea in the almost stagnant waters at Station 2 and H. grisea dominated D. tigrina in the faster flowing waters of Stations 3, 4, and 5 (Appendix I.4). However, when the abundance of each species were compared at each station, it was apparent that the effect of water movement was not as great as that of the nature of the substratum. This is in direct contrast to the observations of Kenk (1944) who considered the nature of the substratum as secondary in importance to water movement. However, Kenk's observations were based on the geographic distribution of platyhelminthes whereas this study applies to a single watershed. Kenk (1944) also reported that such species as D. tigrina and P. fluviatilis occurred in lentic (stagnant) waters because they were eurythermic forms and could tolerate wide temperature changes as opposed to the stenothermic forms which occurred in the rather constant temperatures of lotic waters. Beauchamp (1932) noted that water movement detaches planarians from their holds.

Reynoldson (1958) found that triclads were most abundant in shallows with gentle slopes, irrespective of substrate type. Evidence from this study suggested that the opposite relation was true; the gentle slopes of Station 1 supported few triclads (D. tigrina) than the steeper slopes of Station 2 which has the more suitable substrates.

H. grisea, on the other hand, appeared to prefer the steeper gradients of Stations 3, 4, and 5. Although the slope of the shore at Station 6 was less than that at Station 5 and similar to Station 3, its larger populations of H. grisea could have been attributed to the effects of the CIP effluents at Station 6G; H. grisea, in response to avoiding the adverse effects of the effluents might have moved towards the shores of Kettle Island (Station 6K) and caused aggregations in the 0 to 2 meter depths. The effect of sloping shores, however, failed to explain the small numbers of H. grisea at Station 5, as did the effects of substrate and water velocity.

D. tigrina exhibited a greater degree of tolerance to polluted waters than did H. grisea, but neither species could tolerate gross pollution (Station 6G). Kenk (1944) concluded that a low pH was undesirable for platyhelminthes and that polluted creeks and rivers were similarly undesirable. Hyman (1925) claimed that the effect of pH was not manifested in the hydrogen ion concentration but in the carbon dioxide set free from carbonates when the water was acidified. Reynoldson (1958) reported very large triclad populations from very eutrophic lakes where the water was only 35% saturated with oxygen and had chloride contents of 83 mg/l. The concentrations of the chemical entities in the waters between Stations 1, 5, and 6G did not vary enough to explain the absence of platyhelminthes at Station 6G. The large BOD values and/or the woodfibre contents were probably the determining factors for the absence of platyhelminthes, the woodfibre either causing the large BOD or depriving the platyhelminthes of their preferred substrates.

Seasonal distribution

There were two periods of maximum numbers, as shown in Fig. 6 and 7. At Station 2 where D. tigrina predominated, the maximum standing crop occurred in early August and at Station 5, where H. grisea predominated, the maximum standing crop occurred in mid-September. Black spherical egg capsules, presumably belonging to D. tigrina, were taken in the bottom samples until late July. At all stations where platyhelminthes occurred, the numbers of H. grisea were larger than that of D. tigrina during the spring and fall. D. tigrina dominated H. grisea only during the summer months, particularly in the month of August.

The finding of egg capsules of D. tigrina in the month of July is strong evidence that the period of maximum numbers was due to reproduction and not to other factors such as colonization. Kenk (1940) and Hyman (1939) reported habitats that had either asexual individuals, sexual individuals, or both asexual and sexual individuals. It is not known whether the asexual form does exist in the Ottawa River but if it does there is evidence to suggest that it does not contribute substantially to the triclad populations. Root (1961) showed that the intrinsic rate of increase of the asexual form of D. tigrina was such that it allowed the species to live in an environment that is moderately safe in terms of population growth. He substantiated this by alluding to Hyman's (1951) observations that planarians have few predators because of their distasteful surface secretions. The only predation that could be of any consequence is that through cannibalism (Armstrong, 1964). One would therefore expect the large populations of D. tigrina (Fig. 6) to be maintained subsequent to asexual reproductions, if such reproduction occurred. In fact a dramatic decrease was observed suggesting that the

Fig. 6. Seasonal distribution of Platyhelminthes, Dugesia tigrina, and Hydrolimax grisea at Station 2, 1969.

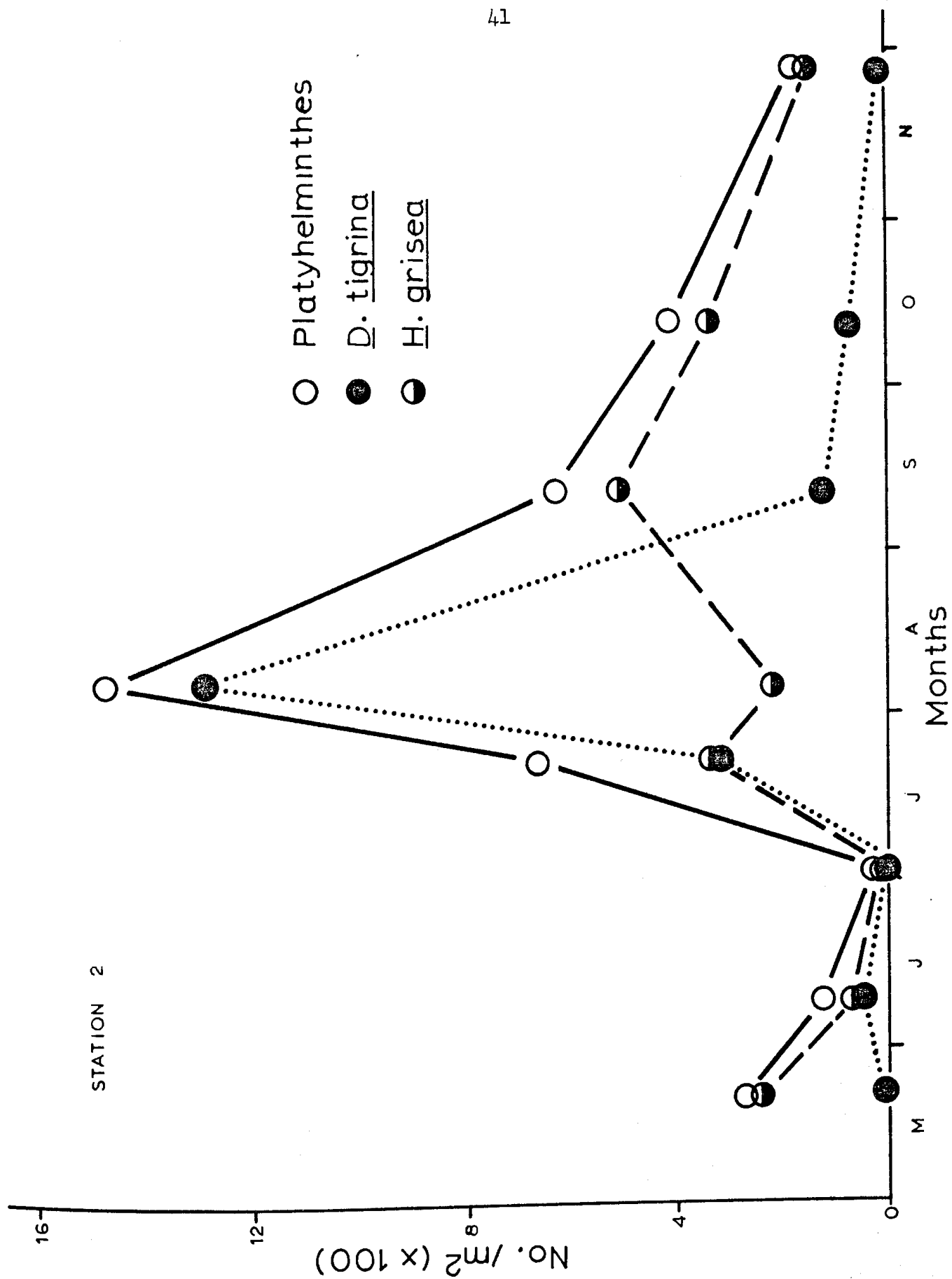
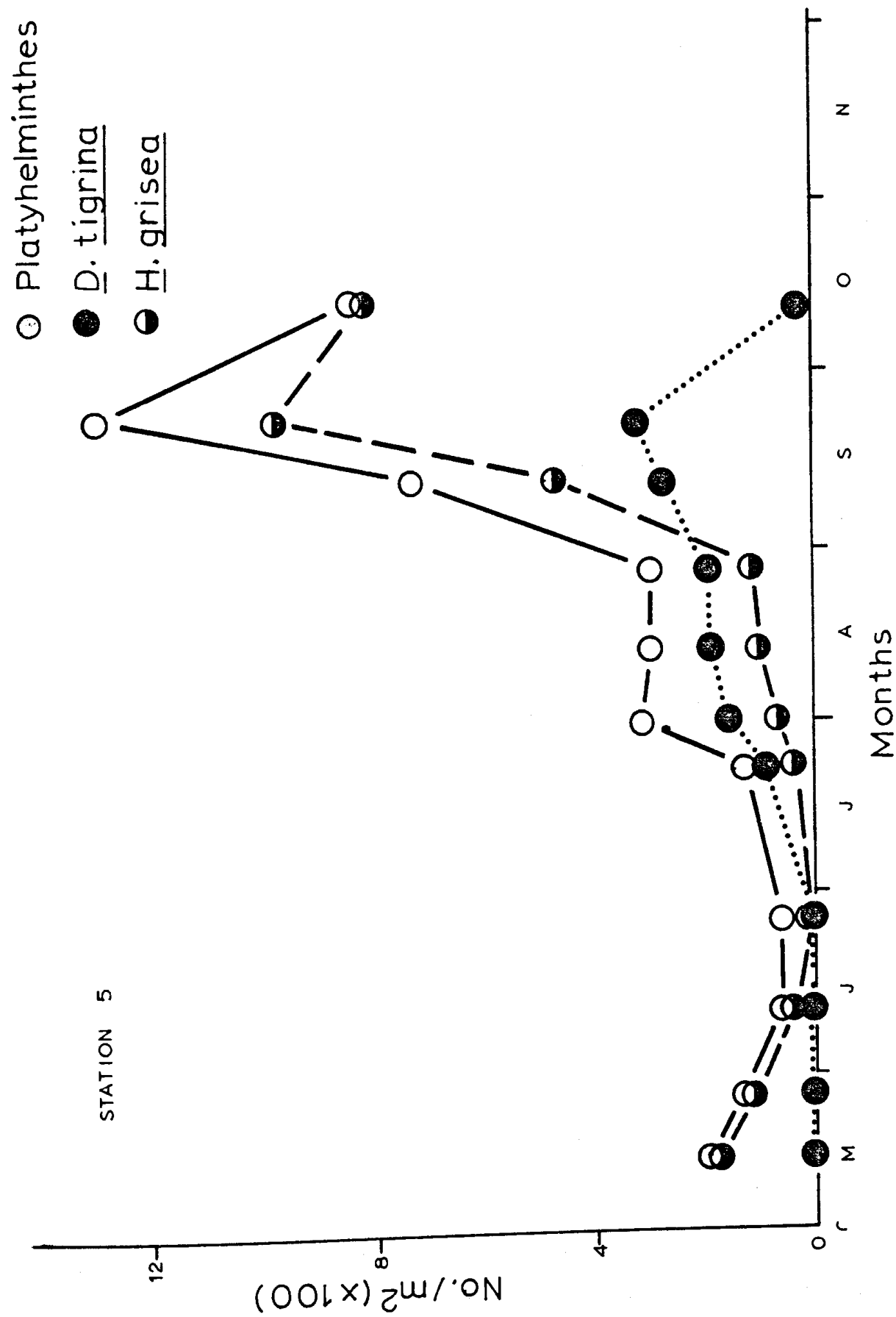


Fig. 7. Seasonal distribution of Platyhelminthes, Dugesia tigrina,
and Hydrolimax grisea at Station 5, 1969.



sexual form predominated since this form lives only a few weeks and dies in the summer (Hyman, 1951).

The reproductive cycles of the allocoeles, particularly of H. grisea, are poorly known. Hyman (1951) and Pennak (1953) suggest that most of the allocoeles are sexual and are represented by only a few asexual species.

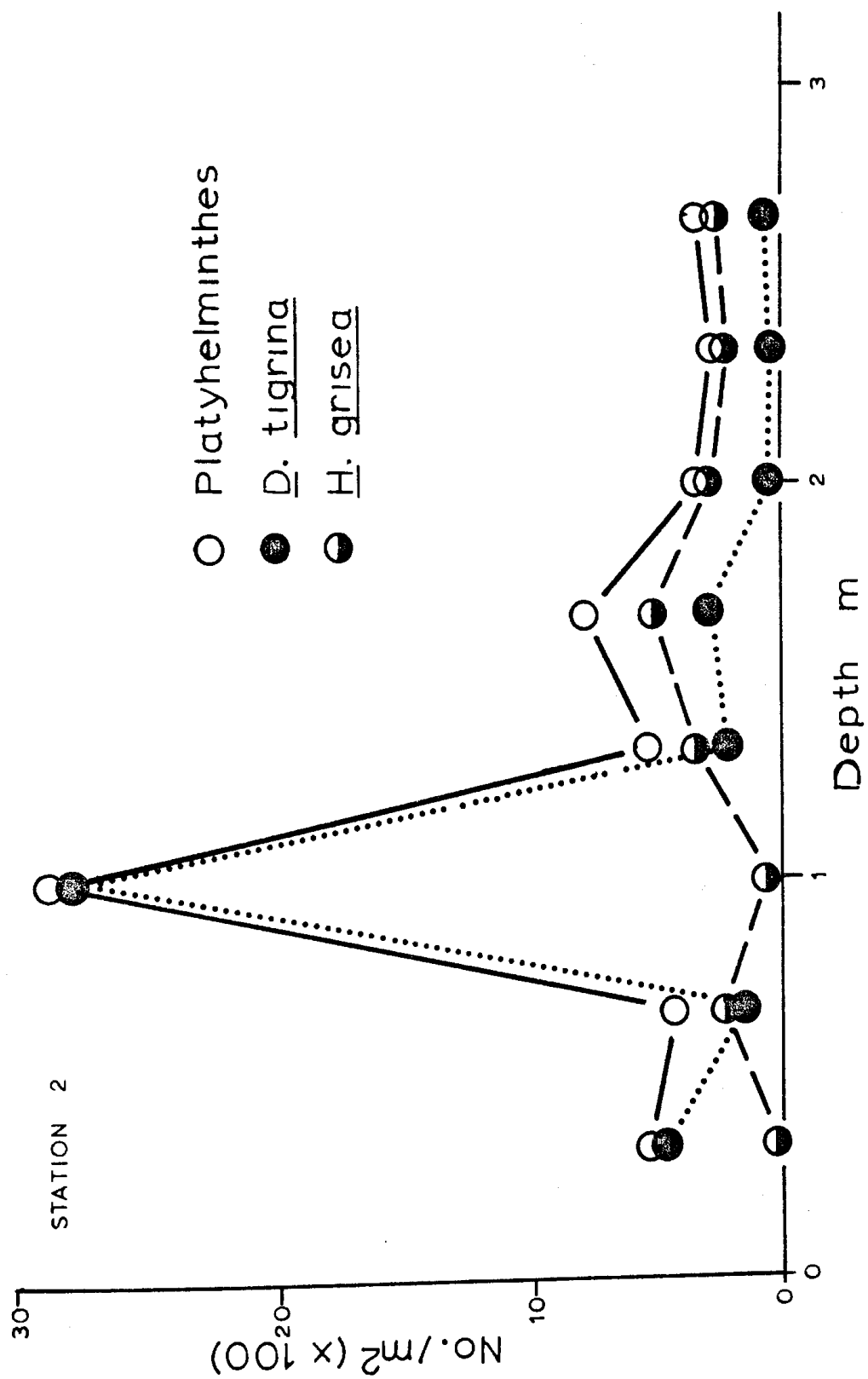
The seasonal dominance of H. grisea (spring and fall) and D. tigrina (summer) suggested that their periods of maximum numbers were also a function of temperature. H. grisea dominated in the spring and fall when temperatures were less than 15 to 17°C and D. tigrina in waters warmer than 15 to 17°C. These results are similar to those of Beauchamp and Ulliyott (1932) who found that the dividing line for two species of Planaria was 13 to 14°C. The periods of maximum numbers can also be related to water flow. Populations of D. tigrina were maximum during periods of reduced water flow while populations of H. grisea were maximum during periods of increased water flow.

There is some suggestion from Fig. 6, 7 that the two species, D. tigrina and H. grisea, were competitors and that their association was a negative one. When the numbers of one species began to increase, the numbers of the other species decreased. Further evidence for this competitive behaviour is seen in their depth distributions, discussed below.

Depth distribution

Fig. 8 shows the depth distribution of platyhelminthes at Station 2. Although D. tigrina dominated the one meter depth, it is

Fig. 8. Depth distribution of Platyhelminthes, Dugesia tigrina,
and Hydrolimax grisea at Station 2, August 1969.



surprising that they were not more abundant in depths less than a meter because they were primarily inhabitants of aquatic vegetation. Perhaps the most striking feature in the depth distribution was the inverse relationship between the numbers of D. tigrina and H. grisea. This relationship implies a form of interspecific competition that was expressed in the antagonistic behaviour between the two dominant species. By alluding to the "competitive exclusion principle" (Hardin, 1960), it can be argued that D. tigrina and H. grisea were mutually exclusive both spatially and temporally. If these two species were complete competitors, then they could have co-existed. Only through seasonal replacement did D. tigrina and H. grisea occupy a single habitat. At Station 2, D. tigrina was replaced by H. grisea in September (Fig. 6). When seasonal replacement overlaps, then the least successful competitor will be removed; at Station 2, the less successful competitor would have been H. grisea in the particular habitat (aquatic plants) at the one meter depth (Fig. 8). When the plants began to disappear in the fall, H. grisea became the successful competitor. This is, however, highly speculative.

Oligochaeta

The oligochaetes were represented by more than 20 species. Not all species were identified, particularly those that belonged to the families Glossoscolecidae, Lumbricidae, Lumbriculidae and Enchytraeidae since they occurred in very small numbers as immature specimens for which no taxonomic keys were available. There was one new tubificid species of the genus Peloscolex that occurred in the study area. Specimens of this new species were given to Dr. D. Cook of the National Museum of Canada, Ottawa, as type specimens for taxonomic description. The

species and the abundance with which they occurred at each station are given in Table 11.

Stations 1, 3, and 5 had the greatest oligochaete diversity with 19 species each but the species composition at these stations were entirely different and many occurred in extremely small numbers. Stations 2 and 6K each had 16 species while Stations 4 and 6G had 14. There were no species unique to any station, but two species, S. appendiculata and D. nivea occurred at all stations except Station 1.

Horizontal distribution

The oligochaete fauna was composed of different populations of species at each station. The dominant species were: U. uncinata, L. hoffmeisteri, and Peloscolex sp. at Station 1; S. fossularis, L. hoffmeisteri, S. lacustris, and D. nivea at Station 2; L. hoffmeisteri and A. lomondi at Station 3; L. hoffmeisteri and S. appendiculata at Station 4; L. hoffmeisteri and A. lomondi at Station 5; only L. hoffmeisteri at Station 6G; L. hoffmeisteri and S. appendiculata at Station 6K. The distribution of each of the above eight species at each station is shown in Fig. 9.

The effect of the substrate as a determining factor in the distribution of oligochaetes seemed to be of secondary importance, particularly for those species that inhabited the clean water environments. Such species as Peloscolex sp., U. uncinata, and A. lomondi were more numerous on substrates consisting of very fine sand but correlations between the average standing crops of each species and the stations containing this substrate type appeared to be wanting. More positive correlations were apparent with the velocity of water flow and the gradient

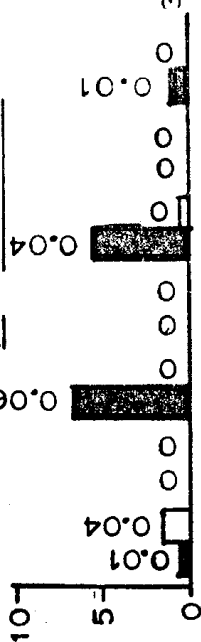
Table 11. Oligochaeta species composition as percent of the average standing crop ($\#/m^2$) at each station in the summers of 1968 and 1969.

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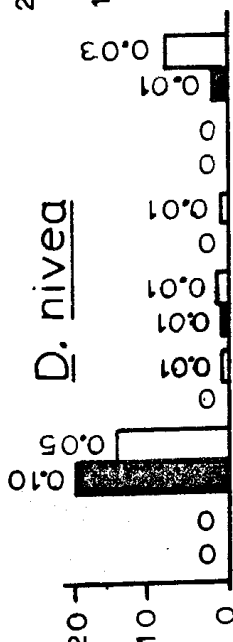
<u>Vejdovskvella comata</u>	0.1	0	0	0	0	0.2	0.5	0.6	0.2	0.2	3.7	4.1	0.2	2.0	0.4	1.5
Tubificidae																
<u>Bothreniurum vej dovskyanum</u>	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0.1
<u>Limnodrilus hoffmeisteri</u>	23.0	19.0	32.3	57.0	59.7	57.8	71.9	90.6	90.6	29.8	61.1	90.6	53.7	61.1	66.0	
<u>Pelosclex</u> sp.	19.1	60.0	0.5	0.1	11.2	22.5	2.7	3.9	10.6	21.0	0.5	3.5	3.5	8.4		
<u>Tubifex tubifex</u>	0.2	0	0.5	0.5	1.0	0	0	0	0	0	0	0	0	0	0	0
Lumbriculidae																
<u>Eclipidrilus lacustris</u>	3.4	0.3	0	0	1.0	0.1	1.6	0.2	1.7	0.1	0	0	0	0.5	0	
<u>Lumbriculus</u> spp.	0.7	0.4	0.3	0	1.4	1.3	0.3	0	1.8	1.4	0.3	0.1	0.5	0.4		
<u>Stylodrilus herringianus</u>	2.1	0	0	0	7.6	0	0	0	2.7	0.5	0	0	0.1	0.1		
<u>Ryachodrilus coccineus</u>	9.1	0.9	0.2	0.6	4.2	0.2	5.1	0	2.2	0	0.8	0	1.2	1.3		
Enchytraeidae	1.3	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	⁴⁷
Lumbricidae	0.1	0	0.1	0	0	0	0	0	0.3	0	0	0	0	0	0	
Glossoscolecidae	0.2	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	
Average #/m ²	608.3	1918.1	932.2	1244.4	681.1	806.3	695.5	1446.1	636.6	664.2	1689.1	1251.7	1783.7	708.5		
Average wt. (mg/m ²)	1.63	4.51	1.62	1.41	2.25	1.83	1.25	1.31	1.26	1.21	1.42	1.44	3.41	1.11		

Fig. 9. Average standing crop (No./m²) of Oligochaeta, Arcteonais lomondi, Pelosclex sp., Uncinais uncinata, Dero nivea, Stylaria fossularis, Stylaria lacustris, Limnodrilus hoffmeisteri, and Slavina appendiculata at each station in the summers of 1968 and 1969. Average dry biomass (mg/m²) above histograms.

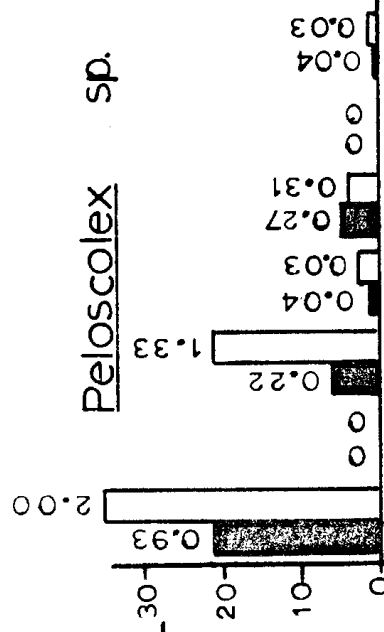
A. lomondi



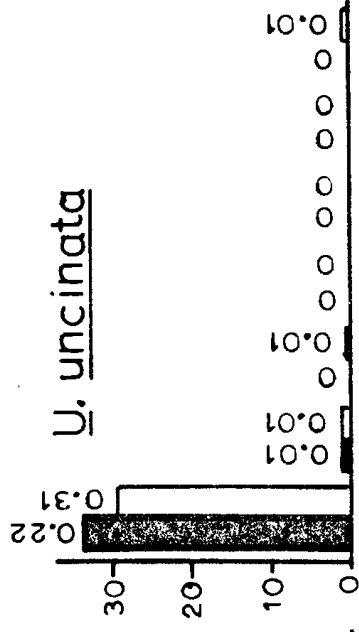
D. nivea



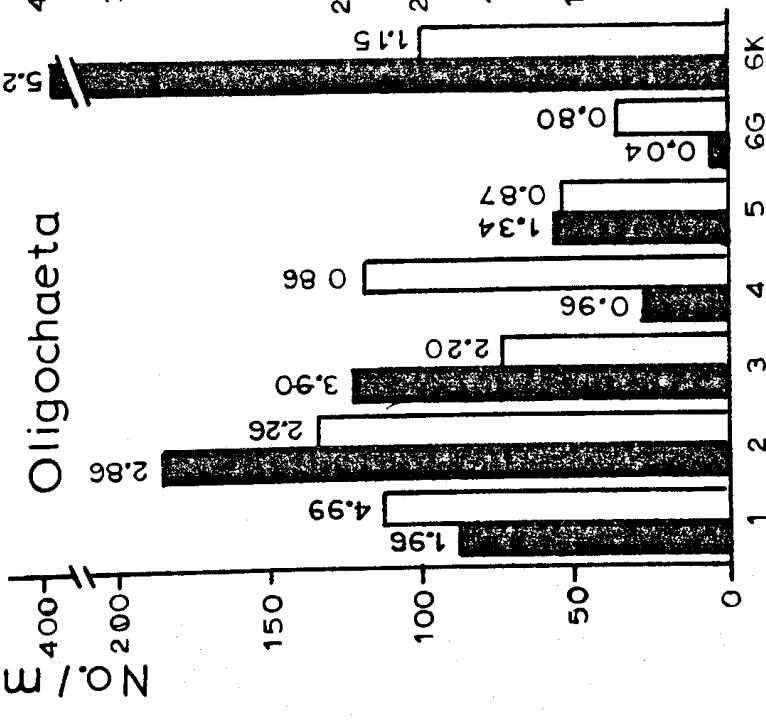
Pelosclex sp.



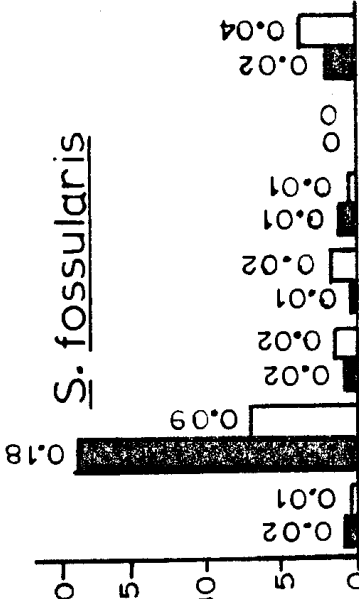
U. uncinata



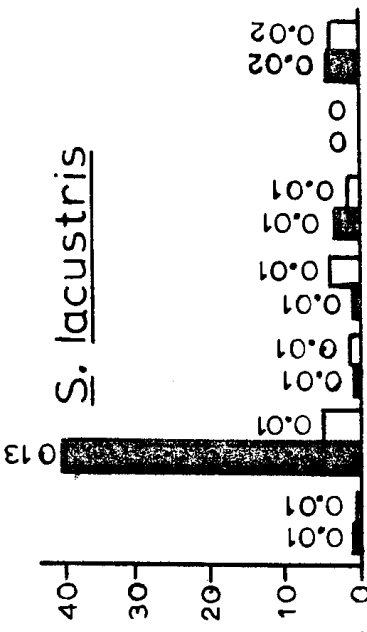
Oligochaeta



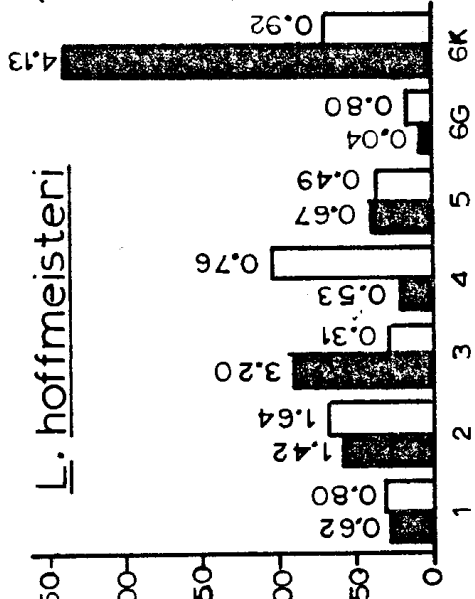
S. fossularis



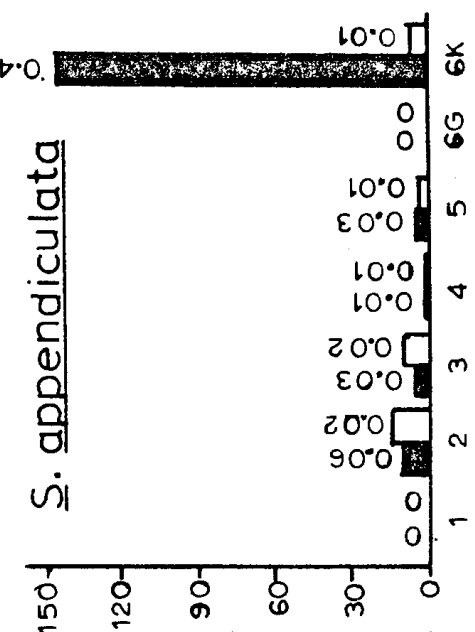
S. lacustris



L. hoffmeisteri



S. appendiculata



Stations

of the shore. Uncinais uncinata and Peloscolex sp. were most abundant in this almost stagnant water and the gradually sloping shore at Station 1 (Appendix II.4) Arcteonais lomondi were present only in the faster moving waters and in the steeply sloped shores of Stations 3 and 5.

Although Peloscolex sp. showed some correlation with the above factors, there is probably greater significance in its association with the algae, Cladophora. The Peloscolex worms were found associated with Cladophora when the algae were attached to stones or empty and living unionid shells of the species Elliptio complanatus in Station 1. The relationship between Peloscolex and Cladophora probably was not a symbiotic one because the worms were often found in samples that did not contain the algae. It is suspected that Peloscolex was feeding on the algae. There was also some suggestion that A. lomondi and S. appendiculata were interspecifically associated since the former was always accompanied in samples by the latter. However, S. appendiculata was not always accompanied by A. lomondi so that the association requires further investigation.

L. hoffmeisteri has long been recognized as a species tolerant of anaerobic conditions (Juday 1908) and has been designated as a pollution indicator organism by such authorities as Richardson (1929), Patrick (1949), Carr and Hiltunen (1965), and Brinkhurst (1966). It has also been shown by Gaufin and Tarzwell (1952) that L. hoffmeisteri is not necessarily restricted to polluted habitats but may also occur as common but generally not major, components of the clean water benthic communities. The mere presence of L. hoffmeisteri then is not indicative of pollution. Of the stations with cleaner water, Station 1 has the smallest average standing crop of L. hoffmeisteri. One can expect an average standing crop

of 280 L. hoffmeisteri individuals (cf. Fig. 9, Station 1) in every square meter of clean water communities. Numbers substantially greater than $280/m^2$ would indicate pollution, while populations with less than $280/m^2$ could be interpreted as an environment too adverse for the propagation of L. hoffmeisteri, adversity here implying such factors as gross pollution, extremely rapid water flow, and unsuitable substrates.

With a population of L. hoffmeisteri at Station 2 that is only slightly larger (Appendix II.1) than that of Station 1, one can expect only a mild degree of pollution. The subpolluted water of Station 2 supported significantly larger populations of the plant inhabiting species, S. fossularis, S. lacustris, and D. nivea, than the other stations (Appendices II.5 - II.7). The predominance and large numbers of these latter three species at Station 2 (Appendix II.1) suggests that they prefer a subpolluted habitat. Stations 3 and 5 were also dominated by L. hoffmeisteri, however, the results at Station 3 were somewhat obscured by a single population. The standing crop of L. hoffmeisteri at one site in Station 3 exceeded $7750/m^2$ while that of the other sites averaged $410/m^2$. The particular site that harbored the large population was visited in mid-June of 1968 so that the increase was not due to reproduction which presumably should have occurred in August as indicated in Figs. 9 - 11. Since large populations of L. hoffmeisteri occur in organically polluted areas, it is suspected that an underwater sewage outfall from the Town of Gatineau Pointe was in the vicinity. If one accepts the value of $410/m^2$ as the average standing crop for Station 3, the environments at the mouth of the Gatineau River and Station 5 could be considered as fairly clean and not significantly different (Appendix II.3) from the control station. The smallest populations of L. hoffmeisteri in

the study area occurred at Station 4. However, in depths between 2 and 5 meters the populations reached an average standing crop of $735/\text{m}^2$. Analyses of the substrate data showed that the shore area was composed of a mud-sand complex which often caused great turbidity during periods of rough water and that the 2 to 5 meter depths carried quantities of organic debris and chunks of animal matter similar to Station 2. What apparently had happened was that the flow of the Ottawa River was impeded and redirected by the New Edinburgh Canoe Club building (cf. Fig 1) so that the resulting backwaters redeposited suspended matter at the 2 to 5 meter depth. These deposits supported the large L. hoffmeisteri populations (as well as Chironomus sp. discussed on p. 99.). The only oligochaete to occur on the shores of Station 6G was L. hoffmeisteri and its small populations can probably be attributed to the gross pollution of CIP. It will be shown below that as recovery proceeded, populations in excess of $26,000/\text{m}^2$ occurred. The large numbers of L. hoffmeisteri at Station 6K (Appendix II.2) can be related to the effects of the CIP effluents and/or raw sewage from Gatineau Township as they spread to the shores of Kettle Island. The occurrence of the large numbers of S. appendiculata is less easily explained, although the effects of the CIP effluents seems to be the most obvious solution.

Since L. hoffmeisteri was the only oligochaete and one of two animals (the other being the chironomid, Chironomus sp.) to occur in the polluted waters below CIP, it is appropriate to discuss the extent of pollution in Station 6G at this point. The effect of pollution on the benthos was followed for 11 km downstream of the CIP outfalls by taking three bottom samples from each of the 0, 0.5, 1, 2, 4, 5, 7, 9, 10 and 11 km distances from the outfalls and from the one meter depths, in 1969.

The dissolved oxygen and B.O.D. values at the outfalls were 0 and 570 ppm, respectively (the data for these values were obtained in 1966 and are used since no new data have been obtained from the area immediately adjacent to the outfalls). These dissolved oxygen and B.O.D. values were diluted extensively by the volume of water rushing through the CIP channel. By the time the water from the main Ottawa River channel began mixing with the CIP channel water, an oxygen content of 7 ppm and a B.O.D. value of 4.8 ppm were observed in early July, 1969. At 7 km downstream, a B.O.D. value of 9.3 ppm was accompanied by a drop in oxygen content of 2.6 ppm. It is not known why these conditions occurred but it is suspected that either the Riviere Blanche (located immediately upstream of the 7 km site) was polluted or that there was a latent period for the active decomposition of woodfibres. Degradative conditions prevailed 11 km downstream where B.O.D. and dissolved oxygen values of 12.3 and 4 ppm were observed.

Conditions were so severe for the 11 km of Quebec shore investigated that submerged aquatic plant life was non-existent. This was probably a direct result of smothering by woodfibres which at some points were deposited on the bottom to depths of at least one meter.

No animals were taken in the bottom samples until 2 km below CIP at which point only L. hoffmeisteri occurred. The numbers of L. hoffmeisteri gradually increased from 150/m² at the 2 km site to 480/m² at 4 km, 650/m² at 5 km, and then rapidly rose to 3000/m² at 7 km and 26,000/m² at the 11 km site. It is difficult to say to what extent pulp and paper wastes were responsible for the removal of animal life since severe pollution from domestic sewage was probably implicated. This was particularly true for the 1 to 4 km sites where the sewage from the

Township of Gatineau increased the total coliform bacteria counts from 9300 MPN/100 ml, prevailing upstream of CIP on the shores of Kettle Island, to counts exceeding 250,000 MPN/100 ml in August of 1969.

The effects that domestic sewage have on bottom organisms is as well documented as the effects of woodfibres on fish (Smith and Kramer, 1963; Smith et al, 1965; Smith et al, 1966; MacLeod and Smith 1966; Thomas and Legault, 1967) but the effects of woodfibres on bottom organisms has not been definitely established. Dymond and Delaporte (1952), in their study of the pollution in the Spanish River, could not stipulate that one depended on the other. Much work is needed to show that woodfibre either reduced the oxygen content in the water, directly smothered the animals, and/or alters the physical nature of the environment to which the animals were previously adapted.

Seasonal distribution

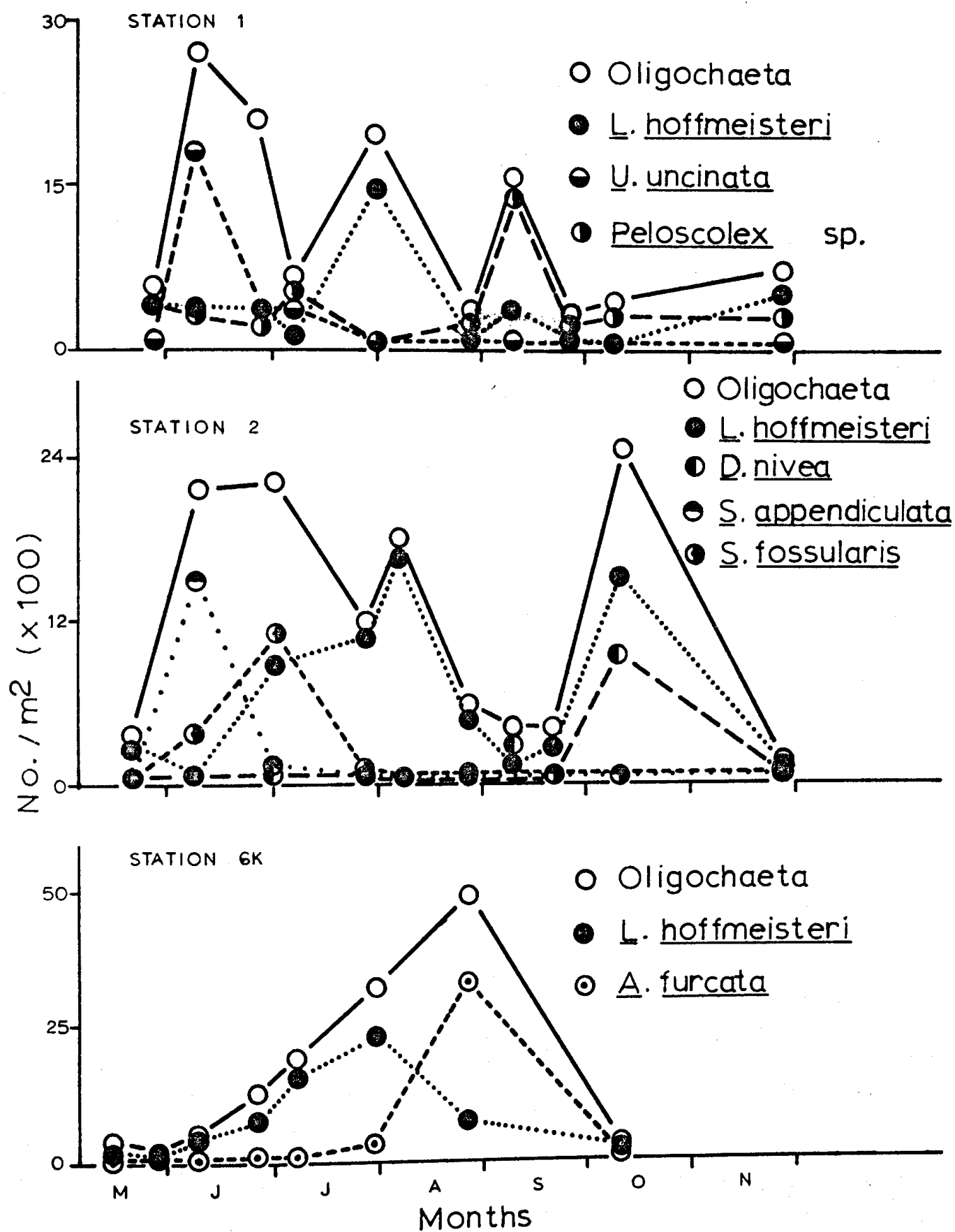
The seasonal distribution of oligochaetes at Stations 1, 2, and 6K are shown in Fig. 10, 11, 12. At Station 1, maximum standing crops occurred in early June, late July, and early September. The peak in early June was primarily caused by an increase in the number of U. uncinata. When the water temperature had risen to 23°C, U. uncinata was replaced by L. hoffmeisteri, the numbers of which had reached a population minimum by late August. The decrease in the numbers of L. hoffmeisteri was accompanied by an increase in the numbers of Pelosclex sp. which culminated in early September.

At Station 2, the maximum standing crop of S. appendiculata, observed in early June, was followed two weeks later by S. fossularis and, to a lesser extent, S. lacustris. As was observed at Station 1, L.

Fig. 10. Seasonal distribution of Oligochaeta, Limnodrilus hoffmeisteri, Uncinatis uncinata, and Peloscolex sp. at Station 1, 1969.

Fig. 11. Seasonal distribution of Oligochaeta, Limnodrilus hoffmeisteri, Dero nivea, Slavina appendiculata, and Stylaria fossularis at Station 2, 1969.

Fig. 12. Seasonal distribution of Oligochaeta, Limnodrilus hoffmeisteri, and Aulophorus furcata at Station 6K, 1969.



hoffmeisteri attained a maximum standing crop in early August when the water temperature was about 23°C. As the water temperature returned to 15°C in early October, an increase in the number of D. nivea occurred as well as another increase of L. hoffmeisteri.

The early August maximum that occurred for L. hoffmeisteri at Stations 1 and 2 was also observed at Station 6K. A. furcata, after being absent in samples until early July, increased in number until they reached a maximum standing crop in late August.

That L. hoffmeisteri achieved maximum standing crops at about the same time in three different stations suggests that the increase was due to reproduction (that began sometime prior to August) and not to the coincidence of other factors (i.e. colonization). Moreover, Brinkhurst and Kennedy (1965) in a study of the life history of L. hoffmeisteri, attributed a July-August increase in the number of young to the hatching of cocoons laid in May and June. The naids U. uncinata, D. nivea, S. appendiculata, S. fossularis, and A. borelli are all capable of both sexual and asexual reproduction (Brinkhurst, 1964). Each of the five naid species were observed by myself to be represented by several individuals consisting of chains of two zooids during their periods of maximum abundance. These observations indicate that the maximum standing crops of each naid species in Fig. 10 - 12 were due to asexual reproduction. There is some suggestion that the temporal replacement of the naid species was related to water temperature since they reproduced either in the spring or in the fall when water temperatures were 15 - 19°C.

Depth distribution

During the month of June, U. uncinata dominated the 2 meter depth at Station 1 while L. hoffmeisteri occupied a subordinate position at this

depth (Fig. 13, 14). When L. hoffmeisteri reproduced in early August, it dominated the 2 meter depth and U. uncinata all but disappeared from the bottom fauna. The seasonal replacement between these two species may indicate that they have the same ecological requirements and tend to be mutually exclusive in the habitat at the 2 meter depth. If these two species were mutually exclusive, the competitive exclusion principle (Hardin, 1960) can be used to explain the seasonal replacement between U. uncinata and L. hoffmeisteri.

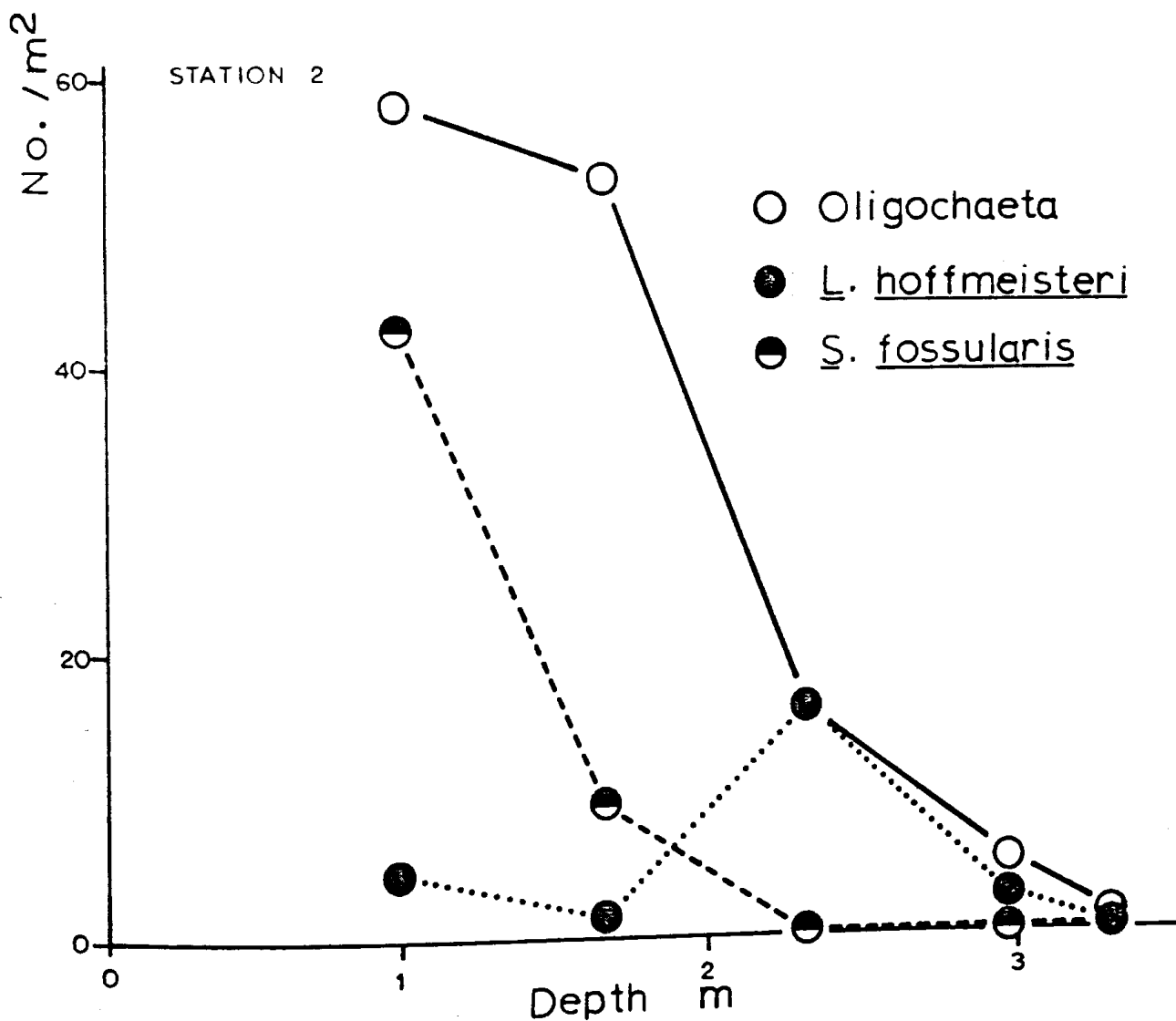
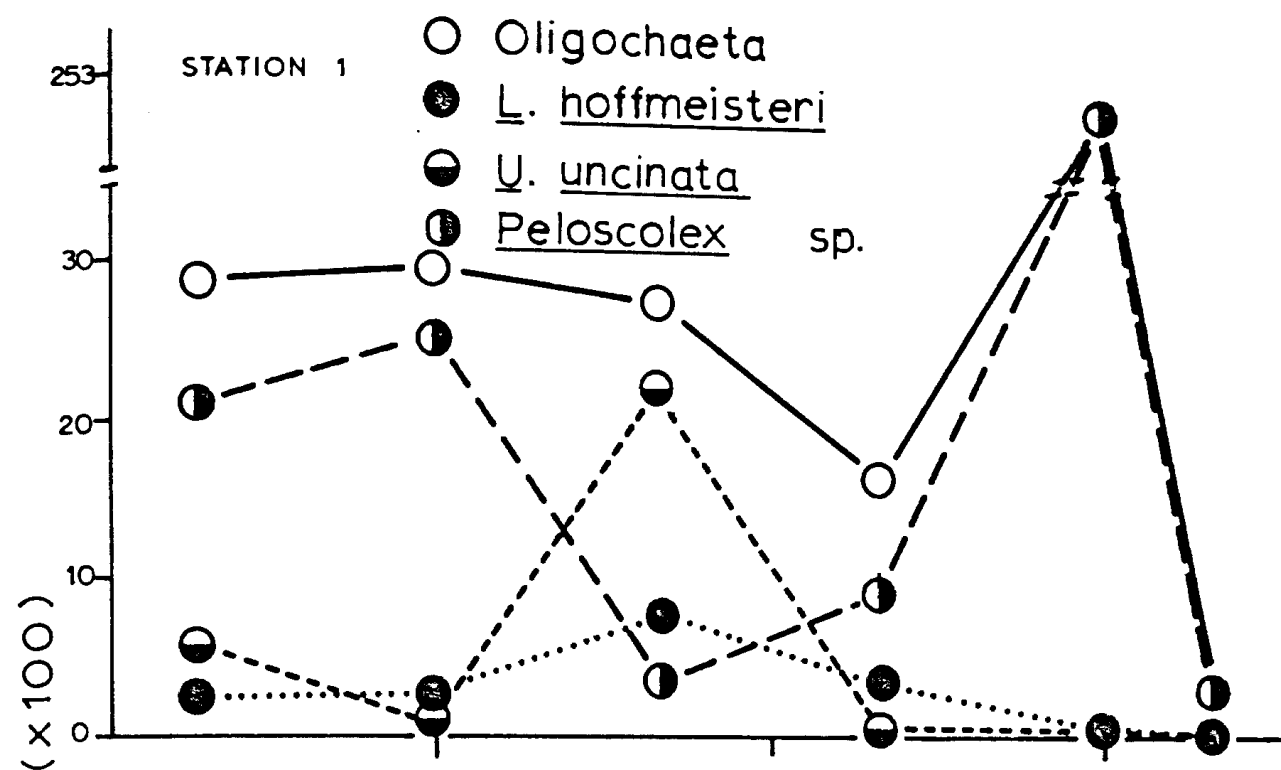
Peloscolex sp. was abundant near the one meter depth and was spatially replaced by U. uncinata (in June) and L. hoffmeisteri (in August) in the 2 meter depth but its largest populations were observed in association with Cladophora that was attached to dead and living unionid shells (Elliptio complanatus) in the 3 meter depth. The Peloscolex worms in the 1 meter depth were not found in association with either the algae or the mussel shells but occurred merely as a component of the benthic communities. Spatial replacement was also observed at Station 2 where S. fossularis and L. hoffmeisteri were both horizontally and vertically distinct from one another; horizontally in that S. fossularis dominated near the 1 meter depth and L. hoffmeisteri near the 2 meter depth; vertically in that S. fossularis inhabited the aquatic vegetation and L. hoffmeisteri the bottom. It may be in part, the result of this interspecific competition that the populations of L. hoffmeisteri are held in check in the cleaner water environments and the lack of it that contributes to the enormous numbers of L. hoffmeisteri in the polluted environments. This is, however, very speculative.

Polychaeta

One species of fresh water polychaeta, Manayunkia speciosa Leidy,

Fig. 13. Depth distribution of Oligochaeta, Limnodrilus hoffmeisteri,
Uncinatis uncinata, and Pelosclex sp. at Station 1, June
1969.

Fig. 14. Depth distribution of Oligochaeta, Limnodrilus hoffmeisteri,
and Stylaria fossularis at Station 2, June 1969.



occurred in the study area. However, the number of specimens found were so small that any discussion must necessarily be limited. Of greatest significance, perhaps, was the presence of M. speciosa in the Ottawa River because it has been found in only ten other locations on the North American continent (Leidy, 1858, 1883; Foulke, 1884; Potts, 1884; Meehan, 1929; Kreckler, 1939 b; Pettibone, 1953; Britt, 1965; Hitunen 1965; Hazel, 1966; Hazel and Kelly, 1966; Holmquist, 1967; Mackie and Qadri, 1971 b). M. aestuarina is the only other fresh water polychaete of the genus Manayunkia that occurs on the North American continent (Light, 1970).

M. speciosa occurred only in Stations 1, 3, and 5 and therefore indicated a preference for fine sandy substrates. Since this species did not occur in the subpolluted habitats of Station 2 nor the grossly polluted areas of Station 6G, it is suspected that they were intolerant of pollution. There was also some indication that M. speciosa preferred moving water since most specimens (177/m²) were found in Stations 3 and 5; Hazel (1966) also suspected that water movement was an influential factor since more specimens occurred at the mouths of rivers than in the lakes that the rivers were draining.

Hirudinea

Eleven species of leeches occurred in the study area, the majority of which belong to the Family Glossiphoniidae (snail leeches). Table 12 lists all the species and their relative abundance at each station. There are undoubtedly other species in the Ottawa River, particularly those that are obligate parasites on fish but only those leeches that appeared in the bottom samples were investigated.

The occurrence of eleven species of leeches in the Ottawa River represents approximately 35% of the Ontario leech fauna, most recently

Table 12. Hirudinea species composition as percent of average standing crop (#/m²) at each station in the summers of 1968 and 1969.

Species	Stations													
	1		2		3		4		5		6G		6K	
	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969
Glossiphoniidae														
<u>Glossiphonia complanata</u>	36.8	0	10.6	4.2	0	15.6	5.5	4.8	0	0	0	0	0	0
<u>G. heteroclita</u>	0	0	0	0.9	0	0	0	0	0	0	0	0	0	0
<u>Helobdella elongata</u>	0	0	0	8.3	0	10.1	0	0	0	5.4	0	0	0	0
<u>H. fusca</u>	0	0	4.5	3.6	7.9	23.3	0	0	0	5.1	0	0	5.1	0
<u>H. lineata</u>	0	0	20.4	0	0	0	5.3	0	0	0	0	0	0	0
<u>H. stagnalis</u>	34.0	100.0	45.3	81.2	25.3	41.3	58.5	75.1	4.8	67.0	0	0	45.2	50.0
<u>Placobdella ornata</u>	0	0	0	0	0	0	0	0	0	4.0	0	0	4.9	0
<u>P. phalera</u>	21.9	0	4.2	0.9	0	0	0	4.1	0	0	0	0	0	0
Erpobdellidae														
<u>Mooreobdella microstoma</u>	7.5	0	15.0	0	47.3	9.7	22.0	9.7	0	3.5	0	0	41.9	50.0
Immature erpobdellids	0	0	0	0.9	18.5	0	8.7	6.3	95.2	15.0	0	0	7.9	0
Average #/m ²	4.7	9.2	76.6	56.5	9.2	22.8	15.6	21.7	19.0	24.8	0	0	27.9	5.4
Average wt. (mg/m ²)	0.04	0.04	0.38	0.38	0.35	0.31	0.30	0.21	0.04	0.20	0	0	0.09	0.02

reported to be 27 species (Meyer and Moore, 1954). Of the eleven species, only H. stagnalis was common in the Ottawa River. Bennike (1943), Mann (1955 a, b, 1957 a, b), and Herrmann (1970) found that soft waters were unfavourable for leech productivity; Mann (1955 a, b) labelled waters as soft for leeches when the calcium content was less than 7 mg/l, as intermediate when 7 - 24 mg Ca/l, and as hard when more than 24 mg Ca/l. Although H. stagnalis has been considered a hard water species, it is generally the most abundant species in the intermediately hard waters (Mann, 1957 b). It is therefore, not surprising that H. stagnalis dominated the Ottawa River leech fauna where calcium contents of 10 mg/l occurred.

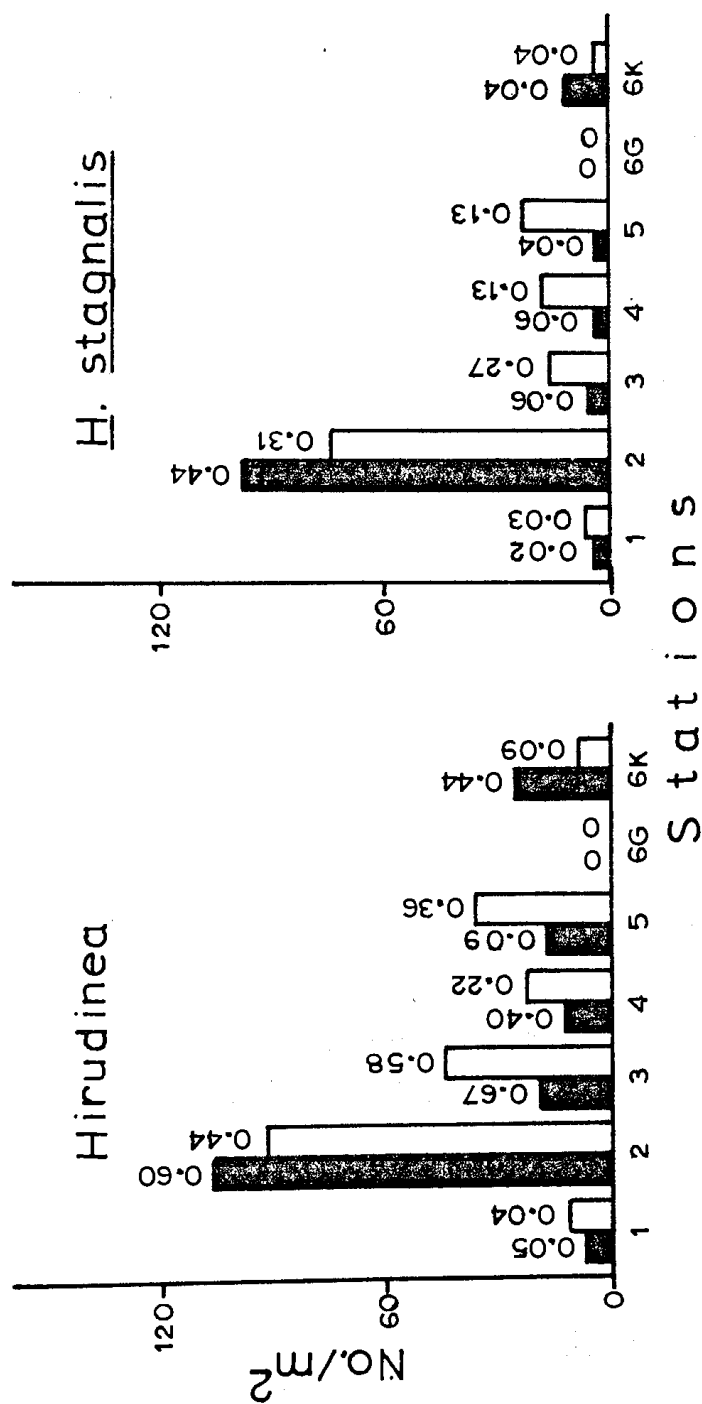
Horizontal distribution

As shown in Fig. 15, the average standing crop of leeches was larger in Station 2 than in the remaining stations. Gross pollution eliminated all leeches from Station 6G. The dominant leech, H. stagnalis occurred with the largest average standing crop in the subpolluted waters of Station 2 (Appendix III.1) where decaying plant and animal detritus formed much of the substrate. The paucity of H. stagnalis on fine sandy substrates (Stations 1, 3, and 5) indicates that this type of substrate was not conducive to the production of large populations. This conclusion was also reached by Herrmann (1970). The effect of organic matter on leeches appeared to be a positive one but it was probably of secondary importance, the limiting factor being the amount of food in the sediments, as discussed later.

There appeared to be little correlation between water movement and leech distribution, particularly, in Brewery Creek where similar standing crops of H. stagnalis occurred in the upper reaches with its

Fig. 15. Average standing crop (No./m²) of Hirudinea and Helobdella
stagnalis at each station in the summers of 1968 and 1969.
Average dry biomass (mg/m²) above histograms.

■ 1968 □ 1969



fast flowing water as in the stagnant portions at its mouth near the Ottawa River. Herrmann (1970) found that such environmental features as rapid current provided harsh environments that only H. stagnalis could tolerate. Mann (1962) suggested that some species of leeches are better adapted to lotic environments than others, especially with respect to the breeding season; such forms as G. heteroclita hold its cocoons loosely under the body whereas H. stagnalis and G. complanata have firm holds of their cocoons so that there is a lesser possibility of the current carrying them away.

Food was probably the main limiting factor in the distribution of H. stagnalis. Although several authors have reported that the food consists of the body juices of snails, oligochaetes and insects (Moore, 1924, 1966; Mann, 1962; Hermann, 1970), I have seen H. stagnalis feeding only on chironomid larvae. Moreover, the distribution of H. stagnalis is closely related to that of the chironomids, Phaenopsectra sp. and Chironomus sp. upon which they were feeding. There was no apparent correlation with the distribution of gastropods and oligochaetes. The decaying organic debris in Station 2 probably imposed an oxygen demand that only H. stagnalis and the chironomids, Phaenopsectra and Chironomus could tolerate. By the elimination of its competitors, H. stagnalis was able to exploit the food resources and establish itself more successfully than it could in cleaner environments where competition might have been of greater consequence.

That H. stagnalis can tolerate high oxygen demands is borne out by the studies of Mann (1956) who found that of five species investigated H. stagnalis was more efficient in consuming oxygen at low oxygen concentrations. Mann (1957 b) also suggested that "H. stagnalis has a higher

biotic potential" than other species (G. complanata), and "accounts for the fact that it is usually the most numerous species in eutrophic lakes." The dominance of H. stagnalis in Station 2 is therefore not surprising.

Seasonal distribution

With the exception of H. stagnalis, very few leeches occurred with sufficient numbers to permit analyses of their seasonal distribution. Consequently, specific information is only given for H. stagnalis, the maximum standing crop of which occurred in mid-July. Parent individuals were observed carrying their young on the ventral surface of the body from June through August. Table 13 gives the percentage of H. stagnalis parents carrying young and the percentage of detached juveniles in each collection at Station 2.

Table 13 Percentage of H. Stagnalis parents carrying young and percentage of juveniles in each collection at Station 2 in 1969

Date	Total specimens	% carrying young	% juveniles
May 21	4	0	0
June 9	4	100	0
July 1	3	100	0
July 22	69	2.8	97.2
August 5	7	0	100
August 27	5	20	80
September 20	23	All appear nearly full grown. None carrying young on or after this date.	

On the basis of Table 13, there is little doubt that the peak in mid-July (Fig. 16) was primarily composed of juvenile H. stagnalis.

These findings are in very close agreement with those of Mann (1957 b) who found that the offspring in July matured quickly so that by August, all were classified as breeders. This might explain the slight increase in late August of Fig. 16. The rapid decrease in their numbers in early August can probably be attributed to a high mortality rate which Mann (1957 b) observed to be about 80% in the first month of life.

That H. stagnalis was feeding on the larvae of Chironomus sp. is also suggested in the seasonal distributions of these two species at Station 2; the plateau reached by Chironomus sp. (Fig. 28) in mid-July, coincided with the maximum standing crop of H. stagnalis (Fig. 16). This is indicative of the cause and effect relationship that is exhibited between predator and prey.

Depth distribution

The leeches, primarily H. stagnalis, prevailed in depths less than two meters as shown in Fig. 17. The depth distribution of H. stagnalis can be related to that of Chironomus sp. (Fig. 31) as one of a predator-prey relationship. Where populations of Chironomus sp. occurred near the 1 meter depth those of H. stagnalis were low. Where the populations of Chironomus sp. were low, those of H. stagnalis were high, hence suggesting a cause and effect relationship.

Isopoda

The study area was inhabited by three species of isopods. Unfortunately, taxonomic keys were not available for the identification of both male and female isopods so that the abundance of each species could not be estimated. Moreover, communication with Dr. W. Williams, of

Fig. 16. Seasonal distribution of Hirudinea and Helobdella stagnalis at Station 2, 1969.

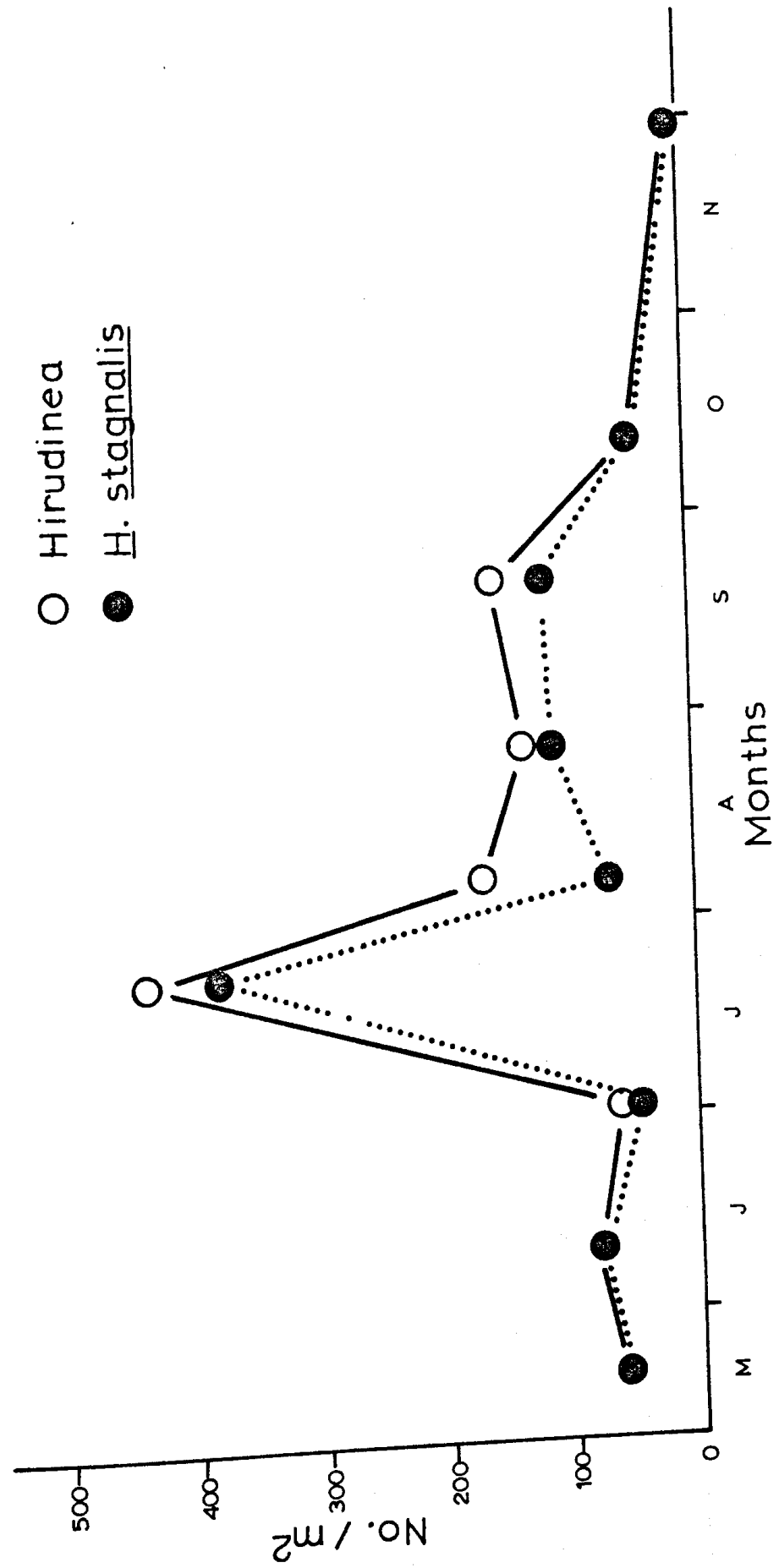
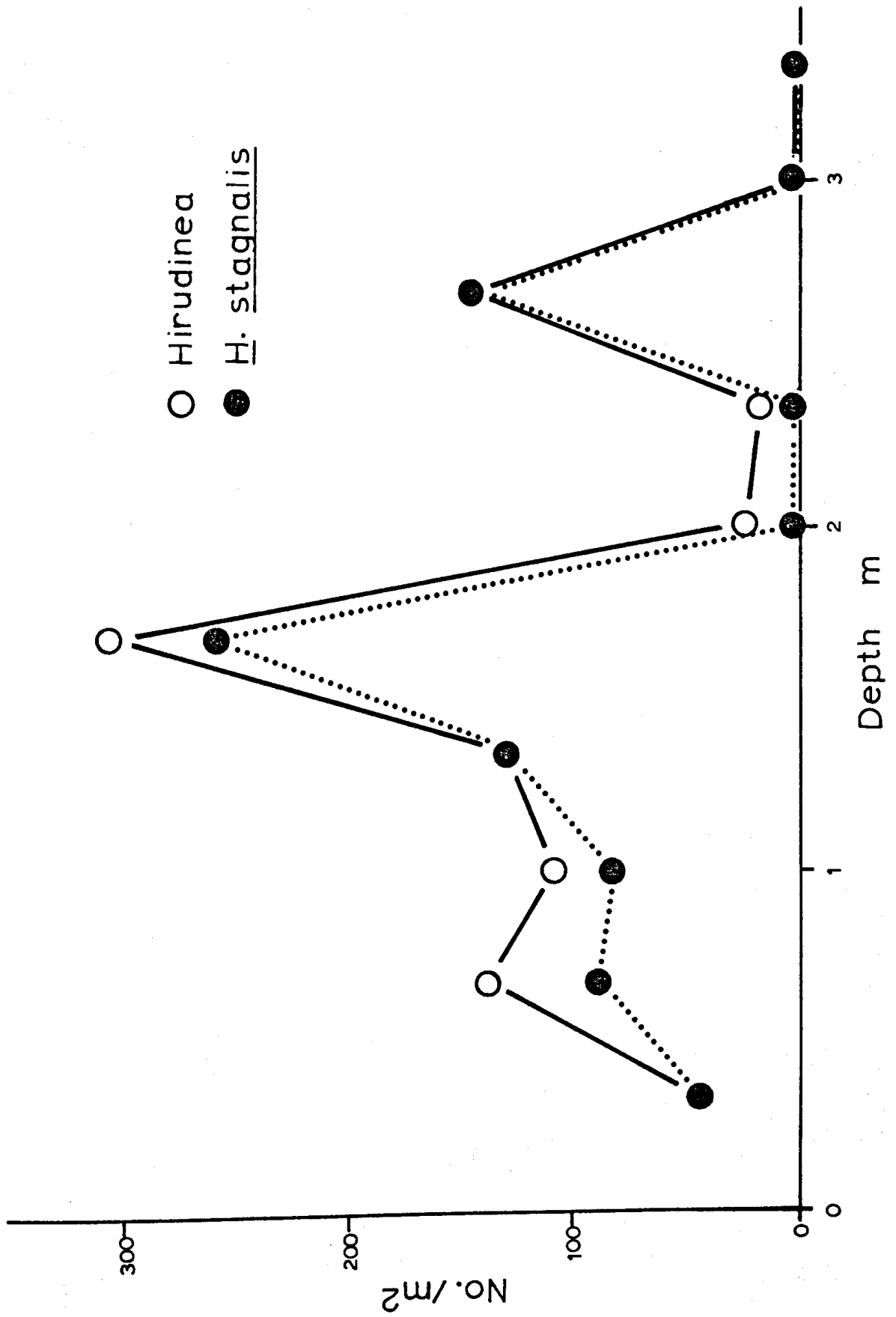


Fig. 17. Depth distribution of Hirudinea and Helobdella stagnalis at Station 2, July-August 1969.



Monash University, Australia, who has recently revised the taxonomy of isopods, has revealed that a new species exists in the study area. Until this new species has been described, its name will remain unknown. The two known species are Asellus intermedius Forbes and Lirceus tenax Say; the new species belongs to the genus Asellus.

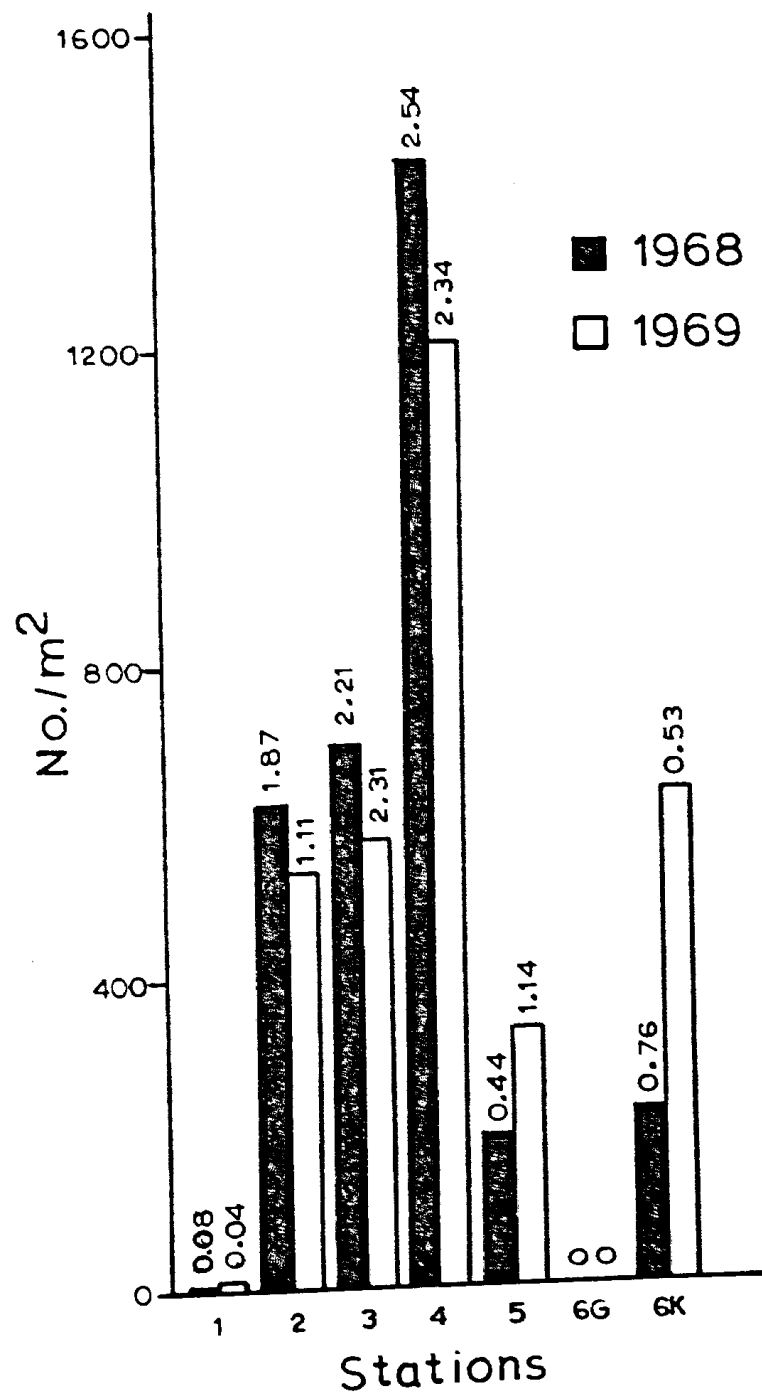
Horizontal distribution

Isopods were least abundant at Stations 1 and 5 (Appendix IV. 1.2) where the substrate was predominantly sand and were absent at Station 6G where gross pollution occurred. Only at Stations 2, 3, and 4 were the isopods prevalent, particularly at Station 4. The horizontal distribution of isopods is shown in Fig. 18.

Unlike many of the other taxa, the isopods showed a preference for subpolluted conditions. This can probably be explained by the suitability of the bottom (organic detritus) and the ample food supply that usually accompanies organically polluted environments. The effect of the substrate type and food supply explains the distribution of isopods in all stations except Station 3. The average standing crop of isopods at Station 3, however, was influenced by a population containing over 2600 individuals per square meter at any one site. This population was approximately twice that observed at any other site. Since at this same site there were enormous numbers of L. hoffmeisteri and Chironomus sp., we have further support for the contention that there is a sewage outfall in the vicinity. The occurrence of isopods in subpolluted habitats has also been reported by Richardson (1929), Hynes (1960), and several others.

Water velocity appeared to be of only secondary importance. In Station 2 the water flow was so slow that much of the matter suspended in the

Fig. 18. Average standing crop (No./m²) of Isopoda at each station in the summers of 1968 and 1969. Average dry biomass (mg/m²) above histograms.



water was deposited on the bottom. The water flow at Station 2, as explained for the oligochaetes, was of such a nature that the New Edinburgh Canoe Club, by redirecting the water flow, created backwaters that deposited and concentrated large amounts of organic debris in the two to four meter depths. These depths contained the largest isopod populations (Fig. 18).

Organic pollution appeared to be a prerequisite for the occurrence of large numbers of isopods in contrast to the pulp and paper wastes, particularly woodfibres, which were not conducive to the formation of large isopod populations. This can probably be related to the food supply in the two types of wastes. The plant and animal debris of Stations 2 and 4 were of more nutritional value than the woodfibres of Stations 6G and 6K.

Seasonal distribution

Gravid female isopods were found at all stations until the middle of June when increases in isopod populations were observed. At all stations the increase in isopod numbers culminated in July as exemplified by Stations 2 and 4 of Fig. 19. In only one instance, Station 5, were gravid females found in mid-September, however no subsequent increases of isopod populations were observed. It is not known whether another reproductive period occurred but population maxima during the winter months have been reported for Asellus species by Jonasson (1948) and Ellis (1961).

Depth distribution

Stations 2, 3, and 5 exhibited isopod aggregations only near the one meter depth (Fig. 20). Station 4 had aggregations in excess of 7500

Fig. 19. Seasonal distribution of Isopoda at Stations 2 and 4, 1969.

OTTAWA, ONTARIO

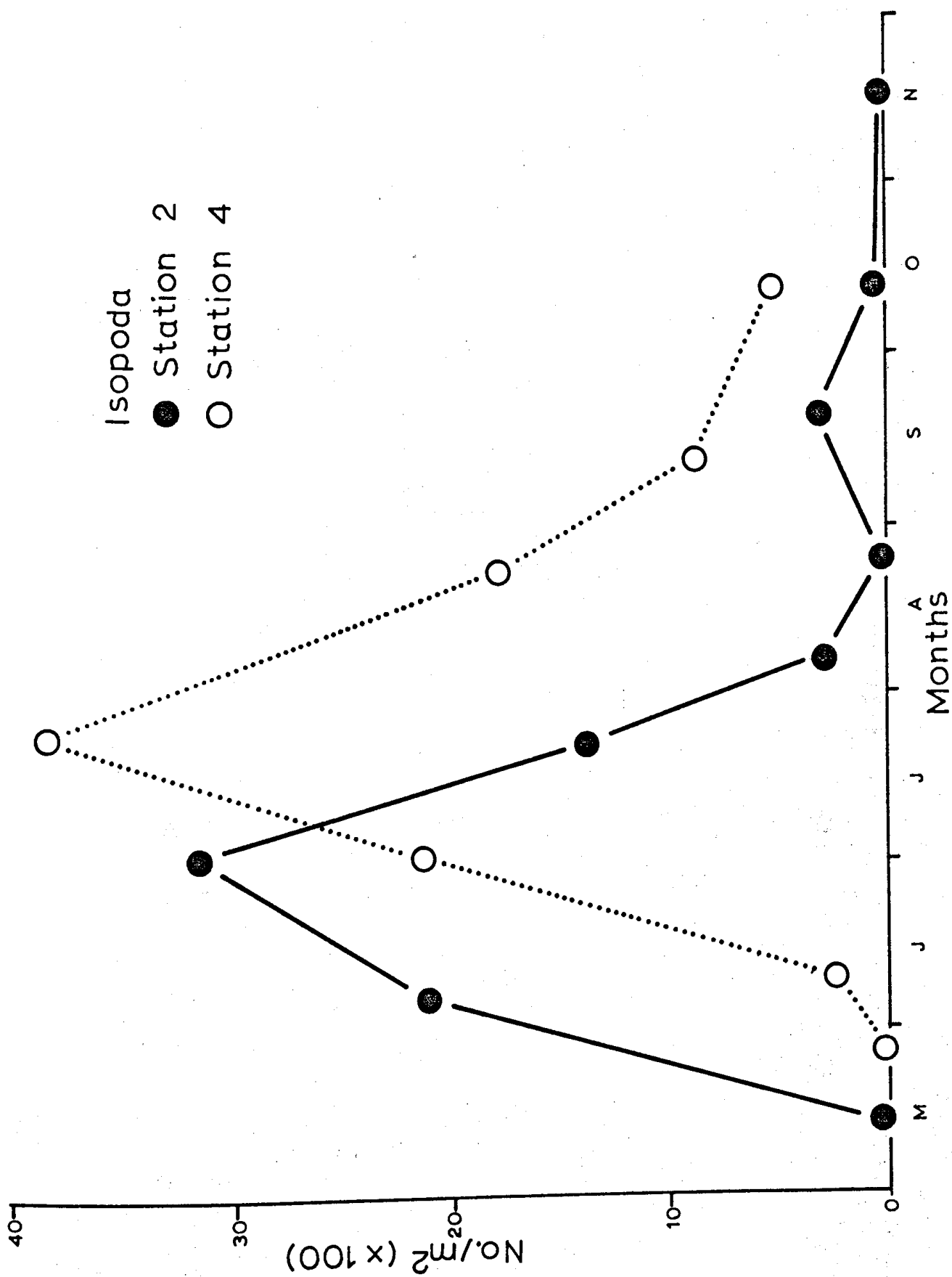
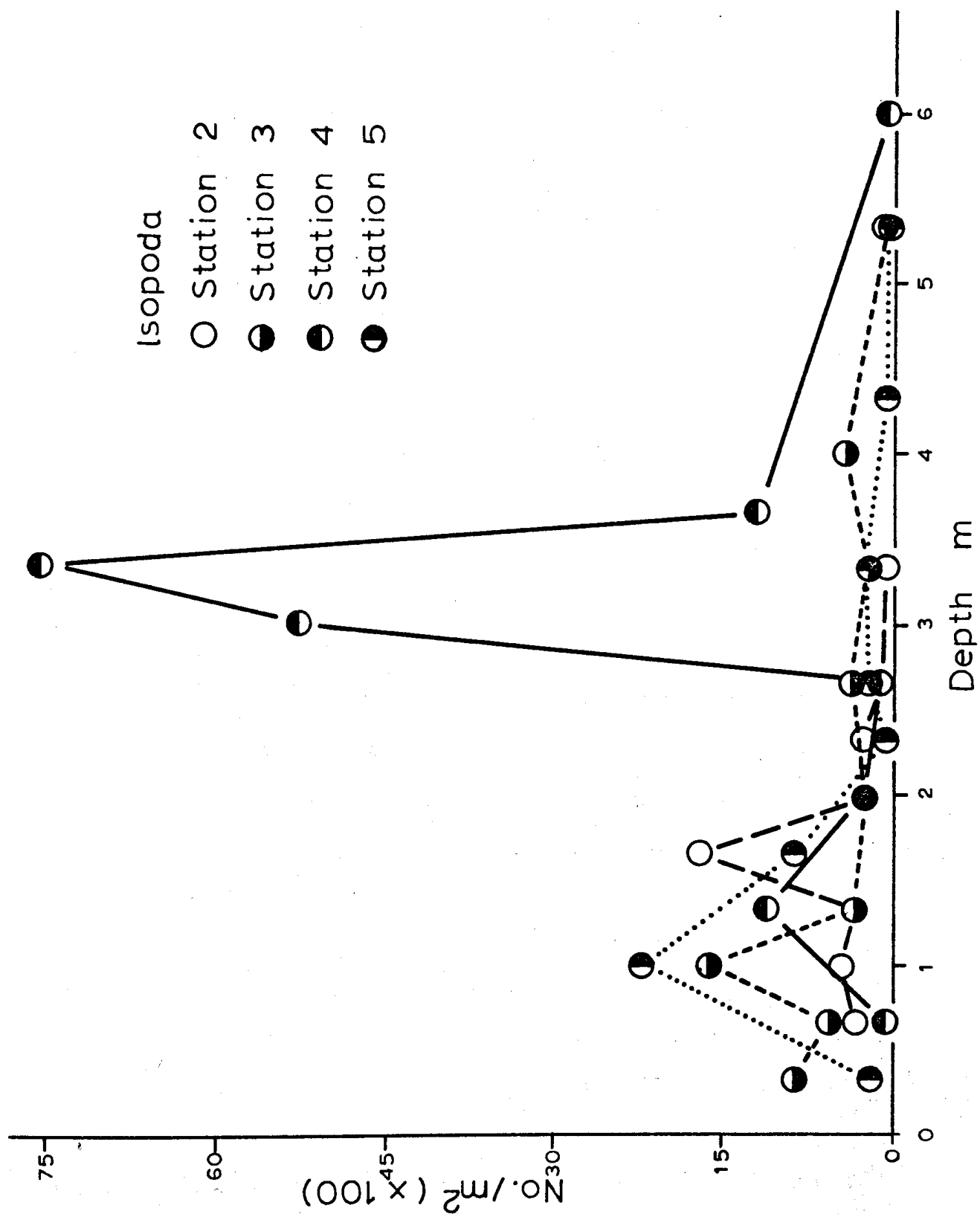


Fig. 20. Depth distribution of Isopoda at Stations 2, 3, 4, and 5,
July 1969.



individuals per square meter near the 3 meter depth. Large populations also occurred in the mud of Station 4 of the 1 meter depth. Isopods were absent in depths exceeding 5.5 meters.

The occurrence of isopods near the one meter depth suggests that it inhabited aquatic plants. As Table 9 shows, the isopods did not occur in the aquatic vegetation but were most abundant on the bottom of the littoral zone so that they were probably browsing on the plant detritus. Isopod populations were larger in the organic debris of the 2 to 4 meter depths than in the mud in the 1 meter depth at Station 4. These results support the contention that the distribution of isopods is primarily a function of substrates containing organic matter.

Amphipoda

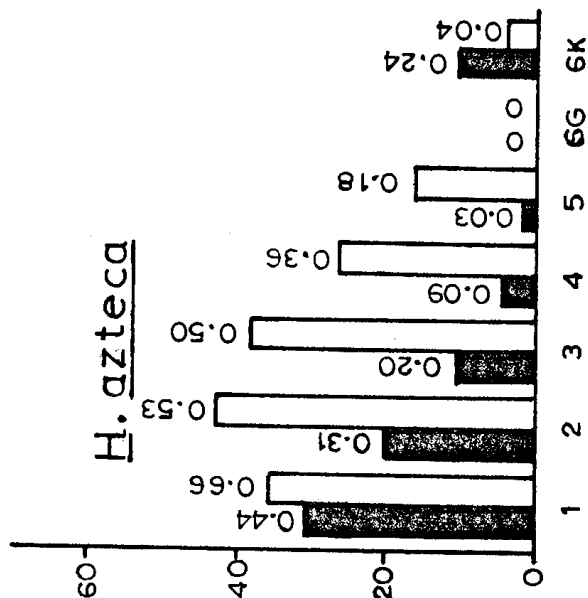
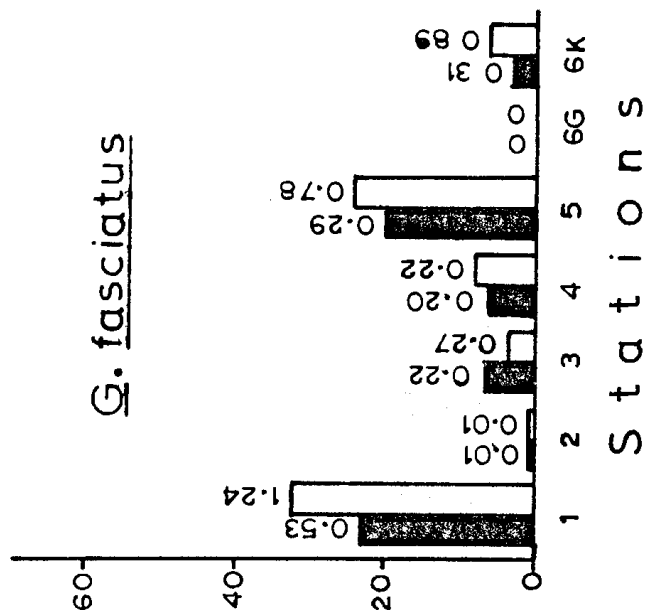
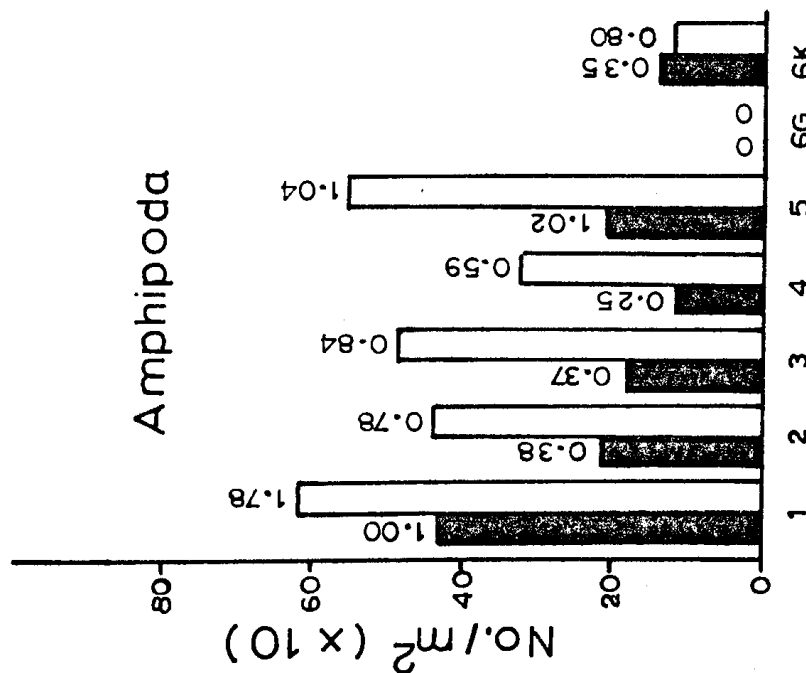
The amphipods were represented by four species, two of which were extremely abundant. The four species and the percent of the average standing crop that occurred in all depths at each station, are given in Table 14. All four species occurred at Stations 3, 4, 5, and 6. Three species, H. azteca, G. fasciatus, and C. pseudogracilis, occurred at Station 2 while Station 1 was represented only by H. azteca and G. fasciatus.

Horizontal distribution

Amphipods were more abundant at the control station (Appendix V.1) than at other stations (Fig. 21). Successively few amphipods occurred from Stations 2 to 4 until at Station 5 another increase was observed. No amphipods occurred on the Gatineau shore below the CIP effluents of Station 6G. Analyses of the amphipod species composition in 1968 at each station revealed similar numbers of G. fasciatus and H. azteca at Station

Fig. 21. Average standing crop (No./m²) of Amphipoda, Gammarus fasciatus, and Hyaella azteca at each station in the summers of 1968 and 1969. Average dry biomass (mg/m²) above histograms.

■ 1968 □ 1969



1 (Appendix V.6). An inverse relationship between the numbers of both species occurred in the remaining stations (Appendices V.2 - V.7). The numbers of G. fasciatus fell from 230/m² at Station 1 to 5/m² at Station 2 and then increased successively at Stations 3, 4, and 5 to 142/m². Conversely, the numbers of H. azteca decreased from 202/m² at Station 2 to 16/m² at Station 5.

Very little is known about the factors that determine distribution of amphipods. Titcomb (1927) found the distribution of G. fasciatus to be dependent on the degree of hardness of the water. Pentland (1930) found that temperature, vegetation, and presence of enemies alone appeared to control the distribution of G. fasciatus. These two studies, however, dealt with ecological factors controlling the geographical distribution of amphipods. Little emphasis has been placed on identifying those ecological factors that affect amphipod distribution in a single watershed.

Sediment types appeared to have very little influence on the distribution of amphipods. It is well known from other investigations such as Pentland (1930), Kreeker (1939 a), Penfound (1956), Gerking, (1957), Cooper (1965) and several others, that amphipods are associated with submerged aquatic plants. This realization initiated an investigation to determine if different plant species harboured larger amphipod populations. The results (Table 9) indicated that Myriophyllum spp. and E. canadensis contained the largest amphipod populations while V. americana had the smallest. Moreover, 90 - 95% of the amphipods on Myriophyllum spp. and E. canadensis were H. azteca while 70 - 90% of the amphipods on Potamogeton sp. (taken with the Ekman dredge) were G. fasciatus, although their numbers were quite small (43 per 100 cc of

aquatic plants). Furthermore, of H. azteca and G. fasciatus that occurred in those dredges without aquatic plants 62 - 81% were G. fasciatus. A possible explanation for the amphipod distribution is to compare these figures to the plant frequencies at each Station (Table 1). The high frequency of Potamogeton spp. within the control station and the presence of Myriophyllum spp. and E. canadensis possibly resulted in its larger amphipod populations. The decrease in the frequency of Myriophyllum spp. and E. canadensis from Stations 2 to 5 may partly explain the successively smaller H. azteca populations and larger G. fasciatus populations, where the latter did not appear as dependent on plants as the former. Exactly why these plants supported larger amphipod populations can be related to the results of other investigators, as subsequently discussed.

One cannot ignore the possibilities that amphipods with their high oxygen requirement (Pennak, 1953) inhabit aquatic vegetation to obtain photosynthetic oxygen. Based on the observations that plants with finely dissected leaves (i.e. Myriophyllum, Fig. 4) occurs in quiet water and plants with broad flat leaves (Vallisneria) in moving water, Whitwer (1955) suggests that, in quiet waters, Myriophyllum could tap a greater volume of water and hence contribute significant amounts of dissolved oxygen. In this respect, amphipods may have inhabited Myriophyllum and E. canadensis in stagnant and subpolluted waters of Station 2 to obtain an immediate supply of photosynthetic oxygen.

Hyalella azteca has a double row of coxal gills on abdominal segments 2-6 (Bousfield, 1958). Further research would be required to determine if these accessory gills are of respiratory significance, particularly in waters with high oxygen demands, such as occurred in the upper reaches of Station 2 where H. azteca was very abundant (2630/m²) and

the only plant was V. americana.

It is doubtful that amphipods inhabited aquatic plants solely for photosynthetic oxygen in moving waters because, as Whitwer (1955) has reported, the oxygen produced from aquatic plants would be insignificant compared to other oxygen already present in the well aerated and clean moving waters. The role of aquatic plants may also be to harbor a food supply. Jackson (1912) and Lineman (1941) have designated H. azteca as a browser feeding on the epiphytes of aquatic plants. Considering the greater ratio of surface area to volume in Myriophyllum than in Vallisneria, it is conceivable that the former would support larger populations of epiphytes than the latter and hence larger amphipod populations. The food relations of amphipods would have to be investigated to establish to what extent it determines their distribution.

Much recent work has been directed to the study of drift of amphipods, particularly of Gammarus spp. It has been well established that lower light intensities increase the drift rates of amphipods (Waters, 1961, 1962, 1965, 1969; Holt and Waters, 1967; Hughes, 1969). Among the factors that affect light intensity are turbidity, shade contributed by the shore line and shade contributed by aquatic plants. The latter is the most obvious because amphipods are highly associated with aquatic plants. If drift is an important factor in the distribution of amphipods, aquatic plants, by virtue of their shading effect and as holdfast devices, may play a significant role in the rate of drift, and hence in the distribution of amphipods.

The absence of amphipods in Station 6G could be related to several factors such as the high B.O.D., phenols, sulfates, turbidity and bacteria. However, the phenols, sulfates and other chemicals investigated were not present in lethal concentrations (Table 6), although there may have been

synergistic effects. The differences in the concentrations of these chemicals between stations did not appear large enough for these chemicals to be considered as factors in the removal of amphipods at Station 6G. The large B.O.D. caused by the CIP effluents and bacteria from Gatineau Township probably contributed towards the removal of amphipods but it is suspected that the removal of aquatic plants was responsible.

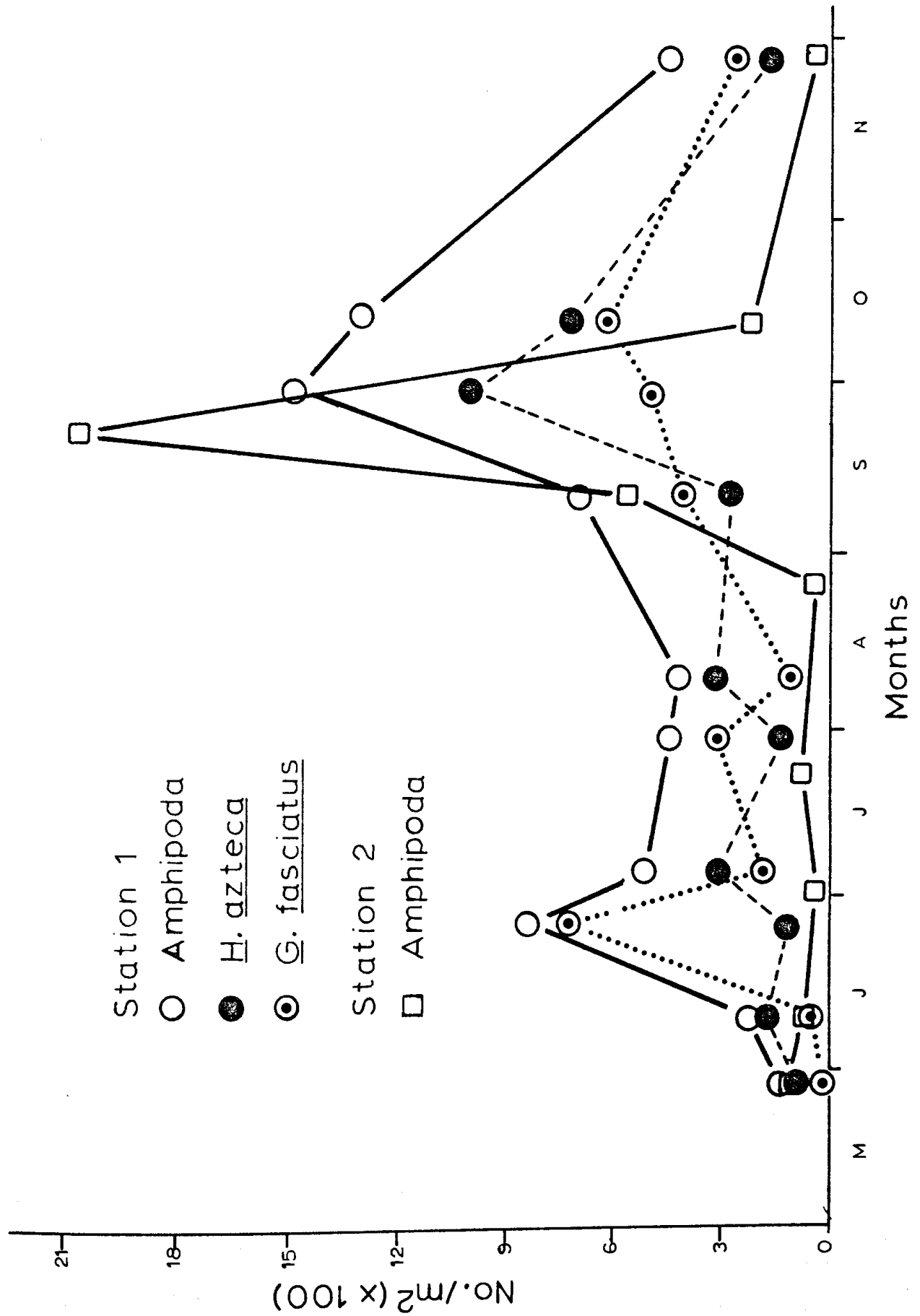
Seasonal distribution

Large populations of juvenile amphipods were observed on two occasions within Station 1. From Fig. 22, the two periods of peak abundance occurred in late June and late September. The peak in late June was the result of an increase in the population of G. fasciatus. During late September increases in the populations of H. azteca and G. fasciatus resulted in a peak that was nearly twice that occurring in late June. Gravid female G. fasciatus were observed from May to mid-July and again in mid-September. Female H. azteca were gravid in late August which in Station 2 contributed to large populations in late September.

Cooper (1965), in studying the dynamics and productivity of H. azteca found that its reproductive cycle was synchronized with water temperature. When the water temperature rose to around 20°C, reproduction and growth proceeded at a rapid rate and with a decline of water temperature in the fall, the mortality, reproduction, and growth rates also declined. Support for Cooper's results are reflected in this investigation where the numbers of H. azteca began to increase in early August when the water temperatures were 23°C.

The seasonal distribution of G. fasciatus is anomalous with other investigations. Clemens (1950) observed maximum standing crops of G. fasciatus in late summer and fall. The fall populations coincide with this

Fig. 22. Seasonal distribution of Amphipoda, Hyaletella azteca, and Gammarus fasciatus at Station 1, and of only Amphipoda at Station 2, 1969.



investigation but there is some discrepancy between the late summer population of Clemens's study and the spring population of this study. However, as Cooper (1965) reported, only juveniles and adults were collected by Clemens since the young were buried in the bottom sediments and were not sampled with nets. Bousfield (1958) cites the reproductive periods of G. fasciatus as occurring in the spring and fall.

Depth distribution

The amphipods predominated in depths less than one meter where, in Station 2, the numbers exceeded 8000/m² (Fig. 23). At Station 1 where populations of H. azteca and G. fasciatus were similar (Appendix V.6), both species were similarly distributed at all depths up to the 3 meters at which point H. azteca disappeared and G. fasciatus occurred in numbers of approximately 150/m².

There can be little doubt from Fig. 23 and Table 9 that amphipods were dependent on the vegetation of the littoral zone and that the disappearance of amphipods coincided with the disappearance of aquatic plants. G. fasciatus appeared to be less dependent on aquatic plants (in cleaner waters) than H. azteca since the latter species disappeared from samples taken in depths beyond three meters. This is also suggested from analysis of dredge contents where, as mentioned earlier, G. fasciatus was more common in samples without aquatic plants.

Hydracarina

Since the water mites constituted a very small portion of the total benthos, no attempts were made to identify them to species. The genera which were tentatively identified are listed as follows:

Fig. 23. Depth distribution of Amphipoda, Hyaella azteca, and Gammarus fasciatus at Station 1, and of only Amphipoda at Station 2, September 1969.

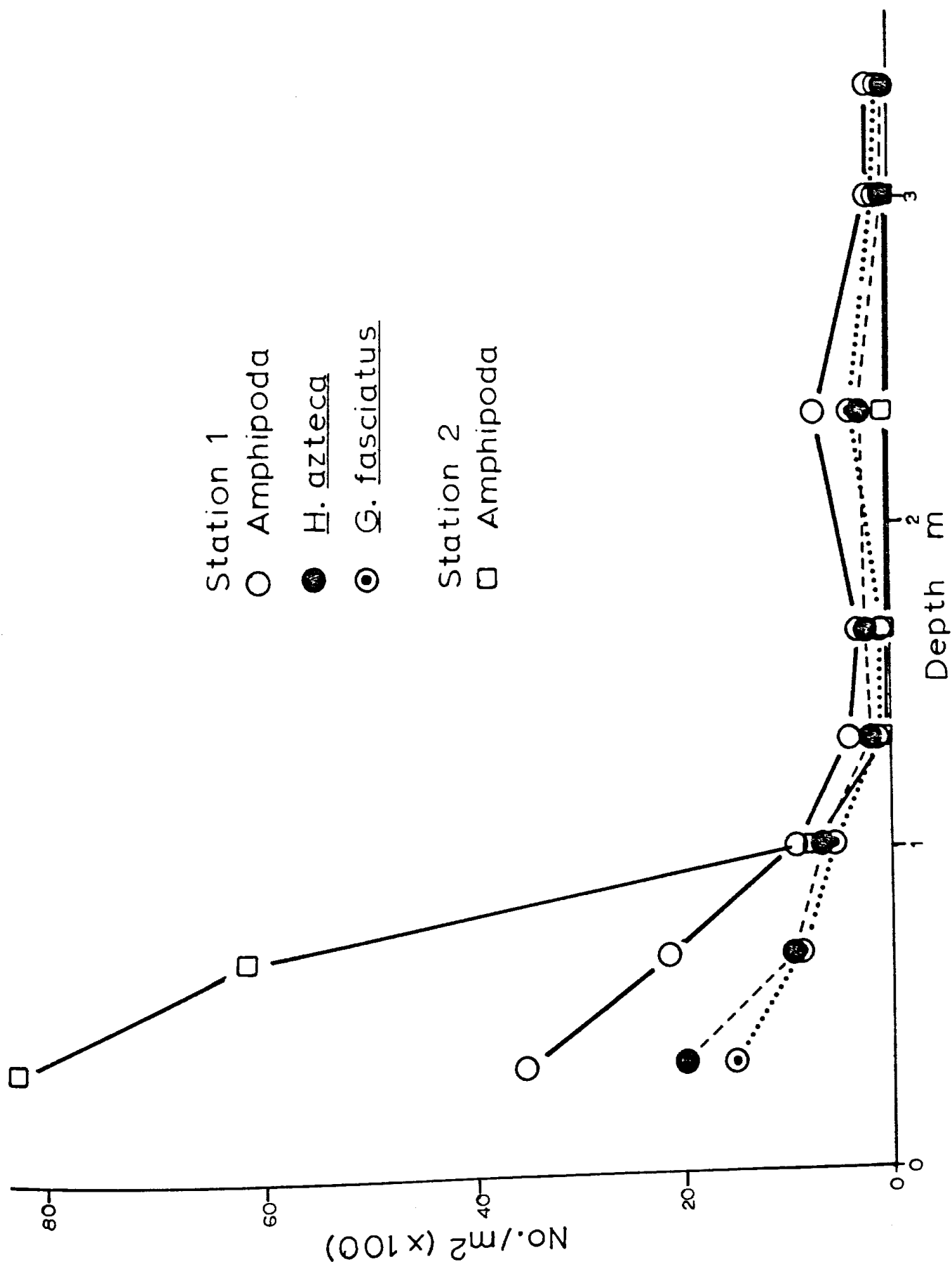
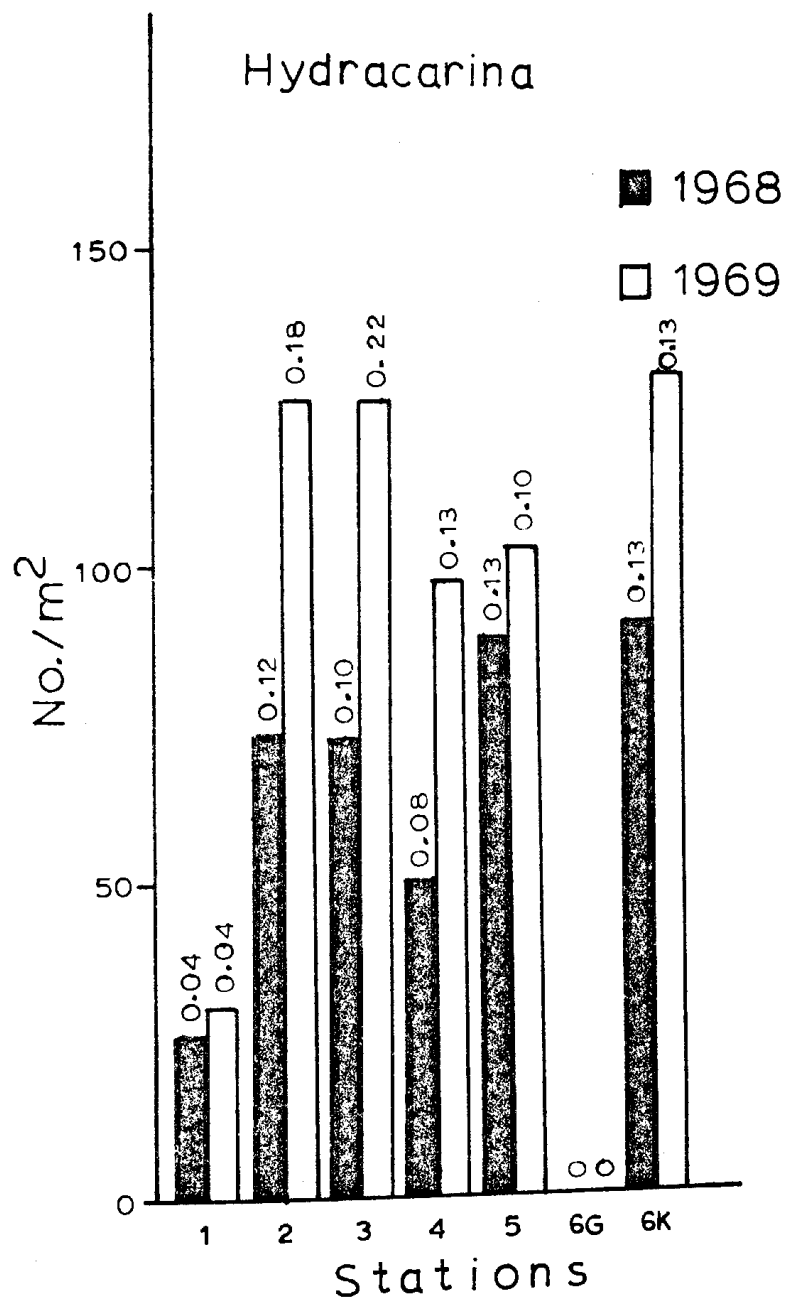


Fig. 24. Average standing crop (No./m²) of Hydracarina at each station in the summers of 1968 and 1969. Average dry biomass (mg/m²) above histograms.

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- Lebertiidae : Lebertia sp.
 Limnesiidae : Limnesia sp.
 Hygrobatidae : Hygrobates sp.
 : Megapus sp.

The water mites exhibited population densities that were significantly smaller at Station 1 than at other stations except Station 6G where no water mites occurred (Fig. 24, Appendix VI.1). Pennak (1953) mentions that they are predators of aquatic insects so that one would expect some correlation between the horizontal distribution of the two groups. In fact there was none, however, the correlation might appear at the generic level.

Insecta

Over 50 genera were encountered in the study area and of these, 40% belonged to the Family Chironomidae. In most instances the insects were only identified to genus and not to species because the diagnostic characters for species in the larval stages are not known. The species can only be ascertained by rearing to adults.

The insect orders, Ephemeroptera, Odonata, Plecoptera, Megaloptera, Tricoptera, Lepidoptera, and Coleoptera together did not form more than 15% of the average standing crop at any station. Therefore, only general accounts are given of them. Since the most abundant insects were the chironomids, the dominant species are discussed in some detail. The remaining dipteran families (Ceratopogonidae, Stratiomyidae, and Syrphidae) are only generally discussed.

I. Ephemeroptera

Four species of mayflies occurred in the study area. The percent of the average standing crop of the total insect fauna for each species is given in Table 15. All species of mayflies, except Ephemerella, were encountered at Station 1 while Stations 2 and 6G had no ephemeropterans. Caenis sp. was the most common being absent only at Stations 2 and 6G.

The standing crops of mayflies (Fig. 25) were not significantly different between stations (Appendix VII.1). Large populations of Hexagenia sp. were found in late May in the two to three meter depths and on the sandy substrates of Station 1. Caenis was also abundant at Station 1 but it was more widely distributed than Hexagenia. The early instar nymphs of Caenis that appeared in late September, formed aggregations on the substrate below aquatic vegetation.

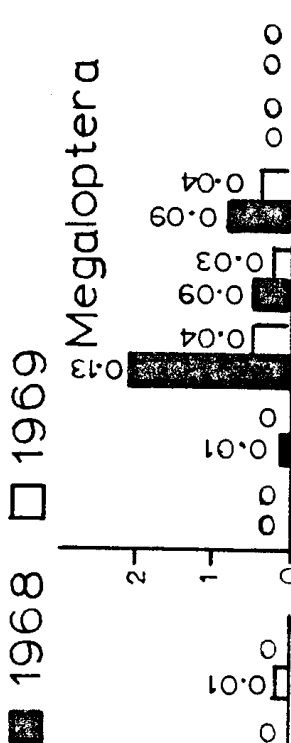
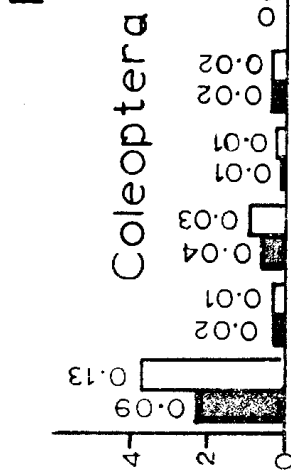
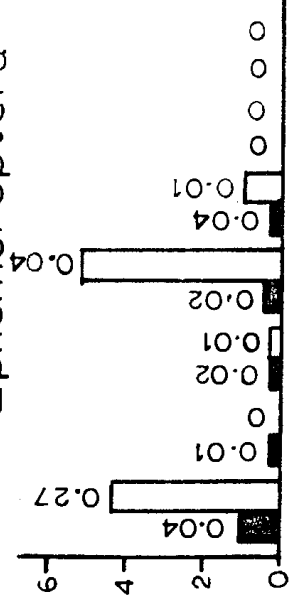
The absence of Hexagenia from Stations 2 and 6G can probably be attributed to the thick deposits of organic detritus (Station 2) and wood fibres (Station 6G) which, together with raw sewage, created high oxygen demands. Britt (1955) attributed a late summer kill of Hexagenia nymphs to low oxygen levels that occurred during summer stagnation of a lake. The paucity of Hexagenia nymphs from Stations 3 and 5 suggests that fast currents do not promote large populations; this can probably be related to the removal of silt which Hexagenia nymphs prefer for burrowing (Hunt, 1953). Swanson (1967) also reported that the nymphal populations decreased as the percentage of sand increased. The effect of water movement (and light intensity) has also been related to drift (Anderson, 1967; Elliot, 1967) where faster waters supported few nymphs because they are subject to greater degrees of drifting than those in quiet waters.

Table 15. Ephemeroptera, Odonata, and Plecoptera species composition as percent of average standing crop ($\#/m^2$) of Insecta at each station in the summers of 1968 and 1969.

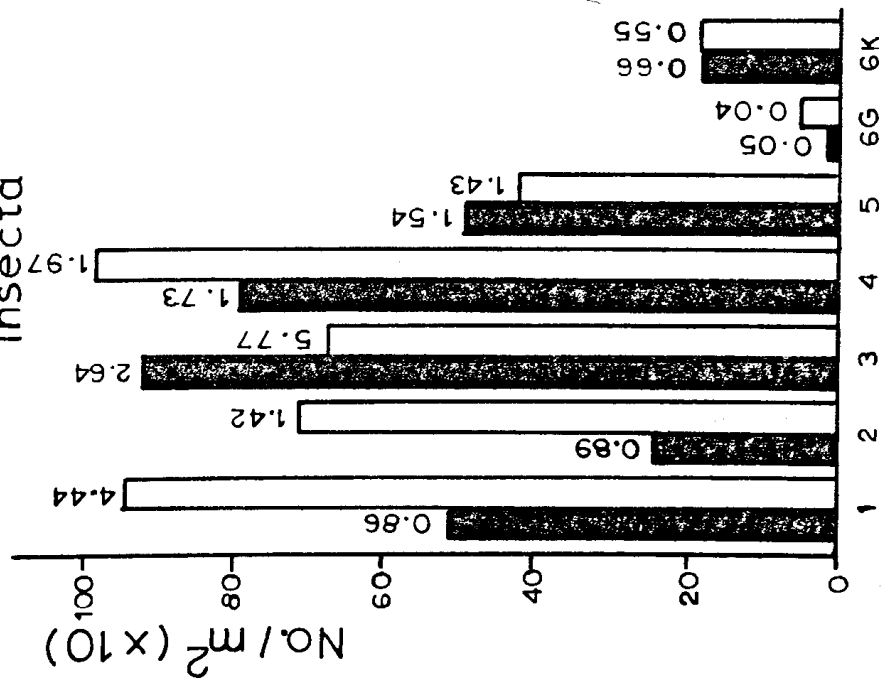
Species	Stations													
	1		2		3		4		5		6G		6X	
	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969
Ephemeroptera <u>Caenis</u> sp.	2.7	3.0	0.4	0	0.2	0.2	0.4	3.6	0.7	1.4	0	0.2	0	0.6
<u>Ephemerella</u> sp.	0	0	0	0.2	0.1	0.1	0	0	0.1	0	0	0	0.6	0
<u>Hexagenia</u> sp.	2.9	1.0	0	0	0.3	0	0	0	0	0	0	0	0	0
<u>Stenonema</u> sp.	0	0.1	0	0	0.1	0.1	0	0.1	0	0.1	0	0	0	0
Odonata <u>Enallagma signatum</u>	0	0.4	1.2	7.0	0.1	5.9	0.1	0.6	0.5	5.1	0	0	1.4	1.2
Plecoptera <u>Isoperla bilineata</u>	0	0	0	0	0	0	0.1	0	0	0.4	0	0	0	0
Average $\#/m^2$ of Insecta	331.7	1021.0	355.9	456.1	744.8	593.1	759.7	995.4	511.7	438.8	64.2	291.7	89.7	215.4
Average wt. (mg/m ²) of Insecta	0.59	4.00	1.07	1.37	1.72	4.03	1.91	1.82	1.43	1.06	0.10	0.37	0.18	0.42

Fig. 25. Average standing crop (No./m²) of Insecta and the major insect groups at each station in the summers of 1968 and 1969.
Average dry biomass (mg/m²) above histograms.

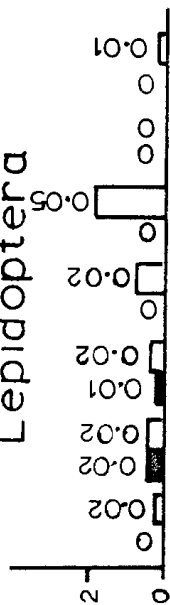
Ephemeroptera



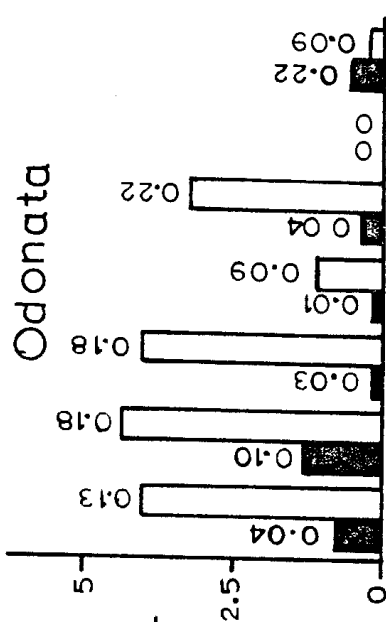
Insecta



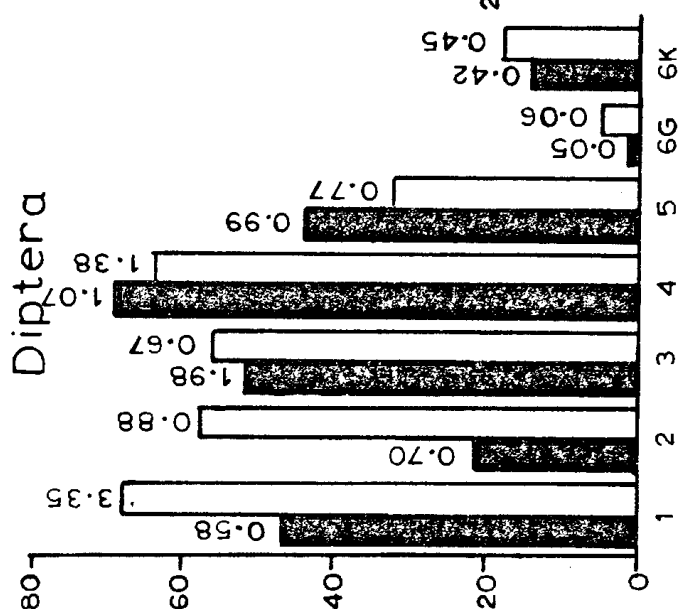
Lepidoptera



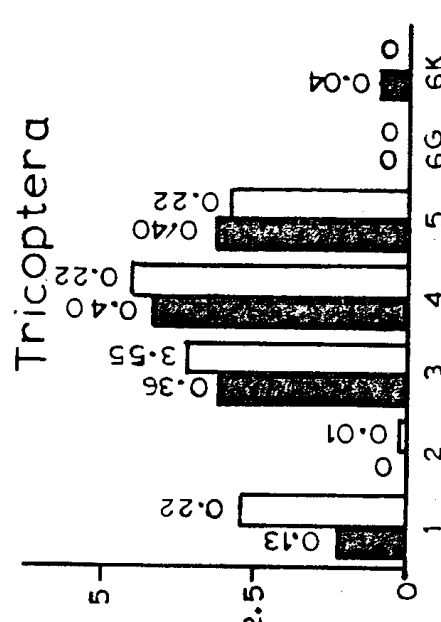
Odonata



Diptera



Tricoptera



II. Odonata

The only Odonata present in the study area was the damselfly, E. signatum which was widely distributed, as shown in Table 15. It was a common inhabitant of the aquatic vegetation. The large numbers of E. signatum in aquatic plants (Table 9) might explain their large numbers in Stations 1 and 2 as shown in Fig. 25. There was some indication that E. signatum could tolerate the subpolluted habitats of Station 2 (when plants were present) but that they normally preferred the cleaner environment of Station 1 since populations were not significantly different between the two habitat types (Appendix VII.2).

III. Plecoptera

Only one species, I. bilineata, occurred in the study area. The numbers of I. bilineata were so small that it may have been a fugitive species. Frison (1935) records I. bilineata as a common species of large rivers since it requires a two year life cycle and is excluded from streams that dry up every year. Stoneflies are very sensitive to pollution (Hynes, 1960) and cannot tolerate low oxygen levels because of their small gill area (Dodds and Hisaw, 1924).

IV. Megaloptera

The alderflies were poorly represented with only one species, Sialis sp. Significantly larger average standing crops occurred at Station 3 than at other stations except Station 5 (Appendix VII.3). They were absent in Stations 1, 6G and 6K as shown in Fig. 25. Populations exceeding 130/m² occurred in the shore zones of Station 3 where the substrate consisted of very fine sand. Large numbers of early instar Sialis sp.

Table 16. Megaloptera, Lepidoptera, and Coleoptera species composition as percent of average standing crop (#/m²) of Insecta at each Station in the summers of 1968 and 1969.

Species	Stations												
	1		2		3		4		5		6G		6K
	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	
Megaloptera													
<u>Sialis</u> sp.	0	0	0	0	0	0	0.5	0.1	0.6	0.5	0	0	0
Lepidoptera													
<u>Nymphula</u> sp.	0	0.4	0.3	0.3	0.1	1.3	0	0.5	0	0.6	0	0	0.4
<u>Paraponyx</u> sp.	0	0	0	0	0	1.3	0	0	0.1	2.5	0	0	0.88
Coleoptera													
<u>Berosus</u> sp.	0.2	0.3	0	0	0.1	0.1	0.1	0.1	0.1	0	0	0	0
<u>Dubiraphia</u> sp.	2.9	2.4	0	0	0.1	0.5	0	0	0.1	0	0	0	0
<u>Haliphus</u> sp.	0	0	0.4	0.7	0.2	0.5	0	0.1	0.3	0.2	0	0	0.7
<u>Microcylloepus</u> sp.	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0
Average #/m ² of Insecta	331.7	1021.0	355.9	456.1	744.8	593.1	759.7	995.4	511.7	438.8	64.2	291.7	89.7
Average wt. (mg/m ²) of Insecta	0.59	4.00	1.07	1.27	1.72	4.03	1.91	1.82	1.43	1.06	0.10	0.37	0.18

occurred in early July near the 0.5 meter depth of Station 3.

There was some suggestion that Sialis sp. preferred fast moving waters and fine sandy substrates since they were most abundant in Station 3 and, to some extent, Station 5. Ross (1937) reports that the success of Sialis sp. also depends on the availability of food for its predaceous habit and well aerated water. The nature of the shore line was probably an important factor. Eggs of Sialis are laid on objects overhanging the water and on hatching, drop into the water (Ross, 1937) so that the presence of such objects as trees, bridges, and reeds on the shore can be determining factors in their distribution.

V. Tricoptera

The caddisflies were well represented with thirteen species occurring in the study area. Their contribution to the percent average standing crop of all insects is given in Table 17. There is probably a fourteenth species which belongs to the family, Helicopsychidae. Several of their empty spiral cases were found at Station 1.

Other than the chironomids, the tricopteran were the most abundant insects at all stations, except in the subpolluted habitats of Station 2 and the grossly polluted areas of Station 6G (Fig. 25). Stations 3, 4, and 5 contained significantly larger populations than the other stations (Appendices VII.4 - VII.6). The dominant tricoptera was Phylocentropus sp. which attained large average standing crops in Stations 3, 4, and 5. Oecetis was represented by two or three species, all of which were abundant in Station 1 on very fine sand substrates.

The nature of the substratum could have been a limiting factor in determining the distribution of caddisflies both as a source of material for

Table 17. Tricoptera species composition as percent of average standing crop (#/m²) of Insecta at each station in the summers of 1968 and 1969.

Species	Stations											
	1		2		3		4		5		6K	
	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969
<u>Agraylea</u> sp.	0	0	0	0	0.2	0	0	0	0	0	0	0
<u>Athripsodes</u> sp.	0	0.1	0	0	0	0	0.1	0	0	0	0	0
<u>Cheumatopsyche</u> sp.	0	0	0	0	0	0	0	0.1	0.1	0	0	0
<u>Hydropsyche</u> sp.	0.1	0	0	0	0	0	0	0	0	0	0.3	0
<u>Ithytrichia</u> sp.	0	0	0	0	0	0.3	0	0	0	0	0	0
<u>Leptocerus</u> sp.	0.1	0.1	0	0	0	0	0	0	0.1	0	0	0
<u>Molanna</u> sp.	0.1	0.3	0	0	0.3	0.2	0	0.1	0	0.3	0	0
<u>Mystacides interjecta</u>	0.4	2.2	0	0	0.4	0.2	0	0.1	0	0	0.6	0
<u>Oecetis</u> spp.	0.8	0.6	0	0.2	0.3	0.4	0.3	0.1	0.2	0.2	0	0
<u>Hydrptila</u> sp.	0.2	0	0	0	0	0	0	0	0	0	0	0
<u>Phryganea</u> sp.	0	0	0	0	0	0.3	0	0	0	0.1	0	0
<u>Phylloctenopus</u> sp.	1.4	0.1	0	0	0.9	2.2	1.5	1.8	2.7	2.9	0	0
<u>Polycentropus</u> sp.	0.1	0.1	0	0	0.2	1.5	0.8	1.0	0.5	0.6	0	1.9
Average #/m ² of Insecta	331.7	1021.0	355.9	456.1	744.8	593.1	759.7	995.4	511.7	438.8	64.2	231.7
Average wt. (mg/m ²) of Insecta	0.59	4.00	1.07	1.27	1.72	4.03	1.91	1.82	1.43	1.06	0.10	0.37
											0.18	0.42

building cases and for food. Such species as Phryganea sp. were confined to stations that contained plant (leaves) material on the sediments for constructing their cases; Phylocentropus sp., Oecetis spp., Leptocella sp., and Mystacides sp. occurred on very fine sandy substrates from which grains of sand were utilized for building cases; Cheumatopsyche sp. and Hydropsyche sp. require submerged objects to which they can attach their nets. Although the food relations of tricopterans were not investigated, the abundance of food, particularly for the carnivorous species, would probably be a limiting factor, as reported by Slack (1936).

Phylocentropus appeared to be indifferent to water movement but Oecetis occurred more commonly at Station 1 where water was slow moving. Dodds and Hisaw (1925) found that most species living in swift water lived there in spite of the mechanical forces of the current, not on account of it, and that the secondary effects of current were important factors in determining the distribution of caddisfly larvae. Anderson (1967), Elliot (1968), and Bishop (1969) showed that tricopterans were a major component of the drift which affected their distribution.

VI. Lepidoptera

There were two species, belonging to the genera Paraponyx and Nymphula, present in the study area. Both were highly associated with aquatic vegetation and as such, occurred only in those stations with plants (Fig. 24). Paraponyx occurred more commonly on V. americana while Nymphula was found more frequently on Potamogeton spp. but both species also occurred on Myriophyllum spp. and E. canadensis. Pyralids inhabit aquatic vegetation for nutrition (Lange, 1968) and oxygen (Berg, 1949).

VII. Coleoptera

The coleopterans were represented by four species (Table 16). They were present at all stations except in the grossly polluted areas of Station 6G (Fig. 25). Only Haliphus sp. occurred in the subpolluted waters of Station 2. Microcylloepus sp. was absent at all stations except Station 1.

Microcylloepus, Dubiraphia, and Berosus showed a preference for substrates containing very fine sand. Microcylloepus and Dubiraphia appeared to show some correlation with water movement, preferring the slow moving water of Station 1. The subpolluted water of Station 2 probably removed most beetles indicating that Haliphus was more tolerant of such conditions. Leech and Chandler (1968) mention that Haliphus has a preference for backwater areas that have an abundance of algae. There was also some suggestion of interspecific competition between Haliphus and Microcylloepus since they were negatively associated (they never occurred together at any one station).

VIII. Diptera (Chironomidae)

Twenty-one genera were collected from the study area, the names of which are given in Table 18. One genus Demicryotochironomus, appeared as a single specimen and its partly mutilated head did not permit a positive identification. Station 3 had the greatest chironomid diversity having 20 genera while Stations 1, 5, 4, 2, 6G and 6K had successively few genera with 18, 16, 15, 12, 9, and 3 genera respectively.

Horizontal distribution

The chironomids, Pseudochironomus, Cryptochironomus, Phaenopsectra,

Table 18. Diptera species composition as percent of the average standing crop (#/m²) of Insecta at each station in the summers of 1968 and 1969.

Species	Stations											
	1		2		3		4		5		6K	
	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969
Chironomidae												
<u>Chironomus</u> sp.	0	0	25.7	38.1	21.0	1.3	40.3	22.1	2.7	0.8	4.4	0.3
<u>Corynoneura</u> sp.	0.8	0.1	0	0	0.4	0	0.1	0	0.3	0	0	0
<u>Cricotopus</u> sp.	0	0.1	0.5	0.1	0.4	0.2	0	0	0	0.1	0	0
<u>Cryptochironomus</u> sp.	8.6	9.8	0.2	0.3	5.3	3.1	3.2	1.3	4.0	5.9	2.2	5.5
<u>Demicryptochironomus</u> sp.	0	0.1	0	0	0	0	0	0	0	0	0	0
<u>Dicrotendipes</u> sp.	12.9	7.2	0	0	0.1	5.5	0.6	0.3	0.2	1.6	0	0
<u>Endochironomus</u> sp.	0	0	0	0	1.0	0	0.1	0	0	1.4	0	0
<u>Harnischia</u> sp.	0.1	0.1	0	0	2.0	0	0.2	0	0	0	0	0
<u>Heterotrissocladius</u> sp.	0	0	0	0	0.6	0	0	0	0	0	0	0
<u>Monodiamesa</u> sp.	0.6	0	0.7	0	1.3	0	0.1	0	0.2	0	0	2.0
<u>Orthocladius</u> sp.	0	0.3	0.3	0.7	0.4	1.5	0	0.8	0.2	0.5	0	4.6
<u>Parachironomus</u> sp.	0.2	0	0	0	0.1	0.1	0	0	0	0.1	0	0

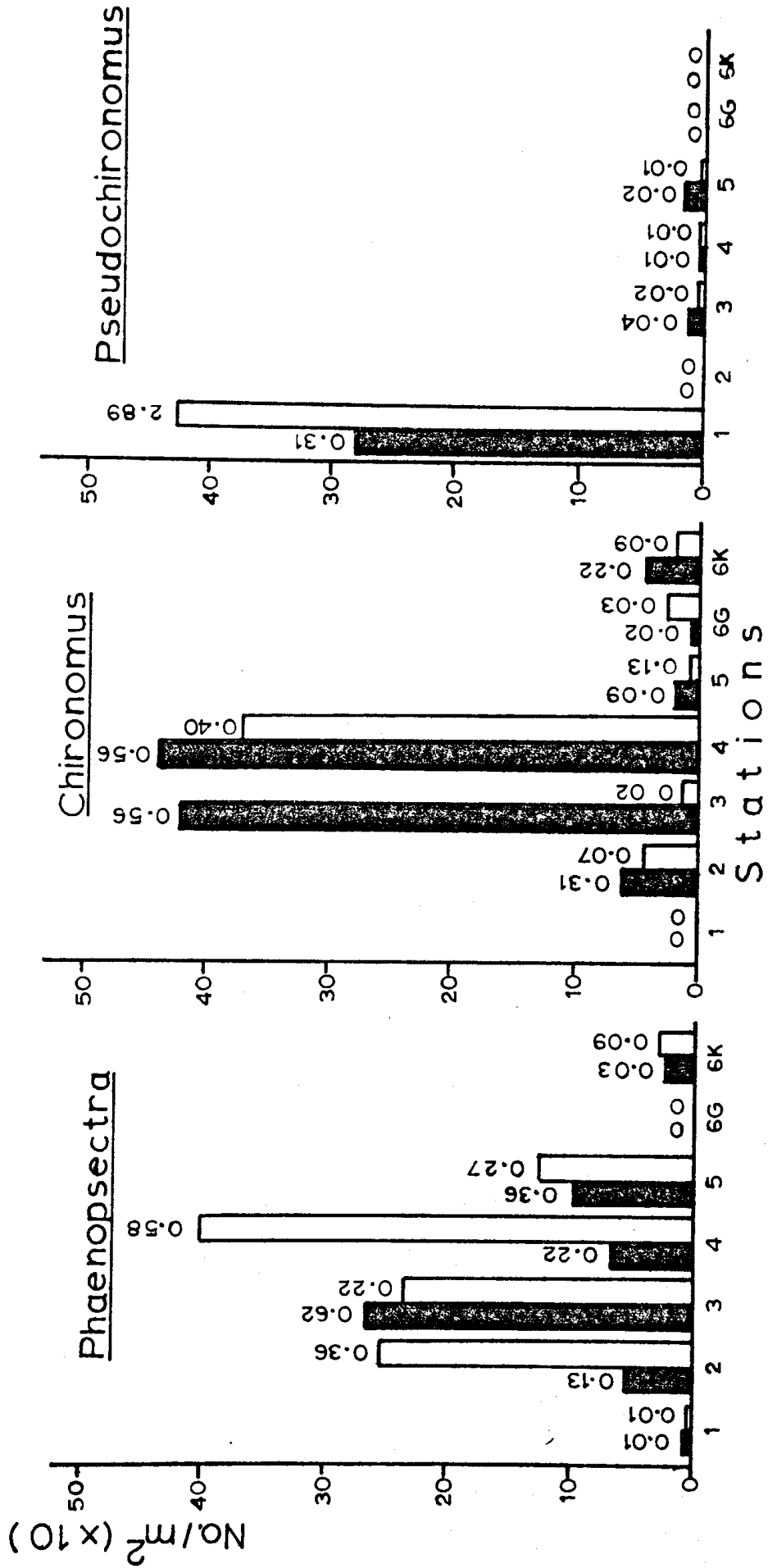
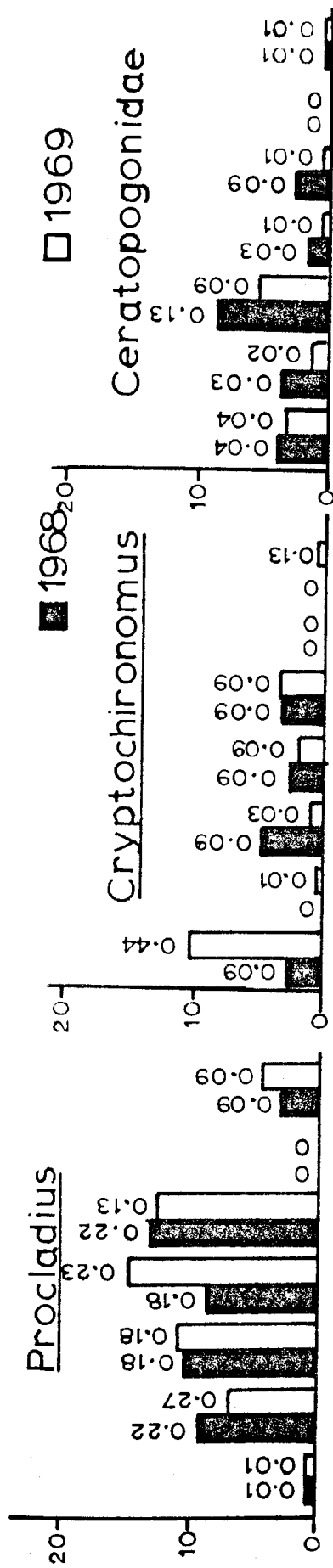
<u>Paracladopelma</u> sp.	0.5	0.2	0.1	0	0.6	0	0.3	0.2	1.1	0	0	0.3	0.6	0
<u>Phaenopsectra</u> sp.	0.9	0.1	34.7	37.6	35.2	37.0	39.6	53.5	57.1	35.4	90.5	80.9	18.1	62.4
<u>Polypedilum</u> sp.	2.5	14.2	0.1	0	3.1	11.8	0.5	0	7.3	5.0	1.1	6.0	0.6	5.6
<u>Procladius</u> sp.	2.5	0.2	14.2	12.2	7.9	11.9	9.2	12.3	15.2	27.7	1.1	1.5	22.3	11.1
<u>Psectrocladius</u> sp.	0.1	0.2	0	0	0	0.7	0	0	0	0	0	0	3.8	0
<u>Pseudochironomus</u> sp.	46.3	33.5	0	0	2.1	0.2	0.1	0.1	0.6	0	0	0	0	0
<u>Stictochironomus</u> sp.	0.8	7.6	0.1	0	2.3	2.6	0.1	0	0.5	0	0.2	0	1.9	0
<u>Tanytarsus</u> sp.	3.1	10.4	1.3	0	2.0	1.1	0.3	0	0.8	0	0.4	0	1.2	1.2
<u>Thienemannimyia</u> sp.	0.3	1.1	0.1	0.1	0.7	2.2	0.1	1.1	0.4	0.4	0.1	0.4	0	1.2
<u>Ceratopogonidae</u>	6.4	2.9	19.5	2.5	8.1	4.9	1.5	0.2	3.2	5.5	0	0	7.3	2.3 ⁸³
<u>Stratiomyidae</u>														
<u>Hedriodiscus</u> sp.	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0
<u>Syrphidae</u>														
<u>Eristalis</u> sp.	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0
Average #/m ² of Insecta	331.7	1021.0	355.9	456.1	744.8	593.1	759.7	955.4	511.7	438.8	64.2	291.7	89.7	215.4
Average wt. (mg/m ²) of Insecta	0.59	4.00	1.07	1.27	1.72	4.03	1.91	1.82	1.43	1.06	0.10	0.37	0.18	0.42

Chironomus, and Procladius dominated the study area as shown in Fig. 26. Standing crops of Pseudochironomus were significantly larger at Station 1 than at the remaining stations (Appendix VII.7). Populations of Phaenopsectra, Chironomus, and Procladius were significantly larger at Stations 2 and 4 than at Station 1 (Appendix VII.8 - V .12).

The average standing crop of Chironomus at Station 3 (Fig. 26) is misleading since it was strongly influenced by a single population which consisted of 6230 individuals per square meter. Without this population the average standing crop of Chironomus was $5/m^2$. As previously discussed with the oligochaetes and isopods, it is suspected that there is an underwater sewage outfall on the shore of Gattineau Pointe since sewage causes an increase in the population size of Chironomus larvae (Richardson, 1929).

The distribution of chironomids appeared to be strongly influenced by the interaction of substrate type with water movement and by pollution. Species which exhibited a preference for very fine sandy substrates and reduced water velocity, were those of Pseudochironomus and Dicortendipes both of which predominated at Station 1 (Fig. 26, Dicortendipes not shown). Cryptochironomus appeared to select fine sandy substrates but it was indifferent to water velocities occurring in near similar quantities at Stations 1, 3, and 5. Chironomus was associated with substrates containing a high percentage of organic matter and as such was associated with polluted environments. Chironomus was the only chironomid that could tolerate the gross pollution of Station 6G where it reached populations of $1300/m^2$ approximately 11 km downstream of the CIP outfalls. Phaenopsectra showed some preference for substrates containing organic matter but it is suspected that competition with Chironomus limited its

Fig. 26. Average standing crop (No./m²) of five chironomid genera and Ceratopogonidae at each station in the summers of 1968 and 1969. Average dry biomass (mg/m²) above histograms.



No./m² (x 10)

distribution as discussed below. Procladius, like Phaenopsectra and Chironomus, showed a tolerance of subpolluted environments but its predaceous habit may also limit its distribution since it feeds on Chironomus (Lindeman, 1941).

Seasonal distribution

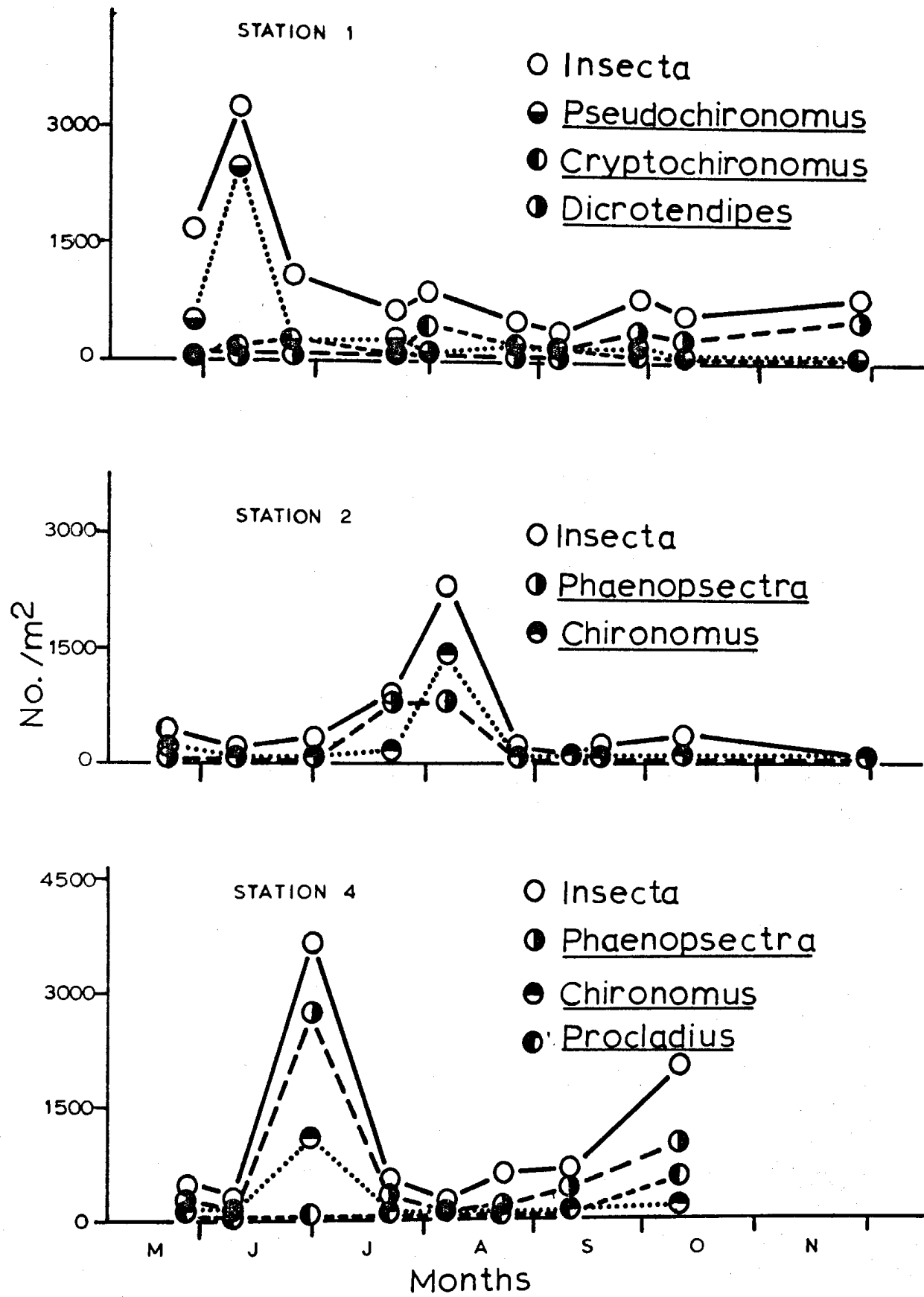
A comparison of the seasonal distribution of Insecta and four species of chironomids between the three stations that contained the largest chironomid populations are given in Fig. 27, 28, 29. The standing crops were maxima in early June, late June and early August at Stations 1, 4, and 2 respectively. The peak in early June at Station 1 was due to an increase in numbers of the chironomid, Pseudochironomus. Two other minor peaks in late July and September were due to numerical increases of Cryptochironomus and Dicrotendipes, respectively. The increase in numbers in early August at Station 2 was primarily due to Chironomus but an increase in numbers of Phaenopsectra beginning in mid-July contributed to the insect population. Phaenopsectra and Chironomus achieved maximum numbers at Station 4 two weeks earlier than at Station 2. Another increase in Phaenopsectra numbers occurred simultaneously with Procladius in early October, however, the absence of samples beyond October 11 at Station 4 provides no knowledge as to the culmination of this increase.

Interspecific competition displayed through temporal replacement may have had a definite role in determining the seasonal distribution of chironomid species. More specifically, when the success of two or more chironomid species was a function of ecological variables common and necessary to each species, the occurrence of each species in a single

Fig. 27. Seasonal distribution of Insecta and three chironomid genera at Station 1, 1969.

Fig. 28. Seasonal distribution of Insecta and two chironomid genera at Station 2, 1969.

Fig. 29. Seasonal distribution of Insecta and three chironomid genera at Station 4, 1969.



habitat was achieved through temporal replacement. This phenomenon is an application of Hardin's (1960) competitive exclusion principle which states that species are mutually exclusive in a single habitat when they have similar ecological requirements. Pennak (1957) and Hutchinson (1951) found that closely related plankton species occupied the same body of water when they had different sizes, different depth distributions or seasonal replacement. More applicable were the results of Heuschele (1969) who showed seasonal replacement for congeneric chironomid species of Tanytus, Procladius and Chironomus.

Temporal differences can be shown for species of Pseudochironomus, Cryptochironomus and Dicortendipes at Station 1 and for such species of Phaenopsectra and Procladius at Station 2. At Station 1, Pseudochironomus sp. was replaced by Cryptochironomus sp. in late July and both of these species were replaced by Dicortendipes sp. in October. At Station 2 Phaenopsectra sp. was replaced by Procladius in October. It has been suggested (see section on Hirudinea) that the sudden decrease in the population size (in mid-July) of Chironomus at Station 2 was due in part to predation by the leech Helobdella stagnalis. Emergence of Chironomus would also explain this decrease.

Lindeman (1941) records Procladius as a predator of Chironomus larvae. The seasonal distribution of these species suggests that Chironomus (and Phaenopsectra) reproduced during the early summer and emerged long before the predaceous Procladius, so that a similar explanation can be given for the early appearance of Pseudochironomus, assuming of course that Pseudochironomus was herbivorous and that the predator was Cryptochironomus.

Heuschele (1949) also observed complete and overlapping replace-

ment of chironomids and attributed the substitutions to the trophic levels and sizes of the chironomids involved; two Tanypus species showed complete replacement (one in the summer and one in the fall) where herbivores and ooze browsers developed after the predaceous species had emerged. Heuschele (1969) referring to Hutchinson's paper (1959), related the overlapping life cycle of Procladius to that of copepods where larger species, in order to survive, must always be larger throughout its life cycle and therefore, larger species (i.e. Procladius) must reproduce first to maintain this difference.

Depth distribution

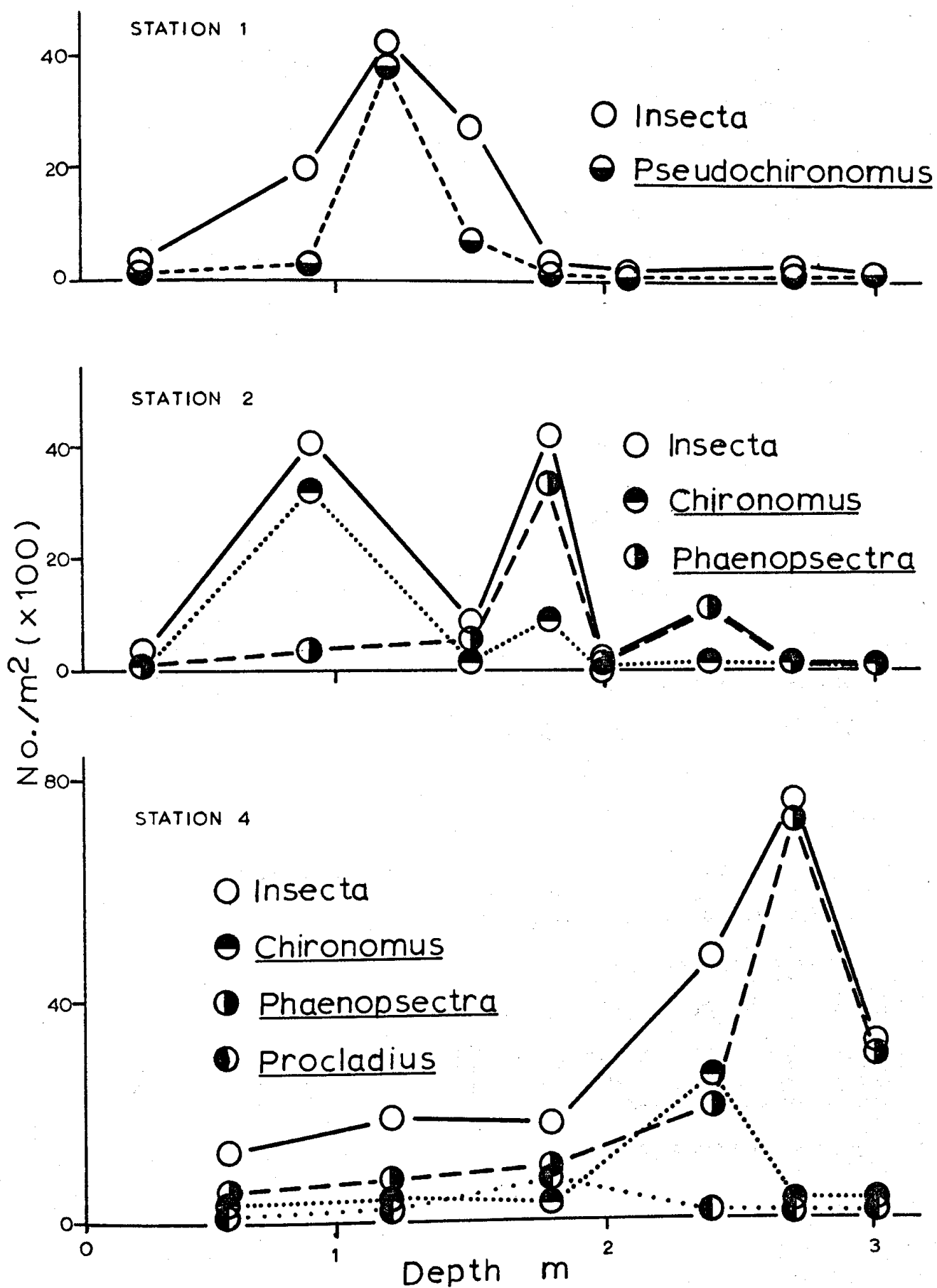
The depth distribution of chironomids was influenced by the species that dominated each station as shown in Fig. 30, 31, 32. At Station 1, where Pseudochironomus was most numerous, the insects distributed themselves around the 1 meter depth. Station 2, being composed almost entirely of two chironomid genera, Phaenopsectra and Chironomus, had two depths with large populations. Near the 1 meter depth, species of the genus Chironomus predominated and near the 2 meter depth, and to some extent the 2.5 meter depth, species of the genus Phaenopsectra were prevalent. At Station 4, the chironomids were evenly distributed to the 2 meter depth. At this point the numbers of Phaenopsectra and Chironomus had increased rapidly. Procladius occurred with maximum numbers near the 2 meter depth.

The spatially distinct populations of Phaenopsectra and Chironomus at Stations 2 and 4 suggests that the species of these two genera were mutually exclusive, although further research is needed to show this.

Fig. 30. Depth distribution of Insecta and Pseudochironomus at Station 1, June 1969.

Fig. 31. Depth distribution of Insecta and two chironomid genera at Station 2, July-August 1969.

Fig. 32. Depth distribution of Insecta and three chironomid genera at Station 4, July 1969.



VIII. Diptera (Certopogonidae, Stratiomyidae, and Syrphidae)

The certopogonids were not identified because of the lack of reared specimens, however, differences in morphological characters suggests that there were two or three species. Their distribution in the study area is shown in Fig. 26. They showed some tolerance of subpollution in Station 2 but it is not known whether they were primarily inhabitants of aquatic vegetation or the bottom. Stratiomyidae and Syrphidae were each represented by a single species (Table 18). Their very infrequent occurrence prohibits any discussion on their habitat preferences.

Gastropoda

The gastropod species and their average standing crop at each station are given in Table 19. Station 1 had the greatest gastropod diversity with 18 species while Stations 2, 3, 4, 5, 6G and 6K had 13, 12, 9, 12, 3 and 6 species respectively. Three species, H. trivolvis, H. campanulata, and G. livescens, were unique to Station 1. The only species that did not occur there was B. tentaculata. The presence of three gastropod species in Station 6G, the most polluted stations, is misleading since they occurred only in midchannel and not on the Gatineau shores where the effects of the CIP effluents were more severe.

G. livescens and L. catascopium appeared to be highly associated with each other. On three separate occasions these two species were seen together on large boulders in Station 1. It was estimated that one individual of each species occurred on every square centimeter of one of the boulders. G. livescens was also associated with very fine sand. Particles of silt are apparently used as tritulating agents (Goodrich, 1945).

Table 19. Gastropoda species composition as percent of average standing crop (#/m²) at each station in the summers of 1968 and 1969.

Species	Stations											
	1		2		3		4		5		6G	
	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969
<u>Lymanaea catascopium</u>	19.1	8.3	0	0	0	0.2	0	0	0.2	0.3	0	0
<u>Physa gyrina</u>	1.2	8.6	7.0	10.4	5.7	15.5	1.1	28.6	9.2	29.5	0	13.4
<u>Ferrissia parallella</u>	0	0.7	0	0.7	0	0.8	0.7	0.7	2.0	5.1	0	0
<u>Gyraulus parvus</u>	4.3	3.6	17.0	39.4	10.9	13.7	3.5	6.7	31.3	9.2	0	5.2
<u>G. hirsutus</u>	0.8	1.2	0.3	7.4	0	3.5	0	13.2	1.2	0	0	0
<u>G. deflectus</u>	1.2	1.5	0.9	0.7	1.2	0.5	0	0	0	0.4	0	0
<u>Promenetus exacnuous</u>	0.6	0.9	20.9	9.1	2.6	6.5	0	6.0	0	1.5	0	0
<u>Helisoma anceps</u>	1.3	1.0	4.7	0	1.2	0.6	0.5	0.3	0	1.6	0	0
<u>H. trivolvis</u>	0.4	0.6	0	0	0	0	0	0	0	0	0	0
<u>H. campanulata</u>	0	0.1	0	0	0	0	0	0	0	0	0	0

102 (i)

Lymanaea catascopium

Physa gyrina

Ferrissia parallella

Gyraulus parvus

G. hirsutus

G. deflectus

Promenetus exacnuous

Helisoma anceps

H. trivolvis

H. campanulata

<u>Amnicola limosa</u>	33.4	47.0	28.3	7.7	39.7	46.7	6.0	2.0	5.6	2.8	0	0	30.6	0
<u>A. deceptans</u>	7.3	4.0	0	1.0	2.9	2.2	0	0	0.2	0	0	0	0	0
<u>Probythinella lacustris</u>	0	0.2	0	0.4	0	0.1	0	0	0	0	0	0	0	0
<u>Pomatopsis lapidaria</u>	5.0	0.2	0	0	1.9	0	3.9	0	0	0	0	0	0	0
<u>Bithinia tentaculata</u>	0	0	3.1	3.4	0.9	0.1	1.6	0	4.2	0.3	0	0	5.5	0
<u>Valvata tricarinata</u>	21.6	18.7	6.2	16.3	0.6	2.0	0	2.2	0	0.1	0	0	0	0
<u>V. sincera</u>	0.6	0.2	5.8	0.7	0.4	0	1.6	0	0	0.1	0	0	0	0
<u>Goniobasis livescens</u>	1.2	0.9	0	0	0	0	0	0	0	0	0	0	0	0
<u>Campeloma decisum</u>	2.0	2.3	6.3	2.8	32.0	7.6	81.1	33.9	46.1	49.1	100.0	81.4	54.1	91.6
Average #/m ²	315.7	462.4	39.5	146.5	78.4	642.0	69.2	140.5	193.7	292.2	29.9	21.1	81.7	155.0
Average wt. (mg/m ²) (with shell)	22.2	41.7	3.4	6.4	149.3	218.5	418.7	221.7	449.2	792.0	72.4	128.0	338.9	812.5

The habitat of the species P. lapidaria has been reported as strictly terrestrial (Shimek, 1930 a, b). This terrestrial habitat has been contested by Baker (1930, 1931) who found that the species was "distinctly amphibious." Subsequent findings of P. lapidaria in aquatic habitats (Ameel, 1938; Berry, 1943; Dundee, 1957) and the present investigation support Baker's views that the species is amphibious.

Very little is known about the ecological factors that determine the distribution of gastropod species. One significant contribution to the ecology of gastropods was presented by Boycott (1936) who concluded that lime content was one of the decisive factors in determining gastropod abundance and diversity. If the water was soft (less than 10 mg of calcium per litre), he expected no more than 20 species of snails. The occurrence of 19 gastropod species in the Ottawa River, which has a calcium content of about 10 mg/l, is therefore in agreement with Boycott's contention.

Horizontal distribution

The average standing crop of gastropods in 1969 was substantially larger than those of 1968 (Fig. 33). However, the results of 1969 were somewhat biased in that a large number of samples were taken from the more productive habitats. The results of 1968 gave a better indication of average standing crops since a greater variety of habitats were sampled at each station.

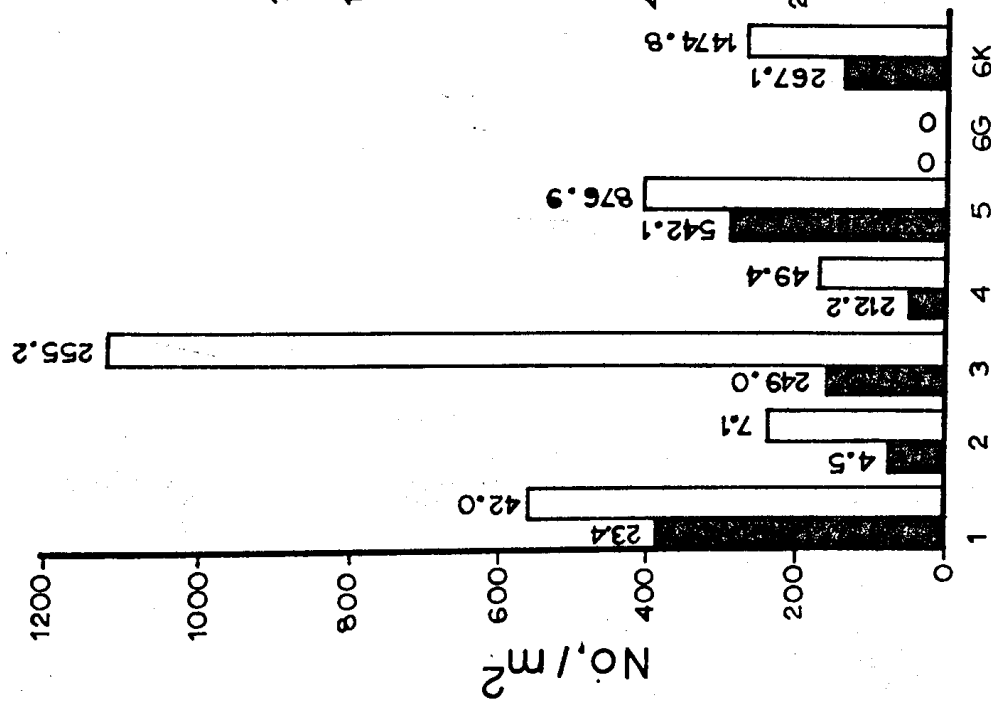
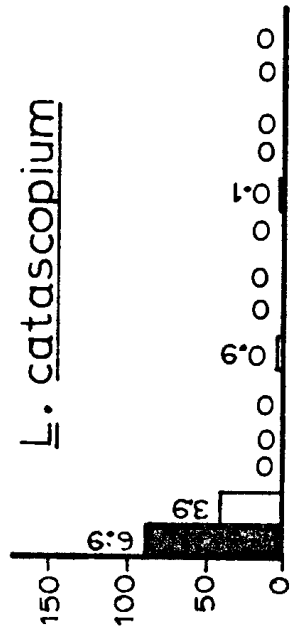
Larger average standing crops of gastropods occurred at Station 1 (Fig. 33) than at Stations 2, 3, 4, and 6G (Appendix VIII.1). The species A. limosa, V. tricarinata, both of which predominated in the aquatic vegetation, and L. catascopium, which was more commonly associated with the substrate, were more numerous at Station 1 than at

Fig. 33. Average standing crop (No./m²) of Gastropoda, Lymnaea catascopium, Valvata tricarinata, Amnicola limosa, Physa gyrina, and Campeloma decisum at each station in the summers of 1968 and 1969. Average dry biomass (mg/m²) above histograms.

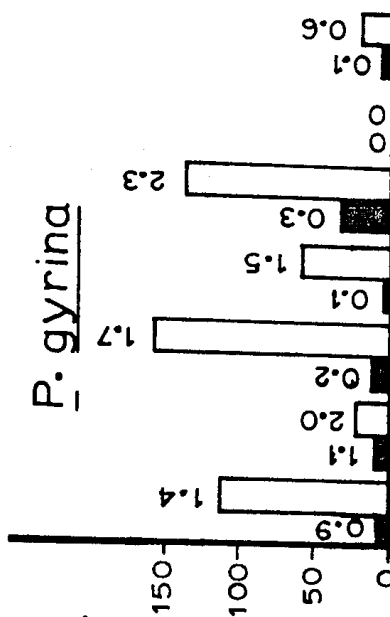
Gastropoda

■ 1968
□ 1969

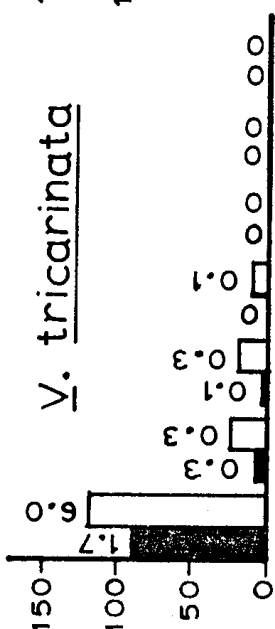
L. catascopium



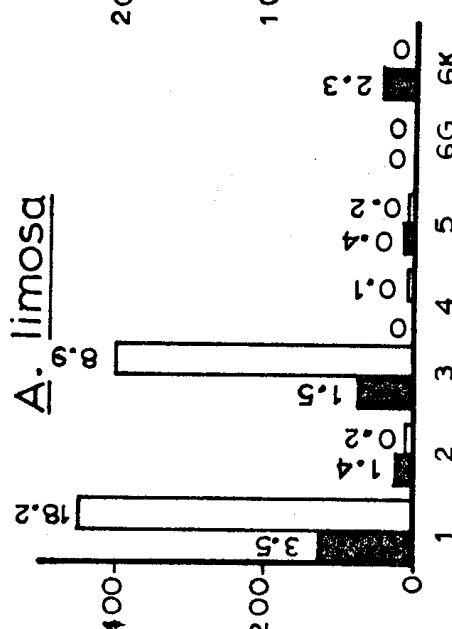
P. gyrina



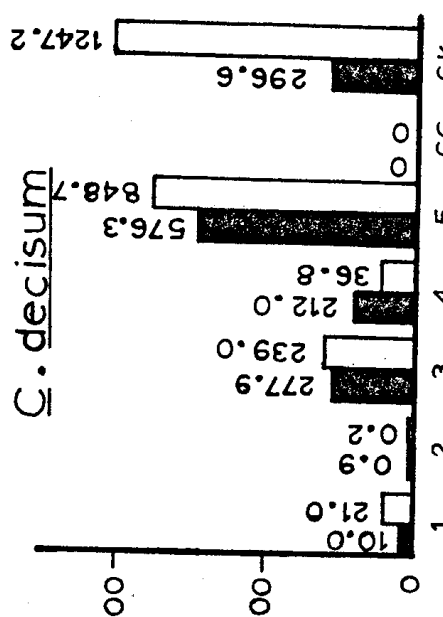
V. tricarinata



A. limosa



C. decusum



Stations

other stations (Fig. 33, Appendices VIII.3 and VIII.4). Effluents from Canada Packers and raw sewage from the City of Hull significantly reduced the gastropod populations at Station 2 (Appendix VIII.2) leaving those species associated with aquatic plants (A. limosa, G. parvus, P. exacuus and B. tentaculata). The role of A. limosa as the dominant gastropod at Stations 1, 2, and 3 was relinquished to the substrate inhabiting C. decisum at Stations 4, 5, and 6K. The only other significant contribution by any one gastropod species was by P. gyrina which composed 10.2% of the average standing crop at Station 5. No gastropods occurred in the grossly polluted 0 to 2 meter depths of Station 6G.

To appreciate the influence of the various ecological factors on the gastropod group as a whole it is necessary to know the sum of the effects of the factors on each species. However, the diversification of the gastropods and the infrequent occurrence of some species, limits the discussion to only a few of the more abundant species.

The influence that calcium has on the geographic distribution of invertebrate animals has been demonstrated by several investigators (Boycott, 1936; Mann, 1955; Moon, 1957; Reynoldson, 1958; Tucker, 1958). Its effects on the distribution of gastropods in the Ottawa River, however, is of no consequence since all stations had similar calcium contents but different gastropod populations. Of the remaining chemical parameters investigated, except B.O.D., all appear to be even less exigent than calcium.

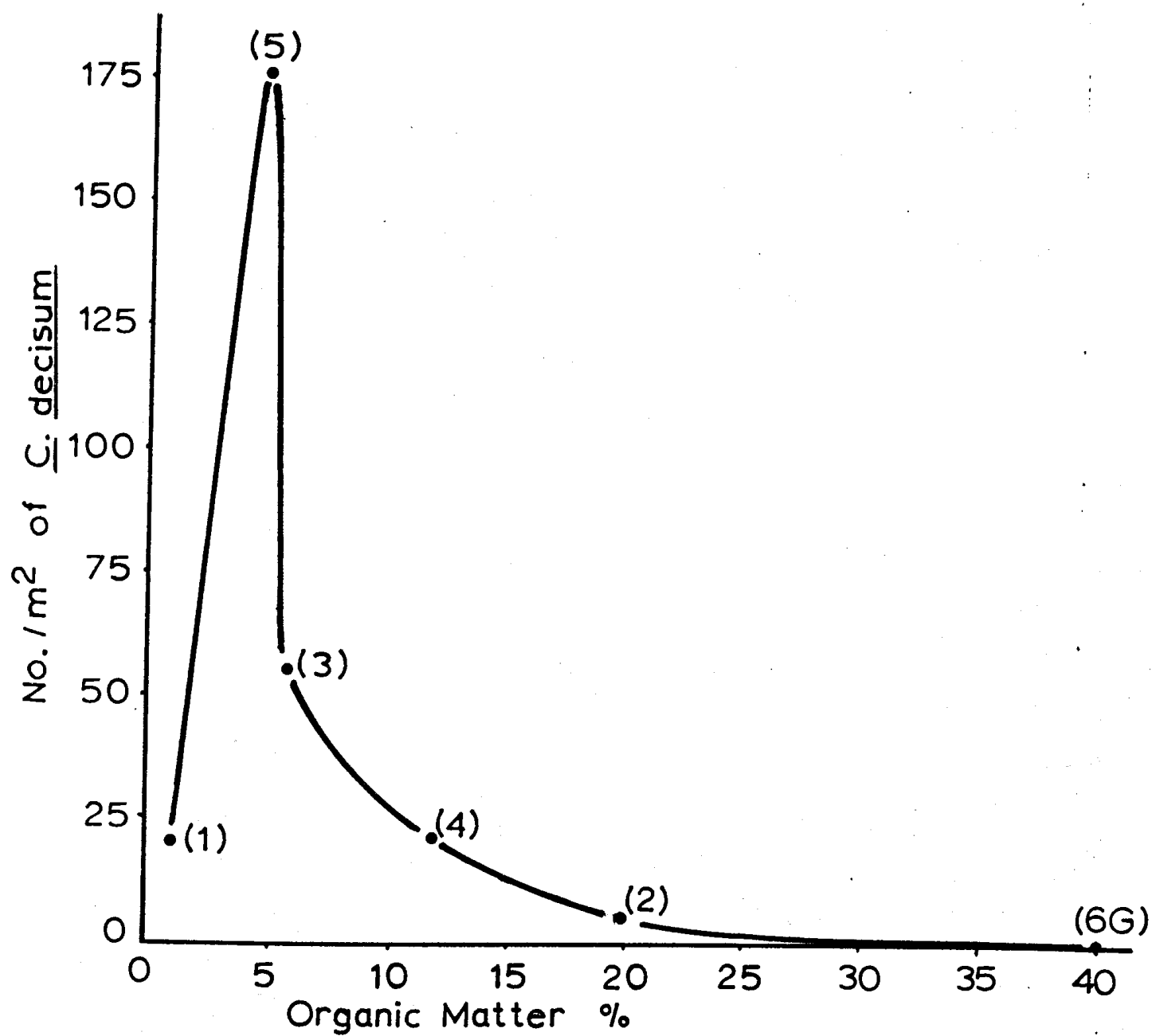
The nature of the substratum appeared to be an important factor in determining the distribution of gastropods, particularly within the polluted stations. Submerged aquatic plants offered a substratum for several species, a partial list of which is given in Table 9. The great

frequency of occurrence of aquatic plants in Station 1 explains the larger numbers of A. limosa and V. tricarinata, particularly the latter since it predominated on Potamogeton spp. which were almost unique to the control station. Heard (1963) also observed large populations of V. tricarinata on Potamogeton spp., particularly on those species with wider leaves. The infrequent occurrence of aquatic plants probably accounts for the small gastropod populations at Stations 3 and 4. Both A. limosa and V. tricarinata were intolerant of the decaying organic matter in the substrate of Station 2 and were invariably confined to the aquatic vegetation. The absence of gastropods in certain samples from Station 2 coincided with the absence of aquatic vegetation, as in Station 6G.

Campeloma decisum occurred with significantly large numbers in the fine sandy substrates of the open littoral zones of Station 5 (Appendix VIII.5) where the organic content did not exceed 5.0%. Bovbjerg (1952) found the largest populations of C. decisum in marginal areas high in organic content and suggested that this preference was a function of food availability. There is evidence from this study to suggest that an optimum concentration of organic matter supported the largest populations of C. decisum. An increase or a decrease from this optimum value resulted in smaller populations. The optimum value of approximately 5% is tentatively suggested (Fig. 34).

Varying contents of organic matter may affect the population size of C. decisum in several ways: increases of up to 5% may increase the food availability and hence the population size; substantial increments of organic matter may result in thick deposits which cannot support the massive weight of the species (i.e. at Station 2); or impose an oxygen demand too great for C. decisum to tolerate (i.e. at Stations 2 and 6G).

Fig. 34. Relation between percent organic matter and average standing crop (No./m²) of Campeloma decisum. Station numbers in parentheses. The curve was fitted by eye.



The large amounts of organic matter at Station 6K were thoroughly mixed with sand and easily supported C. decisum.

Some correlation appeared to exist between populations of C. decisum and P. gyrina and fast flowing waters. Stations 5 and 6K with their fast flowing waters had larger populations of these species than the slower moving waters in Stations 1, 3, and 4. However, DeWitt (1955) noted that C. decisum was most common in slow currents where silt was deposited.

Correlations were also apparent between shore morphometry and gastropod abundance. Species such as A. limosa, V. tricarinata, and L. catascopium were more abundant on the gradual sloping shore unique to Station 1 than on the steeper shore gradients (Table 1) of the other stations. The long shore line at Station 1 might have provided more habitats such as the greater frequency of aquatic plants upon which so many gastropod species depended. The uniqueness of H. trivolvis, H. campanulata, and G. livescens to Station 1 may possibly be explained by the uniqueness of certain habitats. Since gastropods exhibited a negative response to depth (Fig. 38), aggregations would tend to be greater on steep slopes than on shallow ones. These aggregations would increase the proximity of the individuals of all species. Interspecific competition would be more effective so that few species, and a larger number of each would be expected on the steeper slopes of Stations 3, 4, 5, and 6K. This may have explained the dominance of C. decisum at these stations where aquatic vegetation was wanting.

Seasonal distribution

Maximum standing crops of gastropods occurred in early spring and late summer; spring maxima were observed at Stations 4, 5, and 6K and late

summer maxima at Stations 1, 3, 4, 5 and 6k. The spring maxima were due to an increase in the populations of C. decisum, best exemplified at Station 5 (Fig. 35) and the later summer maxima by A. limosa and V. tricarinata, best exemplified at Station 1 (Fig. 36), and P. gyrina at Station 5.

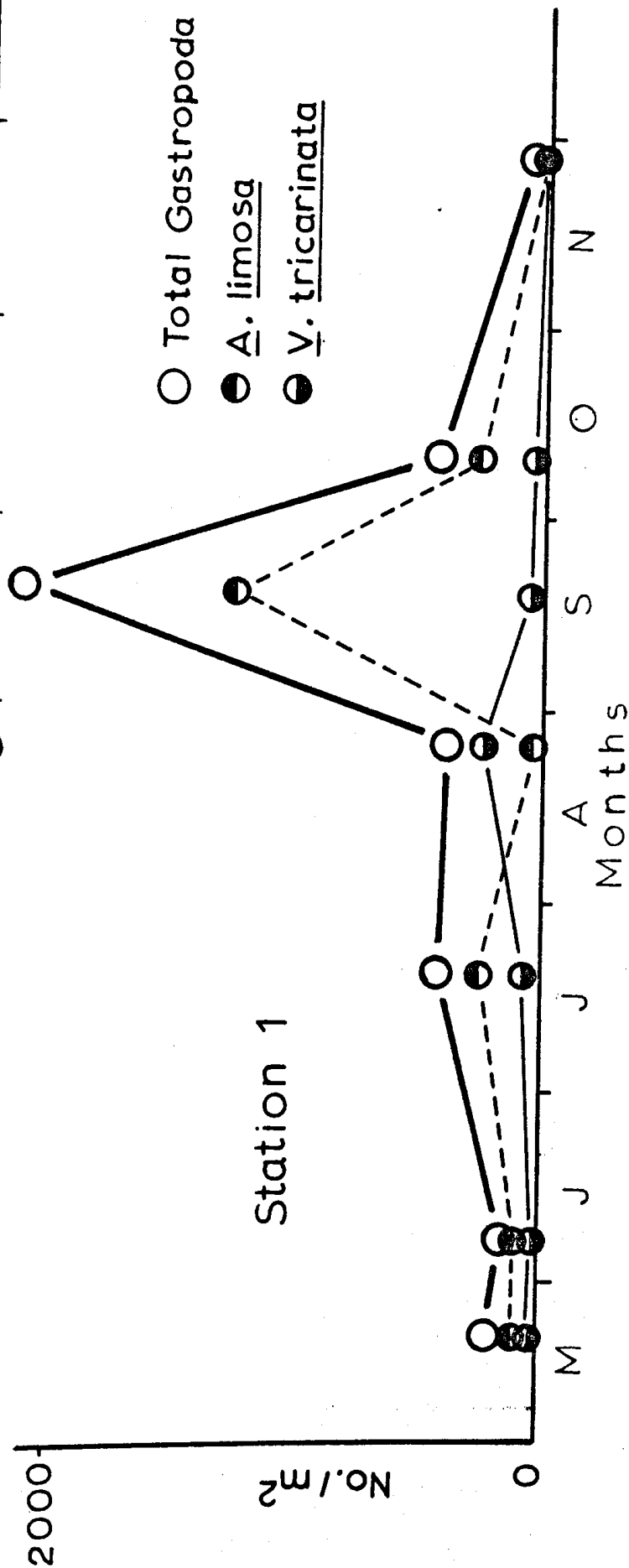
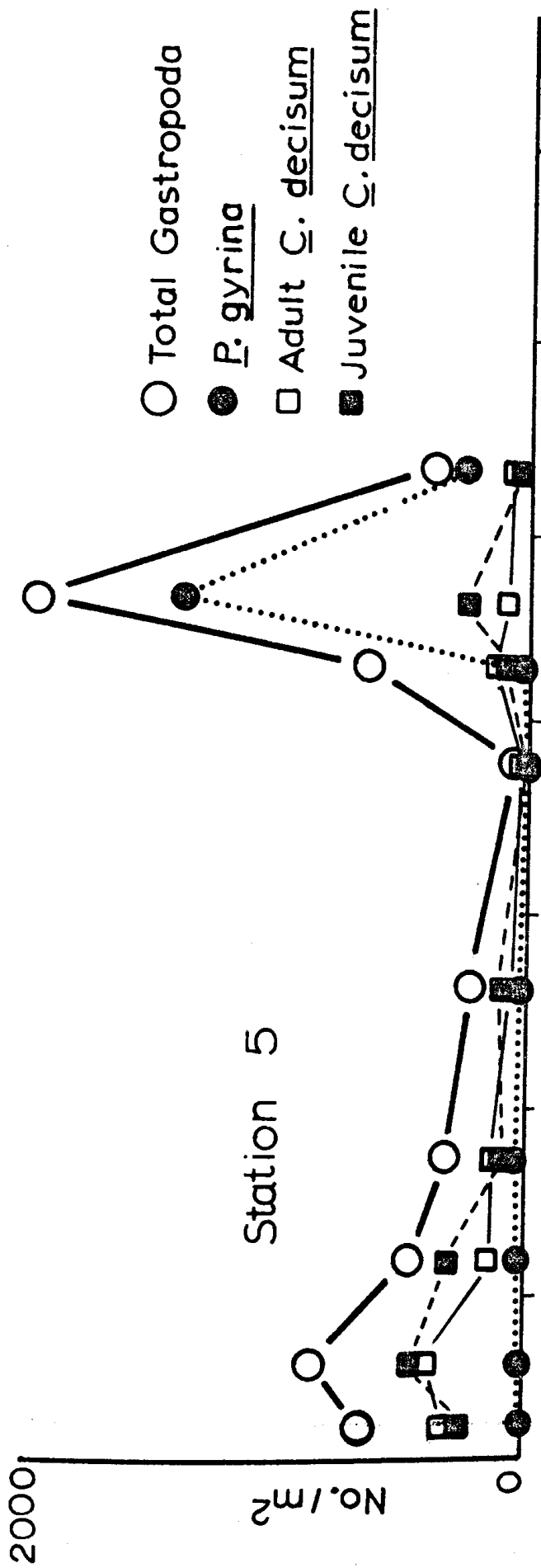
C. decisum, being ovoviviparous (Pennak, 1953) retains its young which appeared in maximum numbers in late May. It is not known how many young there were in each adult C. decisum, but the ratio of adults to young in the substrate in May was 1:1. A young C. decisum was arbitrarily chosen to be any individual less than 5 mm in height and an adult greater than 5 mm in height. Bovbjerg, (1952) also observed spring broods of C. decisum.

Egg capsules of A. limosa were observed on E. canadensis plants of Stations 1 and 3 from June to August. No data was obtained on the growth of individuals but the peak in mid-September was composed primarily of smaller individuals having an average weight of 0.024 mg. Larger A. limosa (adults?) individuals had an average weight of 0.040 mg. A. limosa was absent from the littoral zones only in the November samples. The reproductive seasons of A. limosa are quite variable; Stimpson (1865) reported reproductive activity from April to May, Baker (1928) from July to August, and Berry (1943) "at no particular time".

Since V. tricarinata predominated on Potamogeton spp., it was assumed that the egg masses present on the pond weeds in July, belonged to this species. The average individual dry weight of V. tricarinata in August, during the period of maximum numbers, was 0.018 mg. The largest individuals weighed 0.040 mg. Heard (1963) reported oviposition of V. tricarinata as beginning in late spring and continuing into late summer when the eggs hatch.

Fig. 35. Seasonal distribution of Gastropoda, Physa gyrina, and Campeloma decisum at Station 5, 1969.

Fig. 36. Seasonal distribution of Gastropoda, Amnicola limosa, Valvata tricarinata at Station 1, 1969.



The dates of oviposition for P. gyrina and L. catascopium were not noted by me. Larger individuals of P. gyrina weighed an average of 0.053 mg while the smaller individuals weighed 0.010 mg and larger L. catascopium weighed 0.083 mg while individuals during maximum numbers weighed 0.008 mg. The peak breeding season of P. gyrina was observed by Gillespie (1969) to be in late July with maximum populations occurring in August. No data for the reproductive period of L. catascopium appears in the literature.

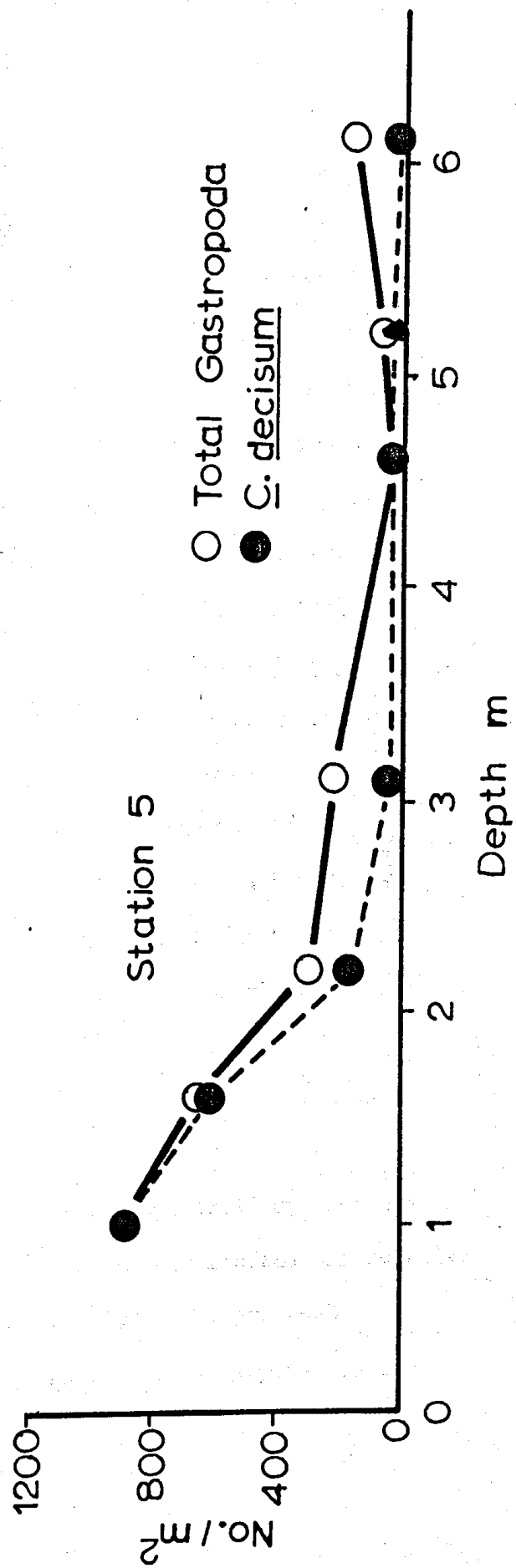
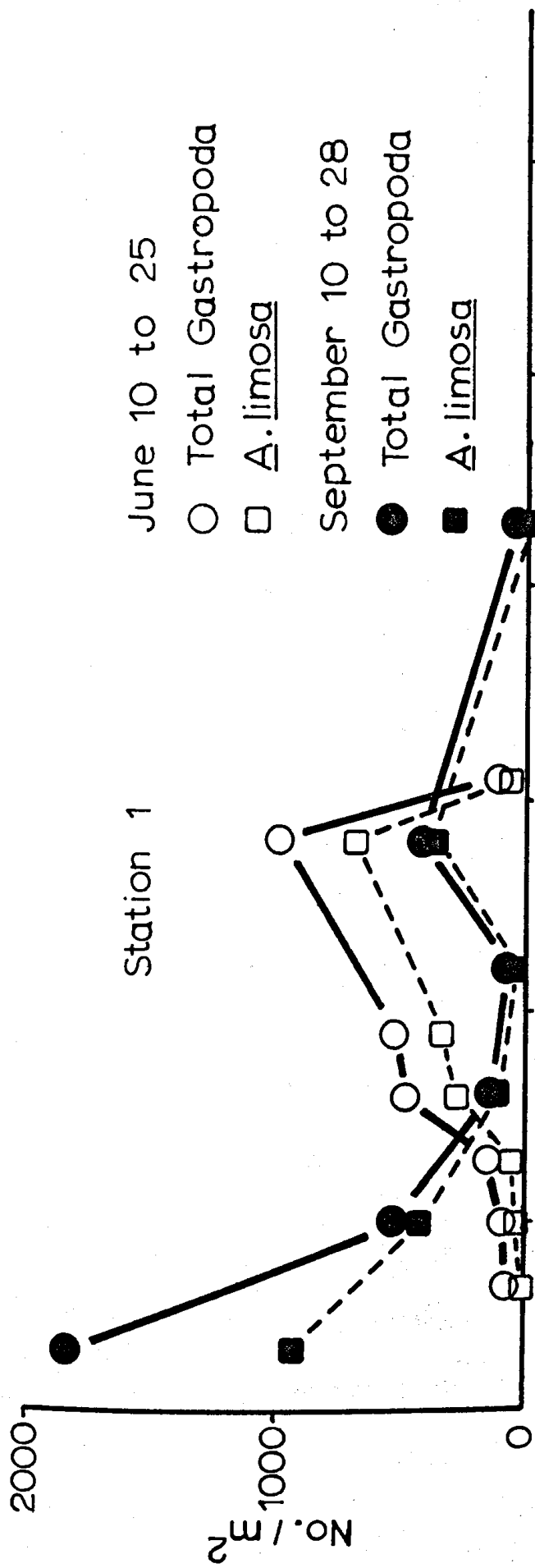
Depth distribution

Gastropod populations showed spring minima and late summer maxima in the littoral zones of Station 1 (Fig. 37). In early June the littoral zone was depauperate of gastropods and they did not reach maximum numbers until the submerged macrophytes were fully grown in August. Conversely, the three meter depth which was consistently devoid of vegetation, had a spring maximum and a late summer minimum. A. limosa formed at least 50% of the total gastropods at all depths. At Station 5, the depth distribution of gastropods followed that of the dominant species C. decisum (Fig. 38). Only one species, C. decisum, inhabited the zone closest to shore; other species did not begin to appear until the 1.5 meter depth after which C. decisum gradually lost its dominance.

Since gastropods, particularly A. limosa and V. tricarinata, were primarily inhabitants of aquatic vegetation, the decrease in their numbers with increasing depth was not unexpected in the September samples of Station 1. The depth distribution of gastropods in June was less easily explained. Reduced growths of aquatic plants perhaps explained the June minimum in the littoral zone but it failed to elucidate the June maximum in the three meter depth. One interpretation of the seasonal

Fig. 37. Depth distribution of Gastropoda and Amnicola limosa at Station 1 during June and September, 1969

Fig. 38. Depth distribution of Gastropoda and Campeloma decisum at Station 5, May 1969.



depth variations may be that of migration. Eggleton (1931) observed mid-summer minima and mid-winter maxima of the profundal bottom fauna of several lakes. He assumed that the seasonal fluctuations were related to littoral and sublittoral migrants that moved into the profundal zone during fall overturn and moved back toward shore during summer stagnation of the profundal hypolimnion. Although thermal stratification, and hence summer stagnation, did not exist in the areas of the Ottawa River under investigation, it is conceivable that some gastropods, such as A. limosa, moved from regions of plant decay to deeper waters during the colder months. This migration may have culminated at the three meter depth. With the onset of plant growth in the spring, the gastropods migrated back to the littoral zone. There are several reasons why gastropods might migrate from the littoral zone; Buscemi (1958, 1961) has shown that prolific growths of aquatic vegetation (i.e. E. canadensis) can deplete the lower strata of water of its oxygen especially in the summer months, so that gastropods may migrate to avoid anaerobic conditions; equally as likely, gastropods may move into the deeper, 4°C water to avoid the freezing conditions on shore; Rawson (1930, p88) cites Lundbeck as interpreting the outward migration of animals as a mechanism of dispersal where the strongest currents in midriver can carry the animals a considerable distance.

Pelecypoda

The pelecypods were represented by twenty sphaeriid species and two unionid species. Table 20 gives the pelecypod species and the relative abundance with which they occurred at each station. The greatest pelecypod diversity occurred at Station 1 where 18 species were found.

Sphaeriidae														
<u>Sphaerium corneum</u>	0	0	0	0	0	0	0	0	0.9	0.3	0	0	0	0
<u>S. lacustre</u>	0.1	0	19.4	15.2	0.9	0.3	0	0	0	0	0	0	0	0
<u>S. occidentale</u>	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0
<u>S. partumeium</u>	0.2	0.2	20.9	3.0	0	0.3	0.6	0	0	0.1	0	0	0	0
<u>S. securis</u>	5.0	3.3	0	0	0.4	0	0	0	1.5	0.7	0	0	0	0.4
<u>S. striatinum</u>	26.4	10.4	0	0	0.6	0.2	0.6	0	0	0	0	0	0	7.2
<u>S. transversum</u>	1.2	4.4	0	0	0	0	0.7	4.0	1.0	2.2	0	0	0	0
<u>Pisidium adamsi</u>	1.1	1.1	0	0	1.6	2.9	2.3	0	0.3	0.2	10.2	0	1.7	0
<u>P. aequilaterale</u>	0	0	0	0	0.6	0	0	0	0.8	0.3	0	0	0	0.4
<u>P. amnicum</u>	0.1	0.8	0	0	1.5	0.4	0	0	0.3	1.0	0	0	0.4	0
<u>P. casertanum</u>	22.1	32.8	33.2	50.1	58.7	75.6	67.6	82.9	78.8	80.3	66.7	94.6	91.5	68.3

<u>P. compressum</u>	2.4	3.4	0	1.7	0.8	4.8	4.7	3.7	1.3	0.1	0	2.1	8.6
<u>P. dubium</u>	1.1	0.4	0	0	0	0	0	0	0	1.0	0	0	0
<u>P. fallax</u>	0.1	0.4	0	0	0	0	1.5	0.4	0	0	0	0	0
<u>P. ferrugineum</u>	1.0	0.4	0	0	11.5	3.1	10.2	4.9	1.2	0.4	0	0	0.4
<u>P. lillieborgi</u>	25.4	33.7	0	0	2.2	4.5	0.6	1.3	0.3	3.7	5.1	0	4.2
<u>P. nitidum</u>	10.3	6.1	26.5	30.0	12.7	2.0	4.0	0	1.9	1.6	18.0	0	0.4
<u>P. punctatum</u>	0	0	0	0	0	0	0	0	3.3	1.2	0	0	3.5
<u>P. supinum</u>	0	0	0	0	0	0	0.6	0	0.8	3.0	0	0	5.5
<u>P. walkeri</u>	0.2	0.1	0	0	0	0	0	0	0	0	0	0	0
Unionidae													
<u>Elliptio complanatus</u>	3.1	2.2	0	0	5.7	5.2	4.9	2.8	4.0	2.2	0	5.4	1.1
<u>Lampsilis radiata</u>	0.2	0.3	0	0	2.8	0.7	1.6	0	3.5	1.7	0	0	0

Average #/m² 327.4 756.8 7.8 26.6 88.7 198.2 65.9 122.7 115.2 258.1 17.3 23.9 106.3 253.2

Average wt. (mg/m²) 1141.1 2305.0 0.1 0.3 111.2 339.3 934.1 14.4 1402.9 1244.6 0.2 1.8 258.6 2.7

Stations 3 and 5 were well represented with 13 and 16 species, respectively. The remaining stations, Stations 2, 4, 6G, and 6K were poorly represented, having only 5, 8, 0, and 9 species, respectively. The larger unionids were present only in Stations 1, 3, and 5 where the substrate was sandy. There is some question as to the identification of S. occidentale from Station 5; only a single specimen was found and its slightly crushed shell did not permit a positive identification by Rev. H. B. Herrington.

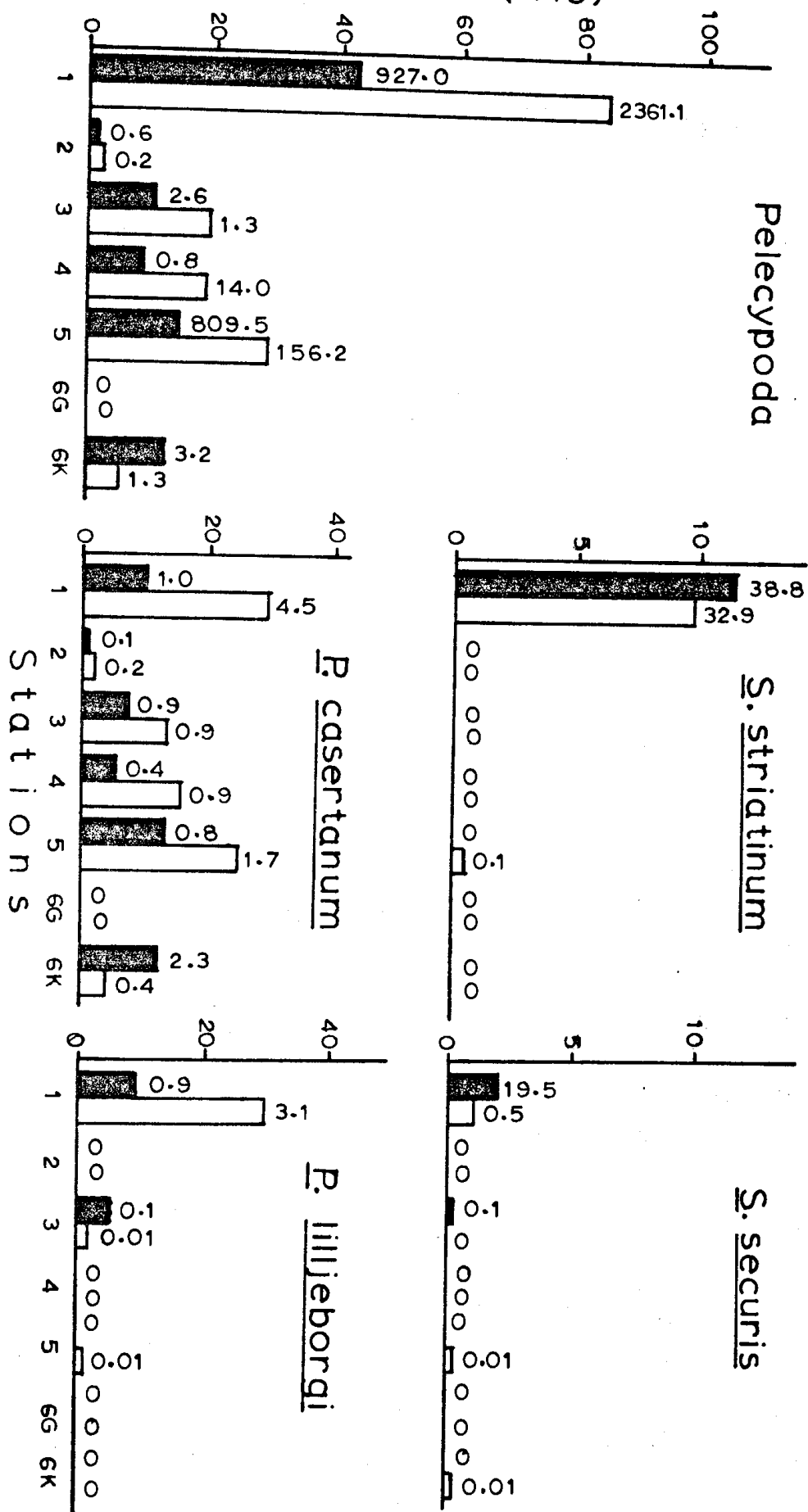
In a survey of several lakes and river, Boycott (1936) found that waters with more than 50 mg Ca/l had the most diverse mollusk populations. He cited the River Thames of England as one of the most productive rivers in his survey with 45 species (gastropods and pelecypods) occurring in about 80 mg Ca/l of water. On the basis of these results, the Ottawa River has a diverse mollusk population since 41 species were supported by calcium contents of about 10 mg/l.

Horizontal distribution

The pelecypods exhibited a preference for the cleaner waters of Station 1 where significantly larger average standing crops occurred than at any other station downstream (Fig. 39, Appendix IX.1). Unsuitable substrates or gross pollution or both resulted in the paucity of pelecypods at Stations 2 and 6G.

Analyses of the species composition at each station showed that the genus Pisidium was more widely distributed than that of Sphaerium. Of the Pisidium species, P. casertanum was dominant in all stations below the control station where it shared its dominance with P. lilljeborgi (Fig. 39, Appendices IX.3, 4). S. striatinum was almost unique to Station 1, with extremely small numbers occurring at only one

Fig. 39. Average standing crop (No./m²) of Pelecypoda, Sphaerium striatinum, Sphaerium securis, Pisidium casertanum, and Pisidium lilljeborgi at each station in the summers of 1968 and 1969. Average dry biomass (mg/m²) above histograms.

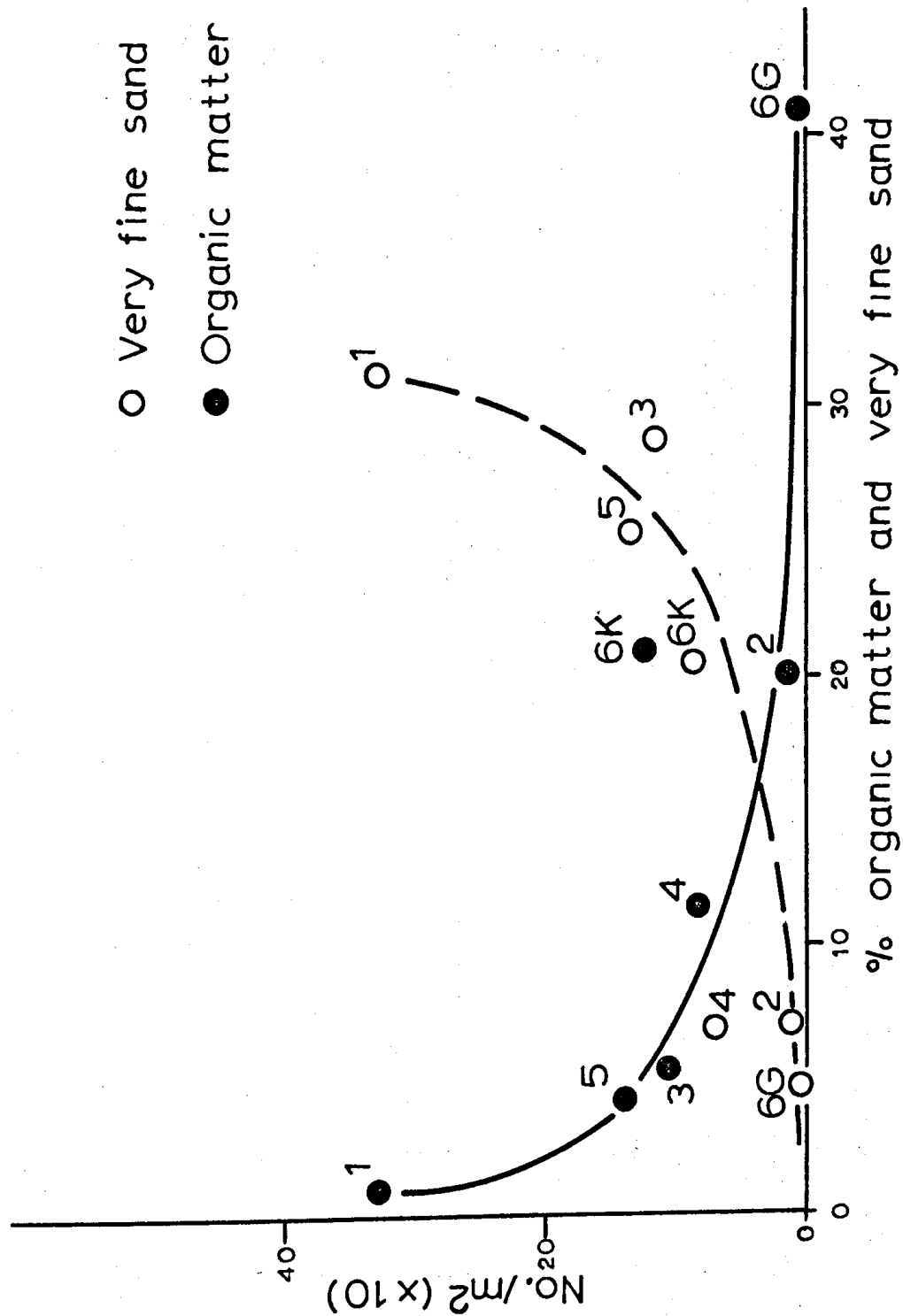
No./m² (x10)

other station, Station 5. Although S. securis occurred as only 4.7% of the average standing crop in the 0 to 2 meter depths at Station 1, it was the dominant pelecypod in depths exceeding 2 meters.

The distribution of pelecypods appeared to be primarily influenced by the type of substrate. Clarke and Berg (1959) reported that substrates were optimum for mussel production when the sediments were of a certain compaction to enable penetration by them; gravel and rocky bottoms were not conducive to mussel penetration and loose, silty sediments did not provide holdfast structures so that rocky and silty bottoms had few pelecypods. There was evidence from this study to suggest that pelecypod production was optimum in very fine sandy substrates. Fig. 40 shows a negative relationship between standing crops of pelecypods and organic matter content and a positive relationship between the standing crop of pelecypods and percent of very fine sand. The large percentage of very fine sandy sediments at Station 1, therefore, may explain the dominance of mussels there rather than in the less fine sandy substrates of Stations 3 and 5. The high percentage of organic matter may explain the significantly smaller pelecypod populations (Appendix IX.2) in Station 2 than in most other stations. Decaying organic matter may have imposed intolerable oxygen demands for the mussels or holdfast structures were buried by the organic ooze at Stations 2 and 6G. Species which showed a preference for very fine sandy substrates were S. striatinum, P. lilljeborgi, E. complanatus, and L. radiata. S. securis predominated in sandy substrates and P. casertanum appeared to be indifferent to substrate types lying between Phi scales of 3 and 5.

The effect of water movement is closely related to the type of substrate. Fast flowing waters will denude the substrate of its finer sediments and slow moving waters are conducive to the formation of finer sediments (Welch, 1952). S. striatinum and P. lilljeborgi

Fig. 40. Relation between average standing crop (No./m²) of Pelecypoda and percent organic matter and very fine sand. Station numbers in parentheses. The curves were fitted by eye.



were associated with fine sandy sediments in the slow flowing water of Station 1. P. casertanum displayed an unusual adaptability to changing environmental conditions, especially with respect to water movement since its populations were not significantly different between the very slow moving water of Station 1 and the faster moving waters of Stations 3, 5 and 6K (Appendix IX.4). Of the unionids, L. radiata occurred more commonly than E. complanatus in the faster moving waters of Stations 3, 4, and 5 than in the near stagnant waters of Station 1.

Correlations between shore morphometry and pelecypod abundance were also apparent where longer shore lines supported larger populations of several species than did the shorter, steeply sloped shores. As discussed earlier, the slowly sloping shores of Station 1 probably provided a greater number of habitats which would support a more diverse mussel population than the more steeply sloped shores of Stations 3 and 5. Pisidium casertanum may have been a better competitor than other Pisidium species and was able to colonize the steeply sloped shores more successfully.

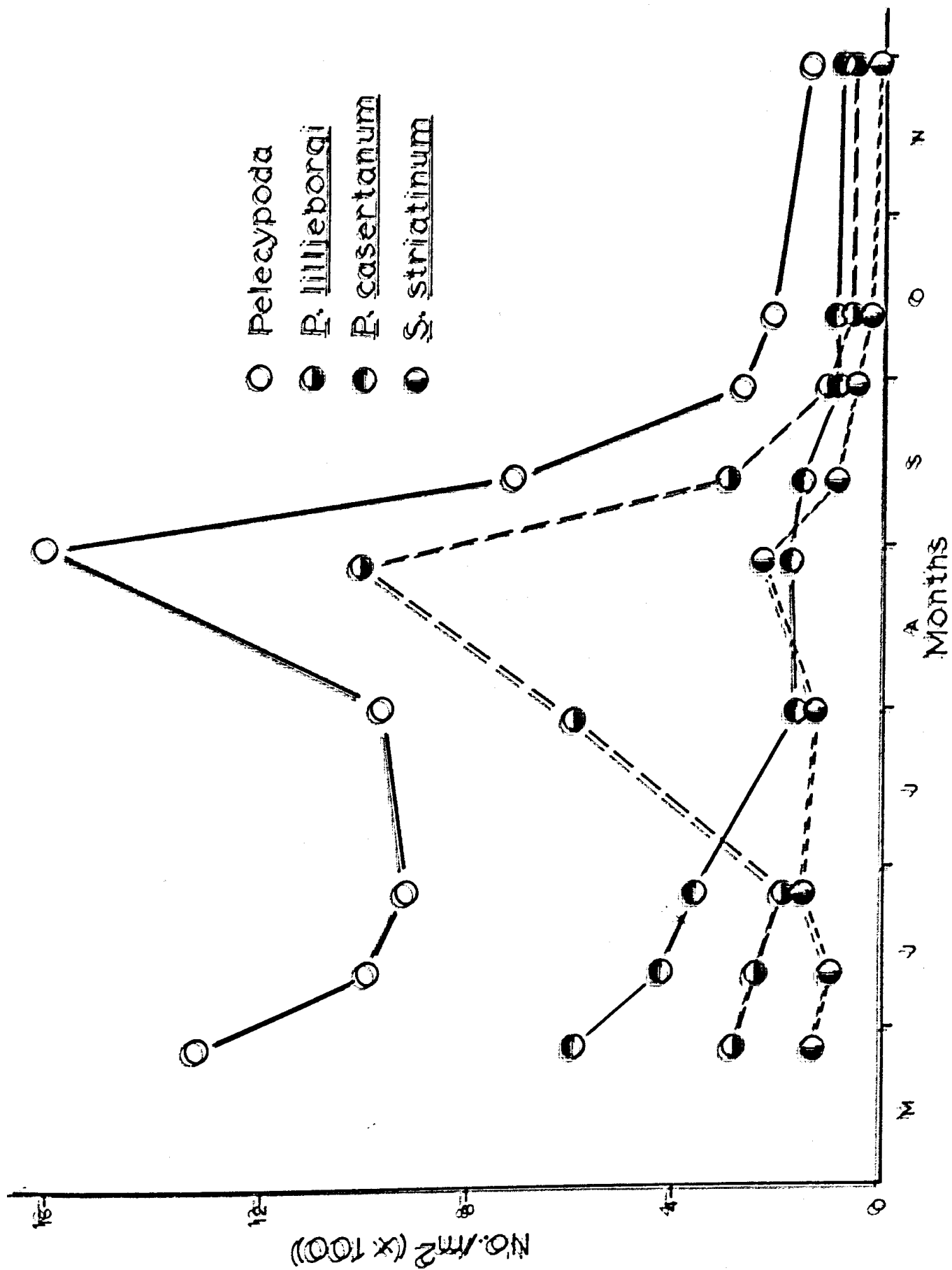
Clarke and Berg (1959) have cited pollution as an important factor in the distribution of pelecypods. The absence of many mussels, particularly E. complanatus and L. radiata may be indicative of polluted water. It is difficult to disentangle the importance of substrate type and water movement from pollution in determining which of these factors is primarily responsible in the paucity of pelecypods at Stations 2 and 6G. Nevertheless, P. casertanum did display a greater degree of tolerance for the adverse conditions at Station 2 than any other pelecypod. S. transversum has previously been reported as a molluscan indicator of pollution (Ingram et al, 1957) and as being more abundant near the source

of pollution (Carr and Hiltunen, 1965).

Seasonal distribution

The seasonal distribution of pelecypods is shown in Fig. 41. There were two periods of maximum numbers. The maximum standing crop in late May was primarily due to large populations of P. casertanum and the maximum standing crop in late August was due to an increase in the population of P. lillieborgi. It is not known whether the large populations of P. casertanum were maximum in late May or at a time prior to that, since sampling only began on May 27, 1969. No life history data was obtained for any of the species so that it is not known whether the maximum standing crops were due to periods of reproduction or to colonization. That the peaks of maximum numbers primarily represent new individuals is in accordance with other studies. Heard, (1965) observed maximum numbers of embryos of P. casertanum in late spring and early summer. The parturition period of P. lillieborgi was reported by Ohdner (1929) as occurring in the spring and fall. Monk (1928) observed maximum numbers of S. striatinum embryos during the summer months. The peaks could also correspond to periods of migration, especially vertical migration, where the peak in late May could represent the movement of P. casertanum from the deeper sediments to the surface. It is unlikely that the peak in late August was due to vertical migration since one would expect such movements to occur earlier in the season. The rapid decline in the number of Sphaeriidae in late August could, however, be related to their burrowing into the substrate to depths beyond that of Ekman dredge penetration.

Fig. 41. Seasonal distribution of Peleceypoda, Pisidium lilljeborgi,
Pisidium casertanum, and Sphaerium stratinum at Station 1, 1969.



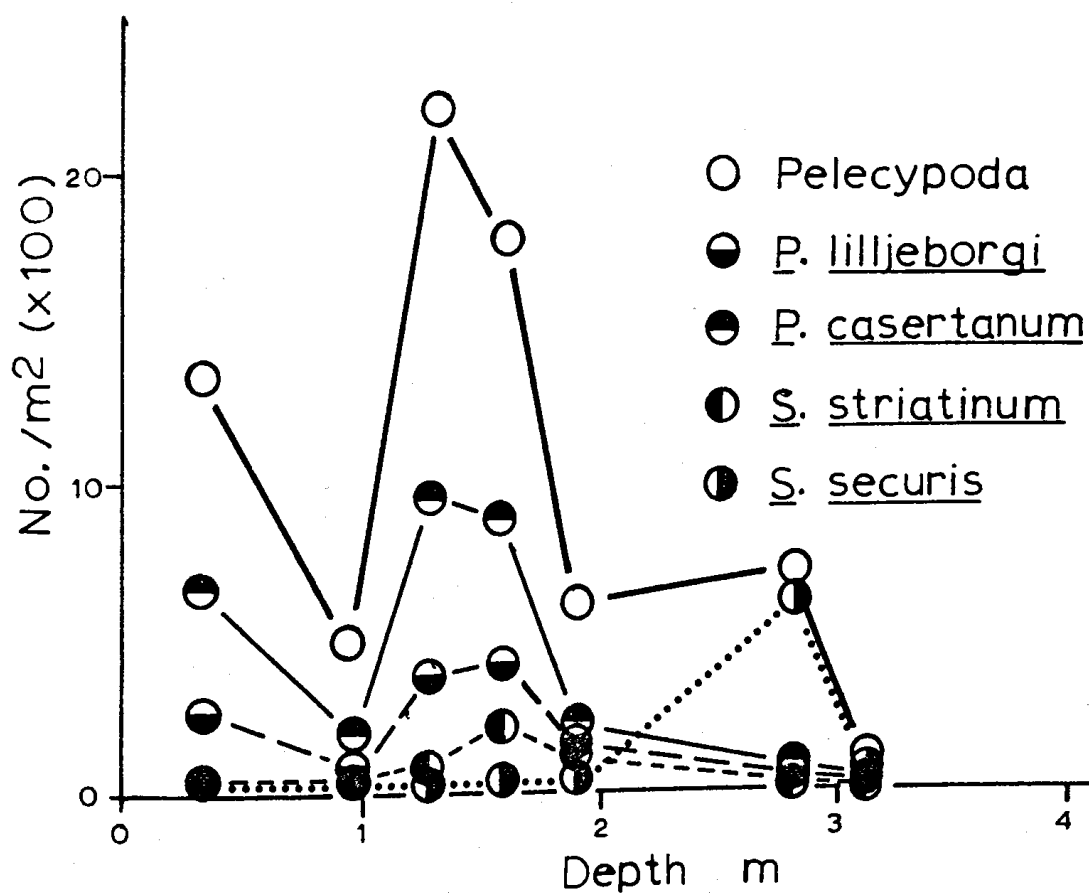
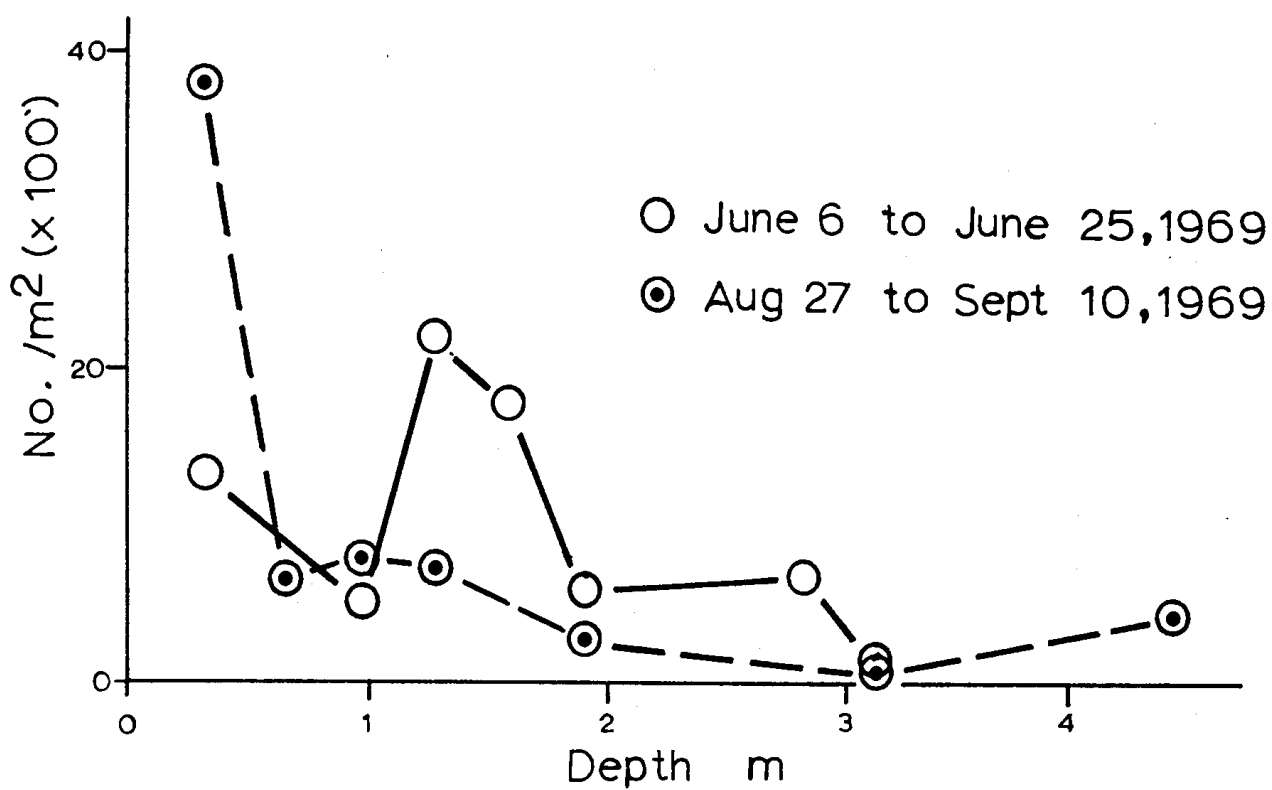
Depth distribution

The pelecypods exhibited seasonal differences in depth distributions (Fig. 42) which on the first interpretation implies horizontal migration. However, an analysis of the water stage data showed that they had not actually moved from their summer habitats. The water level was nearly two meters higher in late spring than that in late summer so that the 0 - 1.0 meter depths of late spring would actually correspond to the inner part of the beach and the waters edge of late summer. Moon (1935) found that when the water level had risen, due to spring floods, the newly inundated portion of the beach was quickly inhabited by "the more active elements of the fauna". The newly inundated portion of the beach at Station 1 would lie somewhere between the 0 and 1.0 meter depths of late spring and the pelecypods that would invade this area would be those from the 0.3 meter depth of late summer. The explanation to the minimum value at the one meter depth might be that this depth was subject to wave action. The waves might have washed the animals from the one meter depth and aggregated them on the shore. The more active elements of the pelecypods would be the species, P. casertanum and P. lilljeborgi (Fig. 42).

In contrast to the co-existing populations of P. casertanum, P. lilljeborgi, and S. striatinum, were the isolated populations of S. securis (Fig. 43) near the three meter depth. The substrate at this depth consisted of mixed coarse and fine sand which may have been the preferred substrate type, or competition with other species may have pushed it into this habitat.

Fig. 42. Depth distribution of Pelecypoda at Station 1 in June and August-September, 1969.

Fig. 43. Depth distribution of Pelecypoda, Pisidium lilljeborgi, Pisidium casertanum, Sphaerium striatinum, and Sphaerium securis, June 1969.



SUGGESTED FIELDS OF RESEARCH

The objects of the previous chapters were to describe the distribution and abundance of macrobenthos in the Ottawa River and to identify some of the ecological factors that may have affected their distribution. Because such a large number of taxa and species were involved, the scope of the ecological studies was necessarily limited. It is one additional object of this discussion to focus the attention of the investigators on those aspects that are in particular need of study. Without any order of importance, these aspects are summarized below with the emphasis on the Ottawa River benthos.

- (1) To relate the chemical, physical, and bacteriological properties of the water at the mud-water interface with the distribution of the benthos.
- (2) To show what and how various factor(s) (i.e. particle size, organic matter, proteins, fats, etc.) in the sediments affect the distribution of the benthos.
- (3) To study how aquatic vegetation affects the distribution of the benthos. It is pertinent to know if animal species derive different benefits from different aquatic plants and under different environmental conditions.
- (4) To do detailed studies on the effect of shore morphometry on benthic species.
- (5) To do detailed studies on the effect of water movement on benthic species.
- (6) To do detailed studies on the effect of food and predation on the benthic species.

- (7) To determine the TLM of benthic species to coliform bacteria counts.
- (8) To determine the TLM of benthic species to various chemicals and suspended materials present in the pulp and paper effluents.
- (9) It is suggested that taxonomic keys for the various benthic groups be constructed, using diagnostic characters that are morphological as well as anatomical since the limnologist, who must enumerate thousands of individuals of several species, must rely on characters that are easily recognized.
- (1) To rear various benthic species, particularly insects, and construct taxonomic keys for each life history stage (larvae, pupae, and imago).
- (11) To study the life histories of the various benthic species.
- (12) To study the seasonal distributions of the various benthic species during the winter as well as the summer months.
- (13) To determine the applicability of the competitive exclusion principle in elucidating the distribution of benthos.
- (14) To improve the techniques employed in benthic surveys.
- (15) To study the effect of drift on the distribution of benthos.

SUMMARY

A limnological survey was carried out in the summers of 1968 and 1969 on the portion of the Ottawa River near the cities of Ottawa and Hull. The study area, approximately 26 km in length, was divided into seven stations; Britannia Bay was chosen as the control station while the other stations were situated in more polluted areas, such as below Canada Packers at the mouth of Brewery Creek and below Canadian International Paper (CIP) Co. on the Quebec shore of the Ottawa River. Weekly determinations of pH, dissolved oxygen, carbon dioxide, conductivity, and temperature and biweekly determinations of over 15 other chemical and physical characters were made on bottom and surface waters at each station. A standard 15 x 15 cm Ekman dredge, with a screen on top, was used to collect 672 bottom samples in the summer of 1968 and 514 bottom samples in the summer of 1969. A new sieve was designed to wash larger volumes of substrate samples with greater efficiency and speed. The benthic samples collected in 1968 were used to study the distribution of benthos between stations (horizontal distribution) while those collected in 1969 were used for depth and seasonal distribution studies. The soil particle size, percent organic matter and the abundance of aquatic plant species (as percent occurrence in randomly collected Ekman dredge samples) were also determined at each station. Paired samples of three aquatic plant species were taken with a newly designed phytomacrofauna sampler to determine which aquatic plants harbored the largest number of macroinvertebrates, hence explaining the distribution of certain benthic species.

The water chemistry did not differ substantially between stations

except in the Gatineau River where the water had lower average values for alkalinity, calcium, hardness (Ca), phenols, and sulfates than the Ottawa River water. The phosphate content was higher in Brewery Creek, probably as a result of the untreated domestic sewage from Hull, while sulfates and phenols were higher below the CIP outfalls than elsewhere in the study area. The biochemical oxygen demand (B.O.D.) was used as the criterion for assessing the quality of the water; waters with a B.O.D. greater than 4 ppm were considered polluted. On this basis, the waters in the mouth of Brewery Creek were subpolluted (average B.O.D. = 3.8 ppm) and in the Ottawa River on the Gatineau shores below CIP were polluted (average B.O.D. = 6.8 ppm). The B.O.D. in the remaining stations ranged from 1.1 to 1.6 ppm. Differences in turbidity between stations were attributed to natural causes in Britannia Bay and the artificial introduction of organic matter into Brewery Creek and waters below CIP. Average total coliform bacteria counts were less than the pollution criterion of 1000 bacteria/100 ml at Britannia Bay but were larger in other stations, particularly in Brewery Creek and below CIP where total coliform counts exceeded 2,000,000/100 ml. Increases in B.O.D. and total coliform bacteria counts in 1968 and 1969 indicates that pollution has been aggravated since a 1954 survey.

More than 150 macroinvertebrate species occurred in the study area. Of these, 29 were discussed with respect to (1) their horizontal distribution, (2) their seasonal distribution during the summer, and (3) their depth distribution. The distribution of the benthos was related to such factors as the nature of the substratum, water movement, shore morphometry, food and predation, and/or pollution.

The study area was inhabited by four species of Platyhelminthes,

of which Dugesia tigrina and Hydrolix grisea were most abundant. Populations of platyhelminthes were significantly smaller in Britannia Bay than in other stations, except below CIP on the Gatineau shores where they were removed by pulp and paper wastes. D. tigrina exhibited a greater preference for and tolerance of subpolluted conditions when aquatic vegetation was present than did H. grisea. In cleaner and faster moving waters, H. grisea was more abundant than D. tigrina. Maximum standing crops of D. tigrina were observed in August and those of H. grisea in September. Depths containing aquatic vegetation supported larger populations of D. tigrina than H. grisea, which was a common component of the bottom dwelling organisms.

More than twenty species of Oligochaeta occurred in the study area. Of these, eight were dominant, including an undescribed species of the genus, Peloscolex. Populations of Uncinaxis uncinata and Peloscolex sp. were significantly larger in the cleaner waters of Britannia Bay while Stylaria fossularis, Stylaria lacustris, and Dero nivea were significantly more abundant in the subpolluted waters of Brewery Creek. Limnodrilus hoffmeisteri dominated the suppolluted waters of the Kettle Island shores below CIP and the mouth of Brewery Creek and was the only oligochaete on the Gatineau shores below CIP. Arcteonais lomondi was a common component of the oligochaete fauna in the Gatineau River and the Ottawa River on the shores of Kettle Island above CIP where the waters were fairly clean and fast flowing. U. uncinata reached a maximum standing crop in June, S. fossularis in June-July, L. hoffmeisteri in July-August, Peloscolex sp. in September, and D. nivea in October. The maximum standing crops of these species were related to their reproductive cycles. Peloscolex sp. and U. uncinata were dominant in the very fine sandy

substrates of the open littoral zones. Pelosclex sp. was also associated with the alga, Cladophora, upon which it was probably feeding. S. fossularis and S. lacustris were distributed amongst the submerged aquatic plants of the littoral zones in the subpolluted waters of Brewery Creek. L. hoffmeisteri predominated in substrates high in organic content, particularly about 11 km downstream of the CIP outfalls where standing crops exceeded 26,000/m².

The occurrence of the fresh-water polychaete, Manayunkia speciosa, in the Ottawa River represents a range extension of the species. Manayunkia speciosa was only found in fine sandy substrates of the cleaner waters of Britannia Bay, Gatineau River, and the shores of Kettle Island above CIP, suggesting that it was not tolerant of pollution.

The leeches were represented by eleven species but only one, Helobdella stagnalis, occurred with significant frequency. Significantly larger populations of H. stagnalis occurred in the subpolluted waters of Brewery Creek where they were apparently feeding on chironomid larvae. Hirudinea were not represented in the polluted waters below CIP on the Gatineau shores. Maximum standing crops of H. stagnalis were related to the appearance of young in July. A comparison of the seasonal and depth distributions of H. stagnalis with that of Chironomidae larvae suggests a predator-prey relationship.

Three species of Isopoda, Lirceus tenax, Asellus intermedius, and an undescribed species of the genus Asellus, were found in the study area. The isopods were most abundant on substrates high in organic content and as such attained significantly larger populations in subpolluted habitats, such as Brewery Creek, than in the cleaner waters of Britannia Bay and the shores of Kettle Island above CIP. The gross pollution

caused by the pulp and paper wastes of CIP removed all isopods on the Gatineau shores. The maximum standing crops observed during June and July at Brewery Creek were primarily composed of juvenile individuals.

Of the four species of Amphipoda, Hyaletta azteca and Gammarus fasciatus were the most widely distributed. H. azteca was more tolerant of subpollution than G. fasciatus, since the former populations were significantly larger in Brewery Creek. In stations below Brewery Creek, H. azteca decreased in numbers while G. fasciatus increased until the CIP outfalls below which all amphipods disappeared. The occurrence of H. azteca in Brewery Creek was a function of its association with submerged aquatic plants since its numbers decreased with increasing disappearance of aquatic plants. Maximum standing crops of G. fasciatus occurred in June and September and of H. azteca in September, prior to which the females of both species were observed carrying eggs. Since both species were associated with aquatic plants, they were primarily distributed in the littoral zones.

Hydracarina was represented by four genera but formed a small proportion of the total benthos. The insects formed one of the largest groups, being represented by approximately 50 genera, 21 of which belonged to the family Chironomidae. Species of Ephemeroptera, Odonata, Plecoptera, Megaloptera, Tricoptera, Lepidoptera, and Coleoptera were common benthic components of the cleaner waters of Britannia Bay, Gatineau River, and/or the shores of Kettle Island above CIP. The damselfly, Enallagma signatum, displayed some tolerance to subpolluted water since its populations in Brewery Creek were not significantly different from those in Britannia Bay, although they were dependent upon aquatic vegetation. Chironomid species of the genera, Pseudochironomus and Cryptochironomus were characteristic

of the sediments in Britannia Bay, with Dicrotendipes dominating the littoral zone. These three genera were replaced by Phaenopsectra and Chironomus species in the sediments and Procladius in the aquatic vegetation of Brewery Creek. The only chironomid present on the Gattineau shores below CIP was Chironomus which began appearing in samples with the oligochaete, L. hoffmeisteri, approximately two kilometers below the outfalls. Pseudochironomus attained a maximum standing crop in June, Phaenopsectra in June-July, and Chironomus in July-August. The distribution studies of chironomids would have more meaning if the species were known.

Of the 19 species of Gastropoda, 18 were present in Britannia Bay. The distribution of most gastropods, such as Amnicola limosa and Valvata tricarinata depended upon the distribution of aquatic vegetation and as such were prevalent in Britannia Bay. The distribution of Campeloma decisum, Goniobasis livescens, and Lymnaea catascopium, were influenced by the nature of the bottom sediments. Species unique to the cleaner and slower moving waters of Britannia Bay were Helisoma trivolvis, Helisoma campanulata, G. livescens, and, to some extent, L. catascopium. Gastropod populations were significantly reduced in the subpolluted waters of Brewery Creek but A. limosa, Promenetus exacuus, Gyraulus parvus, and Bithinia tentaculata were more euryoecous than other gastropods. The Gattineau shores below CIP were devoid of gastropods. Standing crops were largest for C. decisum in May when the ratio of adults to juveniles in the sediments were approximately 1:1, for A. limosa in September, and for V. tricarinata in July. A. limosa and V. tricarinata predominated in the three meter depth in the spring and the littoral zone in the summer. C. decisum distributed itself in the open littoral zones on fine sandy

The pelecypods were represented by 20 sphaeriid and two unionid species. Britannia Bay had significantly larger populations of pelecypods than the remaining stations, particularly the subpolluted waters of Brewery Creek. Pelecypods were absent in the polluted waters on the Gatineau shores below CIP. Sphaerium striatinum, Sphaerium securis, and Pisidium lilljeborgi were significantly more abundant and almost confined to the cleaner waters of Britannia Bay. Pisidium casertanum was the most widely distributed sphaeriid and the most abundant of five species that appeared in Brewery Creek. The distribution of pelecypods was influenced by the nature of the substratum, water movement, and pollution. Pelecypods were associated with fine sandy substrates, slow-moving and clean waters. P. casertanum attained maximum standing crops prior to June and P. lilljeborgi and S. striatinum in August. The depth distribution of pelecypods differed seasonally in that depths near one meter harbored the largest standing crops during the spring while the 0.3 meter depth had the largest populations during late summer.

Although this investigation has answered the questions posed in the introduction, several other questions have been raised that must necessarily remain unanswered for the time being. It is hoped that future investigations on the Ottawa River will find the results of this study to be a stepping stone to answering some of these questions.

CONCLUSIONS

The diversity and large numbers of the benthic organisms characteristic of clean waters, support the water chemistry results that clean waters do exist at Britannia Bay. Large biochemical oxygen demands (B.O.D.) were accompanied by large populations of Limnodrilus hoffmeisteri, Isopoda, Chironomus larvae, and platyhelminthe species indicating deterioration of water quality in Brewery Creek. This deterioration can be attributed to large numbers of coliform bacteria and large quantities of slaughter house wastes, the latter of which covers the bottom of Brewery Creek. A raw sewage outfall is probably responsible for the large populations of L. hoffmeisteri, isopods, and Chironomus larvae on the west shore of Gatineau Pointe where the Ottawa and Gatineau Rivers join. The absence of benthic organisms in waters with large B.O.D.'s on the Quebec shores below Canadian International Paper Co. (CIP) indicate gross pollution. Gross pollution exists for at least 11 km below CIP.

Although this work is not definitive in terms of competition, the competitive exclusion principle may explain the temporal and spatial distribution of several species.

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APPENDICES

Appendix O. Habitat characteristics and the seasonal and depth maxima of populations of common benthic species in the Ottawa River study area.

Appendix O. Habitat characteristics and the seasonal and depth maxima of populations of common benthic species in the Ottawa River study area.

[illegible]

LEGEND

PRESENCE or ABSENCE

- * Species present in indicated habitat with significantly ($P \leq 0.05$) larger numbers.

SUBSTRATE TYPE

OM Organic Matter
V Vegetation
FS very Fine Sand
A Algae

WATER MOVEMENT

S Slower water (i.e. ≤ 0.5 m/sec)
F Faster water (i.e. > 0.5 m/sec)

SHORE SLOPE

Sh Shallow Slope (i.e. $\leq 1\text{m}/15\text{m}$)
St Steep Slope (i.e. $> 1\text{m}/15\text{m}$)

SEASONAL MAXIMUM

M May
J June
Jy July
A August
S September
O October
J-Jy Late June and early July
Jy-A Late July and early August

DEPTH MAXIMUM

Numbers indicate depth range in meters
LV Littoral zone on the vegetation
LB Littoral zone on the bottom

APPENDICES I-IX

The following pages give the statistical treatment of the data discussed in the text. In each table, $\bar{x}$ = mean, SD = standard deviation (i.e. the deviations of the means from the scores of the individual samples), df = degrees of freedom, and t = the Student's "t" value (Simpson et al, 1960, p 176). An asterisk after the t value denotes that the null hypothesis (H_0) or the alternative hypothesis (H_1) is accepted with a 5 percent level of significance. Either a one-tailed or a two-tailed test is used, depending on the null hypothesis.

There is one appendix for each major taxonomic group. These groups are:

Appendix I	= Platyhelminthes
Appendix II	= Oligochaeta
Appendix III	= Hirudinea
Appendix IV	= Isopoda
Appendix V	= Amphipoda
Appendix VI	= Hydracarina
Appendix VII	= Insecta
Appendix VIII	= Gastropoda
Appendix IX	= Pelecypoda

Appendix I.1 - I.4

I.1 H_1 = Average number of D. tigrina per dredge larger at Station 2 than at other stations (i.e. $t_{0.05} \geq 1.71$).

Stations	$\bar{x}$	SD	df	t
1	0.94	2.08	38	2.59*
2	4.33	5.81		
3	1.22	2.31	32	2.06*
4	0.16	0.32	29	2.68*
5	1.83	4.23	31	1.41
6G	0	0	23	1.73*
6K	5.33	11.47	23	-0.68

I.2 H_1 = Average number of H. grisea per dredge smaller at Station 2 than at other stations (i.e. $t_{0.05} \leq -1.71$).

1	0.36	1.40	38	2.27
2	2.00	3.06		
3	6.79	23.06	32	-0.85
4	1.73	3.01	29	0.25
5	4.96	6.29	31	-1.74*
6G	0	0	23	
6K	12.65	11.47	23	-3.64*

I.3 H_1 = Average number of H. grisea per dredge smaller at Station 1 than at other stations (i.e. $t_{0.05} \leq -1.70$).

	$\bar{x}$	SD	df	t
	0.36	1.40		
	2.00	3.06	38	-2.27*
	6.79	23.06	38	-1.34
	1.73	3.01	35	-1.88*
	4.96	6.29	37	-3.40*
	0	0	29	
	12.65	11.47	29	-5.19*

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I.4 H_1 = Average number of H. grisea per dredge larger than that of D. tigrina at each station (i.e. $t_{0.05} \geq 1.70$).

			44	-1.11
	See above tables for		32	-1.74
	$\bar{x}$ and SD values of		32	1.99*
	each species.		26	1.94*
			30	1.71*
			14	
			14	1.28

Appendix II.1 - II.7

II.1 H_1 = Average number of L. hoffmeisteri per dredge larger at Station 2 than at other stations (i.e. $t_{0.05} \geq 1.71$).

Stations	$\bar{x}$	SD	df	t
1	5.68	10.67	38	1.88*
2	11.65	16.63		
3	8.13	14.21	32	0.66
4	4.04	6.83	29	1.92*
5	6.97	7.31	31	1.03
6G	0.46	1.05	23	1.98*
6K	53.92	59.13	23	-2.78

II.3 H_0 = Average number of L. hoffmeisteri per dredge similar at Stations 1, 3, and 5 (i.e. $-2.07 \leq t_{0.05} \leq 2.07$).

$\bar{x}$	SD	df	t
5.68	10.67		
8.13	14.21	38	-0.62*
6.97	7.31	37	-0.42*

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II.3 H_1 = Average number of L. hoffmeisteri per dredge larger at Station 6K than at other stations (i.e. $t_{0.05} \geq 1.75$).

1	5.68	10.67	29	3.85*
2	11.65	16.63	23	2.78*
3	8.13	14.21	23	3.08*
4	4.04	6.83	20	3.15*
5	6.97	7.31	22	3.20*
6G	0.46	1.05	14	2.56*
6K	53.92	59.13		

II.4 H_1 = Average number of Pelosclex n. sp. per dredge larger at Station 1 than at other stations (i.e. $t_{0.05} \geq 1.70$).

	4.42	6.51		
	0.12	0.49	38	2.71*
	1.33	2.50	38	1.80*
	1.10	1.63	35	1.87*
	1.02	1.89	37	2.02*
	0	0	29	1.95*
	0.12	0.17	29	1.85*

Appendix II (Cont'd)

II.5 H_1 = Average number of S. fossularis per dredge larger at Station 2 than at other stations (i.e. $t_{0.05} \geq 1.71$).

Stations	$\bar{x}$	SD	df	t
1	0.45	0.91	38	2.12*
2	12.71	27.82		
3	0.78	2.11	32	1.76*
4	0.99	2.90	29	1.76*
5	0.31	0.79	31	1.78*
6G	0	0	23	2.10*
6K	0.63	0.88	23	1.21

II.7 H_1 = Average number of D. nivea per dredge larger at Station 2 than at other stations (i.e. $t_{0.05} \geq 1.71$).

	$\bar{x}$	SD	df	t
	0	0	38	1.84*
	4.59	10.51		
	0	0	32	1.81*
	0.02	0.08	29	1.36
	0	0	31	1.80*
	0	0	23	1.88*
	0.21	0.40	23	1.64

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II.6 H_1 = Average number of S. lacustris per dredge larger at Station 2 than at other stations (i.e. $t_{0.05} \geq 1.71$).

1	0.10	0.26	38	2.53*
2	9.36	17.59		
3	0.09	0.26	32	2.17*
4	0.62	1.52	29	1.85*
5	0.33	1.16	31	2.05*
6G	0	0	23	2.12*
6K	0.50	0.93	23	1.41

Appendix III.1

III.1 H_1 = Average number of H. stagnalis per dredge larger at Station 2 than at other stations (i.e. $t_{0.05}$ 1.71).

Stations	$\bar{x}$	SD	df	t
1	0.06	0.22	38	2.72*
2	2.60	4.49		
3	0.10	0.23	32	2.30*
4	0.10	4.49	29	2.07*
5	0.10	0.16	31	2.22*
6G	0	0	23	1.22
6K	0.25	0.39	23	1.46

Appendix IV.1 - IV.2

IV.1 H_1 = Average number of Isopoda per dredge smaller at Station 1 than at other stations (i.e. $t_{0.05} \leq -1.70$).

Stations	$\bar{x}$	SD	df	t
1	0.01	0.07		
2	14.03	20.57	38	-3.28*
3	14.77	19.15	38	-3.31*
4	32.45	39.90	35	-3.94*
5	3.92	7.01	37	-2.69*
6G	0	0	29	
6K	2.83	6.72	29	-1.08

IV.2 H_1 = Average number of Isopoda per dredge smaller at Station 5 than at other stations (i.e. $t_{0.05} \leq -1.72$).

Stations	$\bar{x}$	SD	df	t
1	0.01	0.07	37	2.69
2	14.03	20.57	31	-1.87*
3	14.77	19.15	31	-2.14*
4	32.45	39.90	28	-2.82*
5	3.92	7.01		
6G	0	0	22	
6K	2.83	6.72	22	0.36

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Appendix V.1 - V.7

V.1 H_1 = Average number of Amphipoda per dredge larger at Station 1 than at other stations (i.e. $t_{0.05} \geq 1.70$).

Stations	$\bar{x}$	SD	df	t
1	9.67	10.26		
2	4.70	8.14	38	1.71*
3	3.64	5.10	38	2.22*
4	2.61	3.14	35	2.49*
5	4.58	3.74	37	1.89*
6Q	0	0	29	3.00*
6K	3.58	6.28	29	1.70*

V.2 H_1 = Average number of *G. fasciatus* per dredge larger at Station 1 than at other stations (i.e. $t_{0.05} \geq 1.70$).

1	3.40	3.83		
2	0.12	0.49	38	2.86*
3	1.27	2.49	38	1.43
4	1.36	1.80	35	1.31
5	3.20	3.40	37	-0.34
6Q	0	0	29	1.60
6K	0.63	1.28	29	1.54

V.3 H_1 = Average number of *H. azteca* per dredge larger at Station 1 than at other stations (i.e. $t_{0.05} \geq 1.70$).

$\bar{x}$	SD	df	t
6.24	8.49		
4.35	8.06	38	0.64
2.20	3.32	38	1.86*
1.01	1.67	35	2.26*
0.37	0.54	37	2.75*
0	0	29	2.18*
2.33	5.13	29	1.22

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V.4 H_1 = Average number of *G. fasciatus* per dredge smaller at Station 2 than at other stations (i.e. $t_{0.05} \leq -1.71$).

3.40	3.83	38	-2.86*
0.12	0.49		
1.27	2.49	32	-1.98*
1.36	1.80	29	-2.72*
3.20	3.40	31	-3.70*
0	0	23	0.50
0.63	1.28	23	-1.45

Appendix V (Cont'd)

V.5 H_1 = Average number of H. azteca per dredge larger at Station 2 than at other stations (i.e. $t_{0.05} \geq 1.71$)

Stations	$\bar{x}$	SD	df	t
1	6.24	8.49	38	-0.64
2	4.55	8.06		
3	2.20	3.32	32	1.11
4	1.01	1.67	29	1.61
5	0.37	0.54	31	2.07*
6G	0	0	23	1.32
6K	2.33	5.13	23	0.71

V.6 H_1 = Average number of G. fasciatus per dredge different from that of H. azteca at Station 1 (i.e. $-2.01 \leq t_{0.05} \leq 2.01$).

	$\bar{x}$	SD	df	t
<u>G. fasciatus</u>	3.40	3.83		
<u>H. azteca</u>	6.24	8.49	44	-1.77

V.7 H_1 = Average number of H. azteca per dredge different from that of G. fasciatus at Station 2 (i.e. $-2.01 \leq t_{0.05} \leq 2.01$).

	$\bar{x}$	SD	df	t
<u>H. azteca</u>	6.24	8.49		
<u>G. fasciatus</u>	3.40	m 3.83	32	-2.26*

VI.1 H_1 = Average Number of Hydracarina per dredge
smaller at Station 1 than at other
stations (i.e. $50.05 \leq -1.70$).

Stations	$\bar{x}$	SD	df	t
1	0.52	0.61		
2	1.53	2.24	38	-2.07*
3	1.46	2.05	38	-2.09*
4	1.41	1.61	34	-2.39*
5	1.84	1.74	37	-3.37*
6G	0	0	29	
6K	1.79	1.30	29	-3.74*

Appendices VII.1.1 - VII.4

VII.1 H_1 = Average Number of Ephemeroptera per dredge larger at Station 1 than at other Stations (i.e. $t_{0.05} = 1.70$)

Stations	$\bar{x}$	SD	df	t
1	0.20	0.76		
2	0.04	0.11	38	0.87
3	0.04	0.16	38	0.86
4	0.10	0.15	35	0.48
5	0.04	0.10	37	0.86
6G	0	0	29	0.68
6K	0	0	29	0.76

VII.2 H_0 = Average Number of Odonata per dredge similar at Stations 1 and 2 (i.e. $-2.07 \leq t_{0.05} \leq 2.07$)

1	0.22	0.72		
2	0.28	0.59	38	-0.28*
3				
4				
5				
6G				
6K				

VII.3 H_1 = Average Number of Megaloptera per dredge larger at Station 3 than at other stations (i.e. $t_{0.05} = 1.70$)

$\bar{x}$	SD	df	t
0	0	38	4.00*
0.02	0.08	32	3.24*
0.45	0.54		
0.10	0.27	29	2.20*
0.18	0.35	31	1.68
0	0	23	2.56*
0	0	23	2.56*

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VII.4 H_1 = Average Number of Tricoptera per dredge larger at Station 4 than at other stations (i.e. $t_{0.05} = 1.72$)

0.23	0.37	35	3.53*
0	0	29	4.61*
0.60	0.57	26	0.94
0.94	0.84		
0.70	0.73	28	0.84
0	0	20	2.51*
0.08	0.15	20	2.82*

VII.5 H_1 = Average Number of Tricoptera per dredge larger at Station 3 than at other stations (i.e. $t_{0.05} \geq 1.71$)

Stations	$\bar{x}$	SD	df	t
1	0.23	0.37	38	2.51*
2	0	0	32	4.43*
3	0.60	0.56		
4	0.94	0.84	26	-0.94
5	0.70	0.73	31	-0.43
6G	0	0	23	2.50*
6K	0.03	0.15	23	2.55*

VII.6 H_1 = Average Number of Tricoptera per dredge larger at Station 5 than at other stations (i.e. $t_{0.05} \geq 1.72$)

	$\bar{x}$	SD	df	t
1	0.23	0.37	37	2.62*
2	0	0	31	3.93*
3	0.60	0.56	31	0.43
4	0.94	0.84	28	0.84
5	0.70	0.73		
6G	0	0	22	2.23*
6K	0.03	0.15	22	2.33*

VII.7 H_1 = Average Number of Pseudochironomus per dredge larger at Station 1 than at other stations (i.e. $t_{0.05} \geq 1.70$)

$\bar{x}$	SD	df	t
5.75	8.41		
0.02	0.08	38	2.80*
0.26	0.50	38	2.68*
0.06	0.15	35	2.52*
0.17	0.52	37	2.64*
0	0	29	1.91*
0	0	29	1.91*

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VII.8 H = Average Number of Chironomus per dredge larger at Station 2 than at other stations (i.e. $t_{0.05} \geq 1.72$)

$\bar{x}$	SD	df	t
0	0	38	2.10*
1.27	2.93		
0.18	0.36	32	1.53
10.22	25.47	29	-0.84
0.41	1.01	31	1.12
1.31	3.71	23	-0.94
2.08	5.76	23	-0.47

Appendix VII.9 - VII.12

VII.9 H_1 = Average Number of Chironomus per dredge larger at Station 4 than at other stations (i.e. $t_{0.05} \geq 1.72$).

Stations	$\bar{x}$	SD	df	t
1	0	0	35	1.94*
2	1.27	2.93	29	0.84
3	0.18	0.36	29	1.63
4	10.22	25.47		
5	0.41	1.01	28	1.54
6G	1.31	3.71	20	0.94
6K	2.08	5.76	20	0.88

VII.10 H_1 = Average Number of Phaenopsectra per dredge larger at Station 2 than at other stations (i.e. $t_{0.05} \geq 1.71$)

1	0.12	0.37	38	1.71*
2	1.18	2.96		
3	5.61	8.41	31	-2.05
4	1.79	3.29	29	-0.54
5	2.19	4.85	31	-0.73
6G	0	0	23	0.93
6K	0.54	1.01	23	0.59

VII.11 H_1 = Average Number of Procladius per dredge larger at Station 2 than other stations (i.e. $t_{0.05} \geq 1.71$).

$\bar{x}$	SD	df	t
0.06	0.16	38	2.91*
1.63	2.60		
2.09	3.23	32	-0.46
1.95	3.32	29	-0.31
3.00	4.43	31	-0.70
0	0	23	2.86*
0.66	1.22	23	1.47

VII.12 H_1 = Average Number of Procladius per dredge larger at Station 4 than at other stations (i.e. $t_{0.05} \geq 1.72$)

0.06	0.16	35	2.75*
1.63	2.60	29	0.31
2.09	3.23	29	-0.12
1.95	3.32		
3.00	4.43	28	-0.72
0	0	20	2.86*
0.66	1.22	20	1.56

Appendix VIII.1 - VIII.4

VIII.1 H₁ = Average Number of Gastropoda per dredge greater at Station 1 than at other stations (i.e. $t_{0.05} \geq 1.70$)

Stations	$\bar{x}$	SD	df	t
1	8.64	8.77		
2	1.69	2.45	38	3.17*
3.	3.61	4.03	38	2.20*
4	1.10	1.23	35	3.18*
5	6.56	8.02	37	0.76
6G	0	0	29	2.24*
6K	4.14	2.63	29	1.23

VIII.2 H₁ = Average Number of Gastropoda per dredge less at Station 2 than at other stations (i.e. $t_{0.05} \leq -1.71$)

	$\bar{x}$	SD	df	t
1	8.64	8.77	38	-3.17*
2	1.69	2.45		
3	3.61	4.03	32	-1.70*
4	1.10	1.23	29	0.81
5	6.56	8.02	31	-2.39*
6G	0	0	23	
6K	4.14	2.63	23	-2.07*

VIII.3 H₁ = Average Number of *A. limosa* per dredge greater at Station 1 than at other stations (i.e. $t_{0.05} \geq 1.70$)

$\bar{x}$	SD	df	t
2.52	3.63	38	2.15*
0.52	1.42		
0.84	1.70	38	1.76*
0	0	35	2.58*
0.39	0.98	37	2.28*
0	0	29	1.70*
1.03	1.87	29	1.11

VIII.4 H₁ = Average Number of *V. tricarinata* per dredge greater at Station 1 than other stations (i.e. $t_{0.05} \geq 1.70$)

$\bar{x}$	SD	df	t
1.94	2.87		
0.16	0.31	38	2.54*
0.02	0.08	38	2.75*
0.02	0.09	35	2.49*
0	0	37	2.69*
0	0	29	1.71*
0	0	29	1.89*

Appendix VIII.5 - VIII.6

VIII.5 H_1 = Average Number of C. decism per dredge larger at Station 5 than at other stations (i.e. $t_{0.05} = 1.72$).

Stations	$\bar{x}$	SD	df	t
1	0.19	0.33	37	5.04*
2	0.04	0.16	31	4.57*
3	1.03	1.04	31	2.89*
4	0.81	1.11	28	3.12*
5	3.11	2.77		
6G	0	0	22	2.49*
6K	1.27	1.42	22	1.75*

VIII.6 H_1 = Average Number of C. decism per dredge less at Station 2 than at other stations (i.e. $t_{0.05} = 1.71$).

$\bar{x}$	SD	df	t
0.19	0.33	38	-1.70*
0.04	0.16		
1.03	1.04	32	-3.89*
0.81	1.11	29	-2.84*
3.11	2.77	31	-4.57*
0	0	23	
1.27	1.42	23	-3.61

Appendix IX.1 - IX.4

IX.1 H_1 = Average Number of Pelecypoda per dredge larger at Station 1 than at other stations (i.e. $t_{0.05} \geq 1.70$)

Stations	$\bar{x}$	SD	df	t
1	8.80	10.59		
2	0.27	0.46	38	3.30*
3	2.20	2.61	38	2.50*
4	2.07	5.23	35	2.20*
5	3.09	4.84	37	2.01*
6G	0	0	29	1.98*
6K	2.73	2.59	29	1.70*

IX.2 H_1 = Average Number of Pelecypoda per dredge smaller at Station 2 than at other stations (i.e. $t_{0.05} \geq 1.70$)

1	8.80	10.59	38	-2.33*
2	0.27	0.46		
3	2.20	2.61	32	-3.00*
4	2.07	5.23	29	-1.41
5	3.09	4.84	31	-2.38*
6G	0	0	23	
6K	2.73	2.59	23	-2.66*

IX.3 H_1 = Average Number of P. lillieborghii per dredge larger at Station 1 than at other stations (i.e. $t_{0.05} \geq 1.70$)

$\bar{x}$	SD	df	t
1.97	2.71		
0	0	38	3.68*
0.06	0.18	38	2.89*
0	0	35	3.20*
0	0	37	3.39*
0	0	29	1.73*
0	0	29	2.03*

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IX.4 H_1 = Average Number of P. casertanum per dredge at Station 1 different from those at other stations (i.e. $t_{0.50} \geq 2.07$)

1.97	3.29		
0.10	0.26	38	2.33*
1.52	2.10	38	0.54
1.24	2.35	35	0.73
2.76	4.53	37	-0.64
0	0	29	1.43
2.58	3.90	29	-0.43



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