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A STUDY OF BIOLOGICAL COLONIZATION OF THE WEST INTERCEPTOR DITCH AND LOWER BEAVER CREEK

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Aquatic Environments Limited

FOREWORD

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A REPORT TO

SYNCRUDE CANADA LTD.

A STUDY OF BIOLOGICAL COLONIZATION OF THE WEST INTERCEPTOR DITCH AND LOWER BEAVER CREEK

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INTRODUCTION

Development of Syncrude's Lease 17 required the construction of sizeable man-made channels and the alteration of natural streams for the purpose of diverting water away from the mine sites. In essence, new stream habitats are created. The present study is concerned with the development of two of these new waterbodies, the West Interceptor Ditch and a portion of lower Beaver Creek.

The West Interceptor Ditch was constructed to divert water from several small creeks into Bridge Creek, a tributary of Beaver Creek, which eventually flows into the Athabasca River. During the diversion process, a portion of lower Beaver Creek was restructured to accommodate discharge from the North Starter Dyke. The present study, initiated in May, 1977, and completed in September, 1977, is mainly concerned with this restructured section.

Specifically, the objectives of the study were to:

1) describe existing environmental conditions in, and to document natural biological colonization of, the West Interceptor Ditch, and

2) determine the degree of biological colonization of the recently altered section in lower Beaver Creek.

DESCRIPTION OF THE STUDY AREA

Construction of the West Interceptor Ditch was completed in May, 1976, as part of Syncrude Canada Ltd.'s plan to divert stream flow and surface runoff from the mine site. It is located 2.5 km west of the plant site (Figure 1) and flows northward for 13 km before entering Bridge Creek, a tributary of Beaver Creek. Flow originates from three small feeder creeks and from surface runoff. A dam near the south end of the ditch diverts flow from a fourth feeder creek to the Beaver Creek Reservoir.

Physical characteristics of the seven stations selected for investigation (Figure 1) are presented in Table 1. Feeder creeks (Stations 6 and 7) were small, slow moving brown water streams with organic substrates (Plate 1). Their banks were low, stable, and heavily vegetated. By August, aquatic macrophyte growth was also extensive. In June, discharge estimates for Stations 6 and 7 were 0.07 and 0.02 m^3/sec, respectively.

A shallow, slow moving stream varying in width from 4 m upstream (Stations 4 and 5) to 12 m downstream (Station 2) flowed through the West Interceptor Ditch. Ponding was frequent, especially where culverts partially obstructed stream flow. The substrate was mud along most of the ditch, except where cobbles had been placed to form riffled areas

TABLE 1. Physical characteristics of sampling stations on lower Beaver Creek and the West Interceptor Ditch, 1977.

	Lower Beaver Creek	West Interceptor Ditch				Feeder Creeks	
Station:	1	2	3	4	5	6	7
Substrate	80% gravel, 20% rubble, silted pools. Shifting sand at high water.	5% mud, 95% rubble.	90% mud 10% gravel.	80% mud 20% gravel.	95% mud 5% gravel.	100% organic.	100% organic.
Average Width (m)	8	12	12	4	3.5	2	1.5
Average Depth (cm)	18	25	16	12	12	30	25
Banks	Low and stable with overhanging brush. Slumping where clearcut.	Sloping stable. 50% rubble, 50% mud.	Sloping and eroded. Bare until revegetated.	Sloping and eroded. Bare until revegetated.	Sloping and eroded. Bare until revegetated.	Low and stable. Dense vegetation.	Low and stable. Dense vegetation.

FIGURE 1. Sampling stations on the West Interceptor Ditch and lower Beaver Creek, 1977.

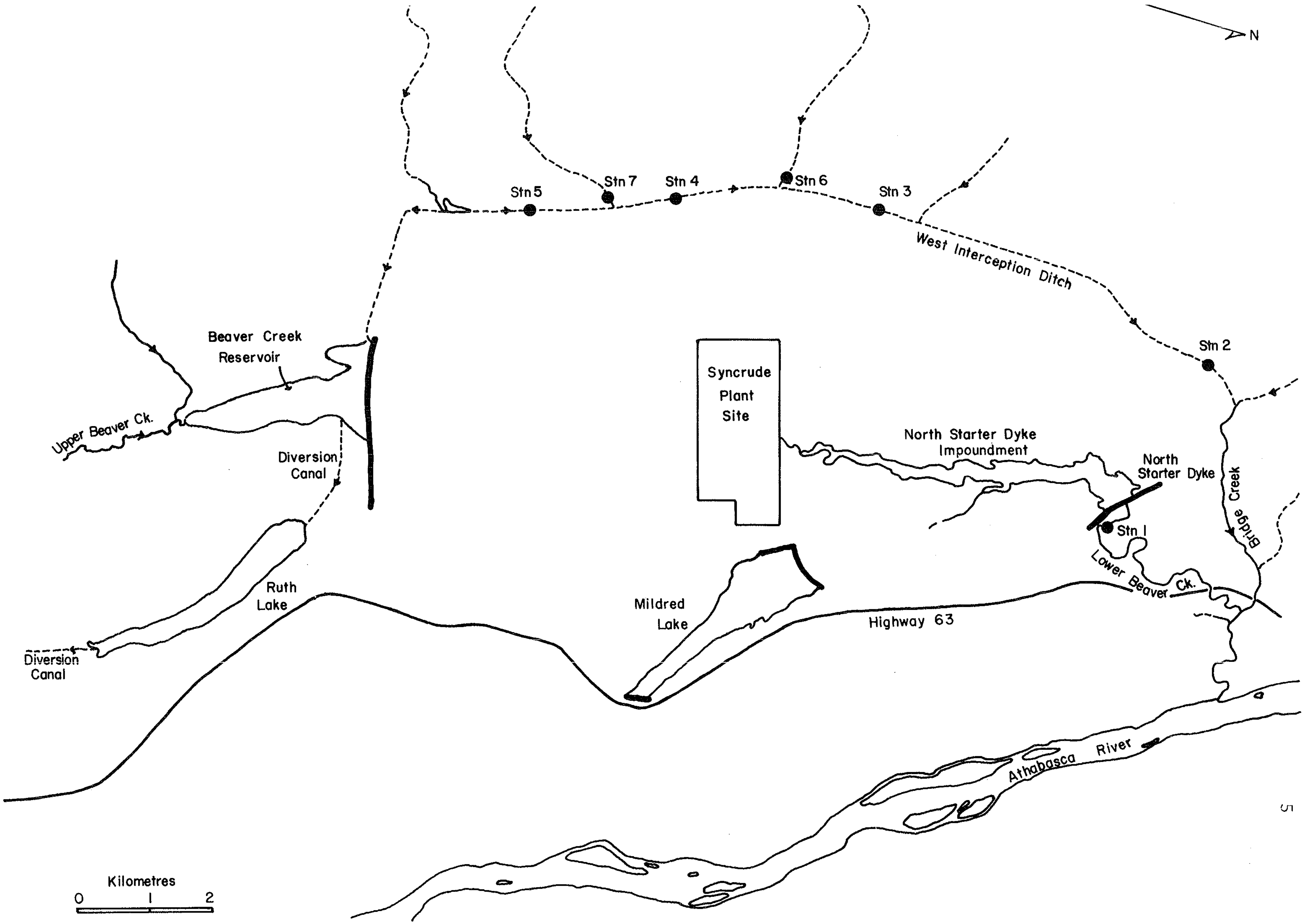

N
Stn 5
Stn 7
Stn 4
Stn 6
Stn 3
West Interception Ditch
Stn 2
Beaver Creek
Reservoir
Upper Beaver Ck.
Diversion
Canal
Syncrude
Plant
Site
North Starter Dyke
Impoundment
North
Starter Dyke
Stn 1
Bridge Creek
Lower Beaver Ck.
Ruth
Lake
Mildred
Lake
Highway 63
Diversion
Canal
Athabasca River
Kilometres
0
1
2

PLATE 1. Feeder Creek (Station 7) on the West Interceptor Ditch, August, 1977.

PLATE 2. Artificial riffle on the lower West Interceptor Ditch (Station 2) with extensive periphyton growth. August, 1977.

(Station 2, Plate 2). Although there was no indication of extensive periphyton growth elsewhere, dense mats of filamentous algae did form in the riffled areas during August and September. Maximum discharge (Figure 2) was recorded at Station 2 in June and decreased upstream. By August, there was little flow at any station.

Banks consisted of exposed soil until after they were seeded in June (Plate 3) and gullies formed by erosion along the ditch were common (Plate 4). By August, the banks were completely revegetated and apparently stabilized (Plate 5).

Station 1 on Lower Beaver Creek (Figure 1) was located 25 m downstream of a newly created riffle that extended from the top of the North Starter Dyke to the original streambed. The substrate consisted of gravelled riffles and silted pools during low water levels but was covered entirely with shifting sand at high water levels. Water flow varied from 0.01 m^3/sec in May, June, and August to 0.90 m^3/sec in July and 0.45 m^3/sec in September. Banks were low and stable with overhanging brush.

FIGURE 2. Seasonal discharge (m^3/sec) at Stations 2, 3, 4, and 5 on the West Interceptor Ditch, 1977. Locations of Stations are indicated in Figure 1.

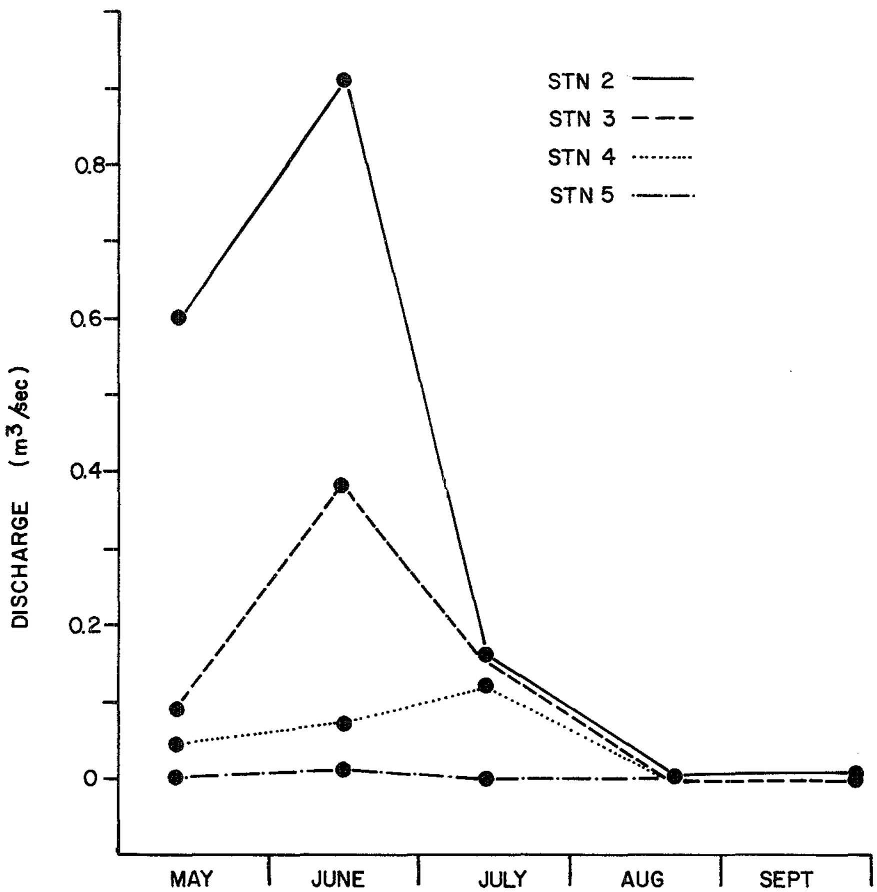

STN 2
STN 3
STN 4
STN 5
0.8
0.6
0.4
0.2
0
DISCHARGE (m3/sec)
MAY
JUNE
JULY
AUG
SEPT

PLATE 3. The West Interceptor Ditch (Station 5) before hydroseeding and fertilization. May, 1977.

PLATE 4. The West Interceptor Ditch (Station 5) completely revegetated. August, 1977. Note *Typha latifolia* in the ditch.

PLATE 5. Heavy silting at a gulley formed by erosion along the West Interceptor Ditch.

PLATE 6. Lower Beaver Creek downstream of the North Starter Dyke in the background.

MATERIALS AND METHODS

Aquatic Environments Limited performed monthly sampling (May-September, 1977) of major biological components within the new habitats. These include the phytoplankton, zooplankton, and benthic macroinvertebrates. Periodically, water chemistry, bacteria, aquatic macrophytes, and fish samples were taken. Observations of waterfowl, shorebirds, and amphibians were also recorded. Table 2 is a summary of the sampling effort at the study sites.

Sample Collection and Analysis

Physical and Chemical Parameters

Physical data gathered at each site included the following:

depth
width
current
temperature
nature of substrate
nature of bank

Width and depth of the sampling site was measured with a standard metre stick, staff gauges were placed to facilitate depth measurements. In many places the water was too shallow for the use of current meters and current was therefore estimated by determining the time it took for a stick to float a measured distance, an average of 10 m. Temperature

TABLE 2. Summary of monthly sampling effort at Stations 1-7.

STATION	MAY	JUNE	JULY
1 Lower Beaver Creek	. Physical and chemical . Bacteria (coliform analysis) . Benthic macro-invertebrates	. Physical . Benthic macro-invertebrates . Fish	. Physical and chemical . Benthic macro-invertebrates
2-5 West Inter-ceptor Ditch	. Physical and chemical . Phytoplankton . Zooplankton . Benthic macro-invertebrates . Amphibians, reptiles, birds	. Physical . Phytoplankton . Zooplankton . Benthic macro-invertebrates . Fish . Amphibians, reptiles, birds	. Physical and chemical . Phytoplankton . Zooplankton . Benthic macro-invertebrates . Amphibians, reptiles, birds
6-7 Feeder Creeks #2 and #3		. Physical . Zooplankton . Benthic macro-invertebrates . Fish	

(Continued)

TABLE 2. Continued.

STATION	AUGUST	SEPTEMBER
1 Lower Beaver Creek	. Physical . Benthic macro-invertebrates	. Physical and chemical . Benthic macro-invertebrates . Fish
2-5 West Inter-ceptor Ditch	. Physical . Phytoplankton . Aquatic macrophytes . Phytoplankton . Zooplankton . Benthic macro-invertebrates . Amphibians, reptiles, birds	. Physical and chemical . Phytoplankton . Zooplankton . Benthic macroinvertebrates . Fish . Amphibians, reptiles, birds
6-7 Feeder Creeks #2 and #3	. Benthic macro-invertebrate drift (Station 6)	

was determined using a mercury pocket thermometer. Stream substrates were visually categorized according to substrate types as outlined by Lagler (1956) as a modification of Roloef (1944). Particle sizes were defined as follows:

mud/sand (<0.004 - 2.5 mm)
fine gravel (2.5 - 25.0 mm)
coarse gravel (25.0 - 75.0 mm)
fine rubble (75.0 - 150 mm)
coarse rubble (150.0 - 300.0 mm)
boulder (>300 mm)

The bank condition was described in terms of its stability (i.e., slumping) and extent of vegetation growth.

At each station, four composite water samples of 500 ml each were collected in plastic bottles from mid-stream for the analysis of total nitrogen, total phosphates, suspended solids, volatile solids, total dissolved solids, pH, alkalinity, hardness, conductivity, and dissolved oxygen. Methods of sample preservation and analysis are summarized in Tables 3 and 4.

Bacteria (Coliform Analysis)

In May 1977, a sterilized 250 ml glass bottle was used to sample bacteria from lower Beaver Creek. Samples were

TABLE 3. Preservation of water samples.

Parameter	Preservative	Filtered or Unfiltered
Total Nitrogen	5 ml 4N HCl	Unfiltered
Total Phosphates	5 ml 4N HCl, sample chilled (2 C)	Unfiltered
Suspended Solids	1 ml $CuSO_4$ solution	Unfiltered
Total Solids	None	Unfiltered
Total Dissolved Solids	None	Unfiltered
Volatile Solids	None	Unfiltered
pH	1 ml $CuSO_4$ solution	Filtered or Unfiltered
Alkalinity System (HCO_3 and CO_3)	$CHCl_3$ (sufficient to leave a small, undissolved bead after shaking)	Filtered (Whatman GF/C filter disc)
Hardness	5 ml 4N HCl	Filtered

TABLE 4. Methods of chemical analysis.

Parameter	Method	Source of Method	Modification
Total Nitrogen	Ultraviolet photo-chemical oxidation followed by Amalgamated Cadmium Column	Strickland and Parsons (1968)	Overnight (15 hrs) irradiation period using a 500 Watt lamp
Total Phosphates	Persulfate digestion followed by Ascorbic Acid PO_4 method	Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971)	None
Suspended Sediments	Filtration and drying	Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971)	Dried at 180 C
Total Solids	Evaporation and drying	Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971)	None
Total Dissolved Solids	Filtration, evaporation, and drying	Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971)	None
Volatile Solids	Ignition of filtered sample	Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971)	None
pH	Combined electrode, type Radiometer GK 2311C	Radiometer pH meter Type 296	None

(Continued)

TABLE 4 . Continued.

Parameter	Methods	Source of Method	Modification
Alkalinity System (HCO_3 and CO_3)	Acid titration	Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971)	None
Hardness	EDTA titration	Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971)	None
Dissolved Oxygen	D.O. Meter		

taken in accordance with methods prescribed in Standard Methods for the Examination of Water and Wastewater (American Public Health Association, 1971). The bottle was kept chilled (2 C) and returned to the Calgary laboratory within 24 hours for analysis. In the laboratory, the sample was analysed for total coliform counts/100 ml and faecal coliform counts/100 ml according to procedures outlined in Standard Methods (APHA, 1971).

Phytoplankton

Information was gathered on monthly changes in the species composition and relative abundance of phytoplankters at the West Interceptor Ditch. A one to two litre unconcentrated water sample was taken at each site and preserved with Lugol's solution. The sample was counted in the laboratory using the method of Utermöhl (1958), and Zoto *et al.* (1973).

The samples for identification were thoroughly agitated and subsamples were pipetted to settling chambers. The volume of the subsamples depended upon the density of the original sample (i.e., amount of silt, detritus, etc.). Settling time was based upon a standard rate of three hours per centimetre of chamber height.

For organisms other than diatoms, a settling chamber was set up and the subsample was allowed to settle out and examined whole, using a Wild M40 Inverted Microscope.

For the identification and enumeration of diatoms, the upper portion of the subsample was removed after settling, leaving a film of liquid and the settled organisms. The remaining 2 ml were then evaporated at a temperature below 38 C. The coverslips with the organisms were then ashed in a muffle furnace (560 C $\pm$ 10 C for 15 min) to remove all debris and extraneous organic matter. The cleared diatoms were then mounted in Piccolyte and examined under a Wild M40 Inverted Microscope. Enumeration of the species present was at 750x, with the samples quantified as cells/cm^2. The algae were identified to the species level where possible, with identifications carried out at up to 1750x.

Taxonomic literature used for the identification of algae include: Bourrelly (1968), Cleve-Euler (1951-1955), Desikachary (1959), Hillard (1966, 1967), Patrick and Reimer (1966), Prescott (1962), Skuja (1948, 1964), Smith (1950), Sreenivasa and Duthie (1973), Tiffany and Britton (1951), and Tilden (1910).

Zooplankton

Samples were taken to determine monthly changes in the species composition and relative abundance of zooplankton in the West Interceptor Ditch. On one occasion, June 14, similar samples were taken from two tributary streams (Stations 6 and 7). Zooplankton was sampled by towing a No. 20 Wisconsin-type plankton net for a total distance of 15 m at each sampling site. The samples were preserved in 5% formalin solution neutralized with sodium tetraborate. Zooplankton was counted in a counting chamber using a Wild M5 binocular microscope at either 25 or 50x magnification.

Identifications were made by preparing temporary mounts of whole or dissected specimens for examination using a Wild M12 compound microscope at magnifications of 100, 400, or 1000x. Identifications were based on one or more of the following: Edmondson (1959), Brooks (1957), Deevey and Deevey (1971), Brandlova *et al.* (1972), Chenoglath and Mulamoottil (1974, 1975), and Ruttner (1974).

Benthic Macroinvertebrates

On each monthly sampling trip, triplicate benthic samples were taken at each station with an Ekman grab sampler, except for Stations 1 and 2 where a Surber sampler was used. A systematic sampling or transect method was used since it was more likely to cut across the range of habitats present in the study area.

In the laboratory, samples were washed in a sieve (600μ mesh size) and spread in a Petri dish. Organisms were removed and examined with the aid of a stereoscopic dissecting microscope. Organisms were counted, identified, and further preserved in 75% isopropol alcohol.

The major taxonomic references used include Allen and Edmunds (1961a, 1961b, 1965), Edmondson (1959), Jensen (1966), Needham *et al.* (1935), Pennak (1953), and Usinger (1963). The Chironomidae were identified according to the provisional key by Hamilton and Saether[1], and Saether (1969, 1975, 1976, 1977).

The benthic samples were analysed for species composition, densities, and biomass (total volume). Shannon-Weaver species diversity indices (Shannon and Weaver, 1949) and equitabilities (Lloyd and Ghelardi, 1964) were calculated.

Shannon-Weaver species diversity indices (Shannon and Weaver, 1949) were computed for all benthic samples by the machine formula of Lloyd *et al.* (1968). This formula is:

$$\bar{d} = \frac{C}{N} \left(N \operatorname{Log}_{10} N - \Sigma n_i \operatorname{Log}_{10} n_i\right)$$

where: $C = 3.32193$

N = total number of individuals

n_i = total number in the i^{th} species (form)

[1]Unpublished key, Environment Canada, Freshwater Institute, Winnipeg

Species diversity is dependent on the number of species (richness) and the distribution of individuals among the species (evenness). Shannon and Weaver's information theoretical measure of mean species diversity per individual ($\bar{d}$) is sensitive to, and increases with, both species richness and evenness. The value of $\bar{d}$ is proportional to the uncertainty of identification of an individual selected at random from a multi-species population. In general, $\bar{d}$ values range from zero to any positive number, but are seldom greater than ten. The $\bar{d}$ value is at a minimum when all individuals belong to the same species, whereas $\bar{d}$ is at a maximum value when each species contains the same number of individuals. In this study, each obtained $\bar{d}$ value was compared with a hypothetical maximum based on MacArthur's broken stick model (MacArthur, 1957) of natural populations (population with a few relatively abundant species and increasing numbers of species with only a few individuals). Such a comparison results in an index termed "equitability" or "e" by Lloyd and Ghelardi (1964). Equitability values were computed by using Table 6 in Weber (1971) in conjunction with the following formula:

$$\bar{d} = \frac{S'}{S}$$

where: S = number of species (forms) in the sample

S'= the tabulated number of species for MacArthur's model of equal diversity.

Values of "e" range from 0 to 1. Environmental Protection Agency biologists in the U.S. have found the equitability index to be very sensitive to even slight levels of environmental degradation.

In order to determine the extent of natural biological colonization at Lower Beaver Creek and the West Interceptor Ditch, benthic data were treated in a manner similar to that of Dickson and Cairns (1972) and grouped as follows:

a) Total number of species found at each sampling date.

b) The number of new species found at each sampling date--those species that have not been recorded before.

c) Recurring species found at each sampling date--species that are eliminated and subsequently become reestablished.

d) Species eliminated--found by adding the number of new species and recurring species to the total number present at the preceding sampling date and then subtracting the current total number from this figure.

Colonization rates (in species/day) can then be determined by adding the number of new species to the number of recurring species divided by the time in days between sampling periods. Extinction rates (in species/day) can be determined by dividing the number of species eliminated by the days between sampling periods.

Benthic Macroinvertebrate Drift

A benthic drift study was conducted at Station 7 during August 21-22, 1977. A total of six one-hour drift samples was collected during a 24 hour period. The net was placed in the stream for one hour, emptied, and then taken out for three hours before being used again for another hour. The drift net used had an opening of 30 cm x 45 cm and the nylon net was 90 cm long with a mesh size of 250 μ. Both current and water depth at the opening of the drift net were recorded.

Aquatic Macrophytes

The emergent, floating, and submergent aquatic macrophytes of the West Interceptor Ditch were surveyed August 21, 1977. Species composition as well as the per cent substrate covered by each species were estimated at numbered points along the ditch. Some points corresponded to the mouths of streams or gullies where there were often distinct assemblages of plants. Other points were within longer, relatively homogeneous segments of the stream. In such segments, the composition of the macrophyte community was determined by averaging data for two points within the segment.

When necessary, plants were preserved in 5% formalin for later identification in the laboratory. References used for identification were Correll and Correll (1972), and Moss (1959).

Fish

Fisheries surveys were conducted May 11, 1977 at Beaver Creek (Station 1). All stations (1 to 7) were surveyed June 14 and September 27, 1977. Both backpack electrofishing units and minnow seines were used, depending on the nature of the substrate. At each station, records were kept of fishing effort (length of stream sampled) and catch by species in order to compare the relative abundance of fish on a catch per unit effort basis. The lengths of stream sampled varied from 20 m in feeder creeks with relatively high fish densities to 75 m at stations with low densities. All fish were measured to the nearest millimetre (fork length) and subsamples taken to assess maturity and breeding condition, i.e., ripe, green, or spawned out. Scales were collected from fathead minnows and examined at 100 x under a compound microscope (sticklebacks were not aged). Criteria for the identification of scale annuli were those of Lagler (1956).

Waterfowl and Shorebirds

During the course of the study, all waterfowl and shorebirds seen along the West Interceptor Ditch right of way were recorded. Whenever possible, sex, age, and breeding status were also noted. Identifications were made in the field following Kortright (1942) and Salt and Salt (1976).

Amphibians

Amphibians and their tadpole stages were collected from the ditch and feeder creeks, preserved in 5% formalin, and identified later following the descriptions and keys by Stebbins (1966).

RESULTS AND DISCUSSION

Water Quality

Water quality data for lower Beaver Creek (Station 1) and the West Interceptor Ditch (Stations 2-5) are summarized in Tables 5 and 6.

Lower Beaver Creek receives water primarily from the North Starter Dyke impoundment (Figure 1). The water was slightly basic with a mean pH value of 7.4, and was relatively high in alkalinity, conductivity, and hardness (Tables 5 and 6) suggesting that the water from the impoundment is rich in calcium, sodium, and magnesium salts. The macronutrient content of the water, as measured by total nitrogen (TN) and total phosphates (TP), ranged from 600-890 μg N/1 to 135-205 μg P/1, respectively.

The West Interceptor Ditch receives water from several small streams which drain an extensive muskeg terrain that is rich in *Sphagnum* growth. Hence the ditch water was slightly basic with a pH range of 7.1-8.1. The ditch water was relatively high in alkalinity and hardness with mean values of 161.3 mg $CaCO_3$/1 and 172 mg $CaCO_3$/1, respectively. The mean total nitrogen (TN) value was 820.4 μg/1 and mean total phosphate (TP) was 107.9 μg/1 (Table 6).

TABLE 5. Water quality data of the lower Beaver Creek (Station 1), and the West Interceptor Ditch (Stations 2-5). May-September, 1977.

	Station 1			Station 2			Station 3		
	May	July	Sept	May	July	Sept	May	July	Sept
pH	7.6	7.5	7.2	7.7	8.1	7.5	7.8	7.5	7.2
Alkalinity (mg $CaCO_3$/1)	230	185	166	106	123	150	100	115	147
Hardness (mg $CaCO_3$/1)	288	220	200	124	116	136	100	112	124
Total Nitrogen (μg N/1)	640	600	890	910	675	800	925	840	860
Total Phosphate (μg P/1)	135	170	205	90	85	50	102	123	70
Suspended Solids (mg/1)	95	2.5	5.1	74	3.3	2.6	32.7	5.5	5.1
Volatile Suspended Solids (mg/1)	220	125	120	80	140	148	130	135	160
Total Dissolved Solids (mg/1)	570	350	328	370	265	240	370	230	220
Conductivity (μmho/cm @ 25 C)	608	546	577	319	294	391	278	247	346
Dissolved Oxygen (mg/1)	7.8	8.4	12.0	10.0	9.8	10.6	8.4	8.8	10.0
Temperature (C)	15.5	16	13	16	17	13	14	17	14.5

(Continued)

TABLE 5 . Continued.

	Station 4			Station 5		
	May	July	Sept	May	July	Sept
pH	7.7	7.1	7.0	7.8	7.6	7.4
Alkalinity (mg $CaCO_3$/1)	102	100	145	396	178	274
Hardness (mg $CaCO_3$/1)	88	104	144	536	184	296
Total Nitrogen (µg N/1)	1065	845	855	640	775	655
Total Phosphate (µg P/1)	124	140	94	68	265	84
Suspended Solids (mg/1)	12.0	4.5	11.4	15.2	6.8	11.7
Volatile Suspended Solids (mg/1)	70	135	128	510	175	152
Total Dissolved Solids (mg/1)	330	240	280	1320	400	672
Conductivity (µmho/cm @ 25 C)	237	227	414	1617	536	937
Dissolved Oxygen (mg/1)	8.5	7.8	9.3	8.0	10.2	8.3
Temperature (C)	14	16	12	23	15	19

TABLE 6. A comparison of the mean values and ranges of several chemical parameters for water samples from lower Beaver Creek and the West Interceptor Ditch, May-September, 1977.

Chemical Parameter	Lower Beaver Creek		West Interceptor Ditch	
pH	7.4	(7.2-7.6)	7.5	(7.1-8.1)
Alkalinity (mg $CaCO_3$/1)	193.7	(166-230)	161.3	(100-396)
Hardness (mg $CaCO_3$/1)	236	(200-288)	172	(88-536)
Total Nitrogen (μg N/1)	710	(600-890)	820.4	(640-1065)
Total Phosphate (μg P/1)	170	(135-205)	107.9	(50-265)
Suspended Solids (mg/1)	34.2	(2.5-95)	15.4	(2.6-74)
Volatile Suspended Solids (mg/1)	155	(120-220)	163.6	(70-510)
Total Dissolved Solids (mg/1)	416	(328-570)	411.4	(220-1320)
Conductivity (μmho/cm @ 25 C)	577	(546-608)	486.9	(227-1617)
Dissolved Oxygen (mg/1)	9.4	(7.8-12.0)	9.1	(7.8-10.6)

In May and June, 1977, areas along the ditch were fertilized with ammonium nitrate and ammonium phosphate. However, this treatment does not seem to have increased the macronutrient content of the water (Table 5). TN and TP values generally declined from May to September, at the same time that there was a general increase in phytoplankton standing crop and aquatic macrophyte development. This suggests that a large proportion of the nutrients reaching the ditch were being used by the primary producers for their growth.

Bacteria

Total coliform bacteria count is generally used as an index of the efficiency of sewage treatment facilities. However, the presence of coliform bacteria can indicate pathogens and numerous other organisms not commonly related to human sanitary facilities (Elrod, 1942). Geldreich *et al.* (1962, 1968) indicated that bacteria in the faeces of non-human warm-blooded animals are at least 93% faecal coliform compared with 96% in human faeces.

Standards for total coliform and faecal coliform organisms in drinking water have been established by the Department of Health and Welfare, Canada (1968). These standards are as follows:

"Acceptable Limit: none of the samples 'positive' for total coliform organisms should have an MPN index greater than 4 per 100 ml;

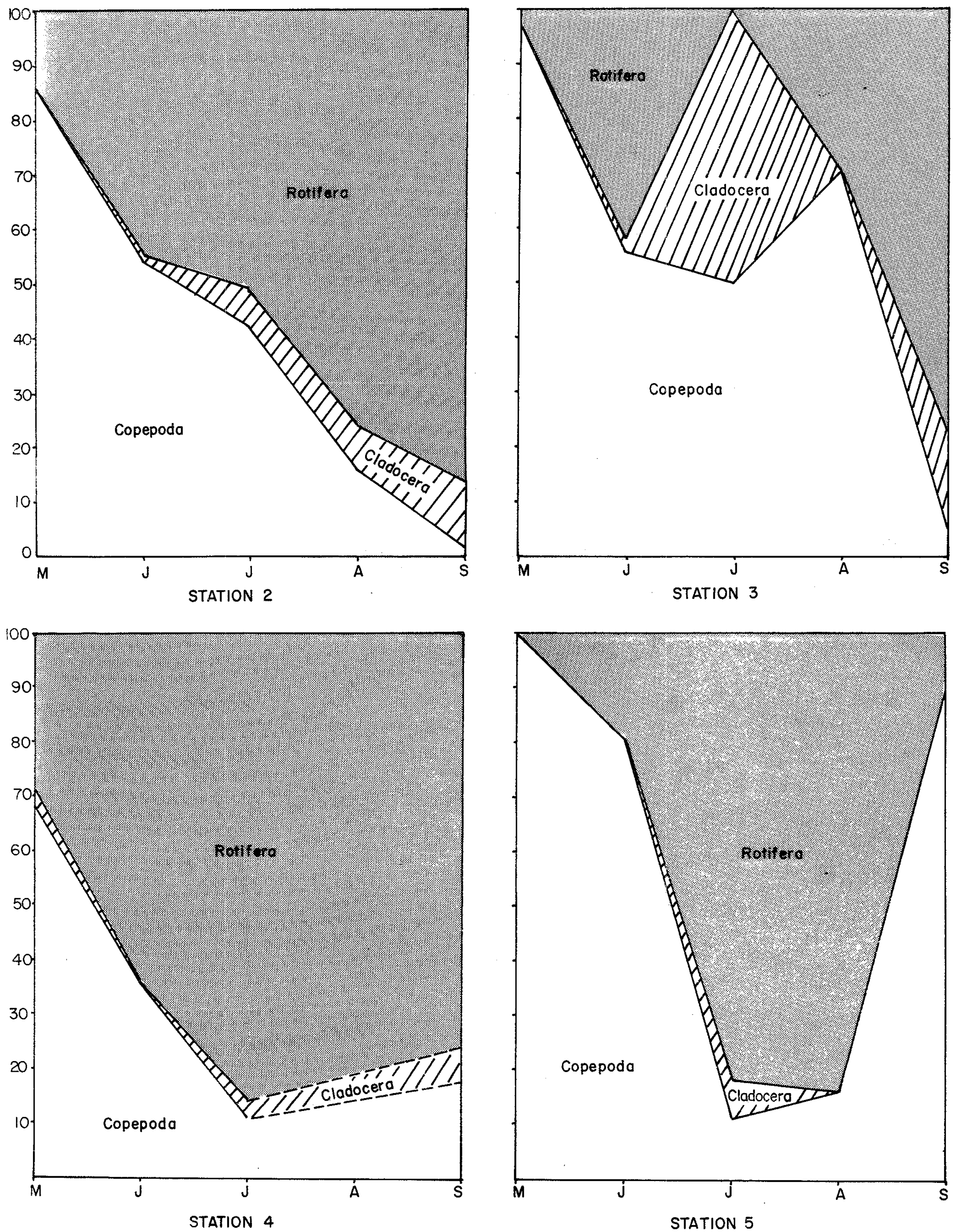
"Maximum Permissible Limit: none of the samples 'positive' for total coliform organisms should have an MPN index greater than 10 per 100 ml. The presence of faecal coliform or *Streptococci* is considered unacceptable."

The concentrations, as MPN (most probable number), of total coliform and faecal coliform bacteria were determined for lower Beaver Creek (Station 1) during the month of May, 1977. The MPN index was 10 per 100 ml for total coliform organisms and zero for faecal coliforms. The single sample therefore indicated that the bacterial content of lower Beaver Creek water exceeded the acceptable limit for human consumption, but still fell within the maximum permissible limit.

Zooplankton

During the sampling period, changes in per cent composition of major groups were generally similar at all four sampling stations (Figure 3). Generally the zooplankton was dominated by copepods (70-100%) during the early spring but this group experienced a gradual decline throughout the summer. Rotifers were a minor component of the zooplankton community in samples taken during the spring but generally replaced the copepods and became the numerically dominant group. Cladocera formed only a small part of the zooplankton

FIGURE 3. Seasonal variations in the percentage composition of zooplankters in the West Interceptor Ditch, May-September, 1977.


100
90
80
70
60
50
40
30
20
10
0
Rotifera
Copepoda
Cladocera
M
J
J
A
S
STATION 2
Rotifera
Cladocera
Copepoda
STATION 3
Rotifera
Cladocera
Copepoda
STATION 4
Rotifera
Copepoda
Cladocera
STATION 5

numbers during all sampling periods. Exceptions were samples taken at Station 3 in July in which approximately equal numbers of Cladocera and Copepoda were present.

Of the four sites sampled intensively, Stations 2, 3, and 4 had the greatest number of zooplankton species (18-21) while Station 5 had considerably fewer (10) (Table 7).

Seasonal variations in the taxonomic diversity and mean density of zooplankton in the ditch are shown in Figure 4. Taxonomic diversity and standing crop were highest in September, mainly due to the increased number of taxa and individuals found among the rotifers.

Copepoda

Cyclopoids dominated the copepod fauna and no calanoids and only small numbers of harpacticoids were collected (Table 7). May samples were dominated by nauplii and immature cyclopoids. The numbers of nauplii decreased during the sampling period and they were nearly absent from September samples.

A total of five copepod species was identified from the study area. The most common was *Eucyclops agilis* which was collected in low numbers at all sites. The harpacticoid *Canthocamptus* sp. was found at all four main sampling sites but was absent from Stations 6 and 7 when they were sampled

TABLE 7. Zooplankton collected from the West Interceptor Ditch, May-September, 1977.

	Station 2				
	M	J	J	A	S
Copepoda (Total)	112.8	29.3	12.3	6.4	5.9
Macrocyclops albidus	2.3	8.8			
Eucyclops agilis	2.3				5.3
Eucyclops speratus		9.4			
Cyclops vernalis					
Immature cyclopoids	35.5		3.5	1.7	
Nauplii	69.2	8.8	8.8	4.7	
Canthocamptus sp.	3.5	2.3			0.6
Unidentified copepods					
Cladocera (Total)		0.6	2.3	3.5	21.1
Chydorus sphaericus					
Pleuroxus denticulatus		0.6	2.3		4.7
Pleuroxus procurvus				3.5	
Simnocephalus vetulus					1.7
Macrothrix laticornis					14.7
Rotifera (Total)	27.1	22.9	14.1	27.7	188.2
Keratella cochlearis					4.7
Keratella quadrata	13.6	4.7			
Keratella serrulata					
Euchlanis sp.					
Mytilina sp.					
Trichotria sp.	4.7		4.7		8.8
Monostyla sp.		4.7	4.7	4.7	46.0
Lecane sp.				23.0	
Brachionus sp.		4.7	4.7		124.0
Ploesoma sp.					
Trichocerca sp.	8.8				4.7
Species A		8.8			
Total No. of Taxa	8	9	6	5	10
Total No. Individuals/100 ml	139.9	52.8	28.7	37.6	215.2

(Continued)

TABLE 7. Continued.

	Station 3				
	M	J	J	A	S
Copepoda (Total)	169.8	203.7	4.7	86.1	50.2
Macrocyclops albidus		18.9			
Eucyclops agilis				3.5	27.2
Eucyclops speratus				1.1	
Cyclops vernalis					
Immature cyclopoids	56.6	28.4		8.2	18.3
Nauplii	113.2	147.0		73.3	
Canthocamptus sp.			4.7		4.7
Unidentified copepods		9.4			
Cladocera (Total)		9.4	4.7		331.1
Chydorus sphaericus		9.4			55.0
Pleuroxus denticulatus					64.4
Pleuroxus procurvus					
Simnocephalus vetulus			4.7		36.6
Macrothrix laticornis					175.1
Rotifera (Total)		147.2		36.2	1409.6
Keratella cochlearis					18.3
Keratella quadrata		110.6			
Keratella serrulata					8.8
Euchlanis sp.					8.8
Mytilina sp.					
Trichotria sp.		36.6			
Monostyla sp.				8.8	534.9
Lecane sp.				4.7	
Brachionus sp.				4.7	830.0
Ploesoma sp.				13.6	
Trichocerca sp.				4.7	8.8
Species A					
Total No. of Taxa	2	7	2	9	13
Total No. Individuals/100 ml	169.8	360.3	9.4	122.6	1790.9

(Continued)

TABLE 7. Continued.

	Station 4				
	M	J	J	A	S
Copepoda (Total)	142.3	152.4	8.9		11.7
Macrocyclops albidus					
Eucyclops agilis					2.3
Eucyclops speratus		7.1	0.6		
Cyclops vernalis	8.8	2.3			
Immature cyclopoids	33.6	33.1	1.2	*	9.4
Nauplii	89.3	107.6	7.1	*	
Canthocamptus sp.	10.6	2.3			
Unidentified copepods					
Cladocera (Total)	7.0	2.3	2.3		4.6
Chydorus sphaericus		2.3	2.3	*	2.3
Pleuroxus denticulatus	7.0				2.3
Pleuroxus procurvus				*	
Simnocephalus vetulus					
Macrothrix laticornis					
Rotifera (Total)	116.7	256.5	55.4		44.7
Keratella cochlearis		27.2			
Keratella quadrata					
Keratella serrulata				*	
Euchlanis sp.			41.4	*	
Mytilina sp.					18.3
Trichotria sp.	54.8	165.6	2.3	*	8.8
Monostyla sp.		18.3			8.8
Lecane sp.			7.1		
Brachionus sp.					
Ploesoma sp.					
Trichocerca sp.		8.8	2.3		
Species A	61.9	36.6	2.3	*	8.8
Total No. of Taxa	7	11	9	8	8
Total No. Individuals/100 ml	266.0	411.2	66.6	*	61.0

*The algae were too dense to allow an accurate zooplankton count.

(Continued)

TABLE 7. Continued.

	Station 5					Station 6	Station 7
	M	J	J	A	S	J	J
Copepoda (Total)	114.2	776.3	22.9	11.1	40.1	250.5	62.5
Macrocyclops albidus					9.4	1.2	14.1
Eucyclops agilis			3.5				
Eucyclops speratus							
Cyclops vernalis		776.3	9.4			10.1	7.0
Immature cyclopoids	114.2			2.3	28.4	2.5	7.0
Nauplii			8.8	8.8	2.3	236.7	27.4
Canthocamptus sp.			1.2				
Unidentified copepods							7.0
Cladocera (Total)			13.0	1.2			
Chydorus sphaericus			13.0	1.2			
Pleuroxus denticulatus							
Pleuroxus procurvus							
Simnocephalus vetulus							
Macrothrix laticornis							
Rotifera (Total)		183.2	165.6	54.9	4.6	705.1	137.0
Keratella cochlearis						18.9	
Keratella quadrata						493.0	
Keratella serrulata							
Euchlanis sp.		36.6		18.3		18.9	27.4
Mytilina sp.						18.9	
Trichotria sp.		73.3				78.4	27.4
Monostyla sp.				18.3	2.3	39.2	27.4
Lecane sp.		73.3	165.6	18.3	2.3	18.9	
Brachionus sp.							
Ploesoma sp.							
Trichocerca sp.							
Species A						18.9	54.8
Total No. of Taxa	1	4	6	6	5	12	9
Total No. Individuals/100 ml	114.2	959.5	201.5	67.2	44.7	955.6	199.5

during June.

There appears to be little difference in the copepod populations at the four main sampling sites.

Cladocera

Five species of Cladocera were collected from the study sites. Cladocera were generally least abundant during the early sampling period and became more numerous in later samples.

The most common cladocerans were *Chydorus sphaericus* and *Pleuroxus denticulatus* both of which were found at three sites. Of the four main sampling sites, Station 5 had the fewest cladoceran species, only 1.

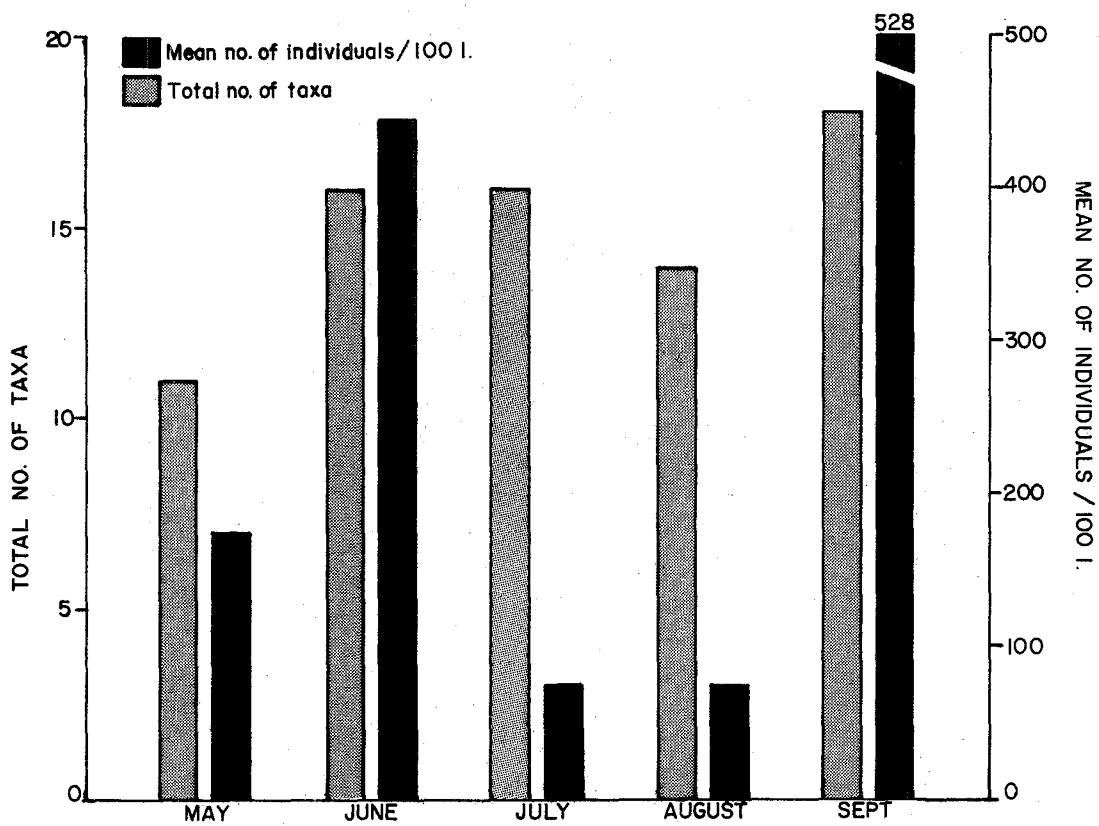
Rotifera

Twelve species of rotifers were identified from the study area. The most common were *Trichotria* sp. and *Monostyla* sp. Stations 2, 3, and 4 had 8-10 species while Station 5 had only 4 species.

Others

Because of the shallow nature of the study sites, a number of benthic organisms were collected along with the zooplankton. Ostracods and chironomids were the most common of these.

FIGURE 4. Seasonal variations in zooplankton diversity and density, West Interceptor Ditch, May-September, 1977.


Mean no. of individuals/100 l.
Total no. of taxa
TOTAL NO. OF TAXA
MEAN NO. OF INDIVIDUALS / 100 l.
528
0
5
10
15
20
0
100
200
300
400
500
MAY
JUNE
JULY
AUGUST
SEPT

Phytoplankton

Table 8 summarizes phytoplankton data obtained during the study. A total of 120 species of algae was recorded from the West Interceptor Ditch. The Bacillariophyceae (diatoms) were the most common with 56 species represented. The other algal groups encountered were the Chlorophyta (green algae) with 27 species, the Chrysophyceae (golden-brown algae) with 17 species, Cyanophyta (blue-green algae) with 9 species, Euglenophyta with 6 species, Cryptophyta with 3 species, the Pyrrophyta (dinoflagellates), and the Xanthophyceae with one species each.

Taxonomic diversity was highest during the month of August, when a total of 55 algal species was recorded, and lowest for the month of June, when only 37 species were recorded (Figure 5). The most common algal taxa observed belonged to two major groups, the diatoms and the green algae. The common diatom genera were *Navicula*, *Nitzschia*, and *Achnanthes*; the common green algal genera were *Ankistrodesmus*, *Scenedesmus*, and *Tetraedron*.

Standing crop was highest for the month of August with a mean density of 1,832 cells/ml, and lowest during May with a mean density of 618 cells/ml (Figure 5). Seasonal variation in the relative abundance of the major algal taxa is shown in Figure 6. The diatoms were numerically the most

TABLE 8 . Phytoplankton of the West Interceptor Ditch, May-September, 1977. All entries as cells/ml.

Species	Station 2 Month:	M	J	J	A	S
Chlorophyta						
Actinastrum hantzschia						
Ankistrodesmus convolutus				14	40	47
Ankistrodesmus falcatus		7	142		11	
Ankistrodesmus falcatus var. *acicularis*						
Chlamydomonas spp.					4	
Chlorella sp.			85			
Coeloastrum microporum				57		
Cosmarium humile					4	
Cosmarium regnellii var. *minor*						
Cosmarium acerosum				7		
Cosmarium acutum		7				
Cosmarium spp.						
Dictyosphaerium ehrenbergianum			170			
Dictyosphaerium pulchellum					72	
Franceia droescheri						
Lagerheimia wratislavensis						
Oocystis borgei					4	
Oocystis crassa					4	
Oocystis parva			170		4	
Pandorina morum						
Pediastrum tetras				28	43	
Scenedesmus bijuga				28		
Scenedesmus denticulatus						
Scenedesmus obliquus			114		29	
Scenedesmus serratus					43	47
Tetraedron minimum				7	4	12
Tetraedron muticum						

(Continued)

TABLE 8. Continued.

Species	Station 2 Month:	M	J	J	A	S
Cyanophyta						
Anabaena spp.						
Chroococcus dispersus						
Coelosphaerium kuetzingianum						
Lyngbya epiphytica		156				
Merismopedia glauca						
Oscillatoria agardhii		213				
Oscillatoria minnesotense					7	
Oscillatoria spp.					284	
Phormidium spp.						236
Chrysophyta						
Class Chrysophyceae						
Bicoeca spp.						
Chromulina spp.					47	
Chrysochromulina parva						
Chrysococcus rufescens		21				
Dinobryon divergens		7				
Dinobryon sertularia						
Dinobryon sociale						
Epipyxis utriculus						
Kephyrion littorale						
Mallomonas akrokomonas						
Mallomonas sp.						
Ochromonas sp.						
Pseudokephyrion pseudospirale						
Pseudokephyrion undulatissimum						
Pseudokephyrion striatum						
Pseudopedinella erkensis						
Synura petersenii						
Class Xanthophyceae						
Tribonema spp.						

(Continued)

TABLE 8. Continued.

Species	Station 2 Month:	M	J	J	A	S
Class Bacillariophyceae						
Amphipleura pellucida						
Achnanthes lanceolata						
Achnanthes linearis var. *curta*		7			29	
Achnanthes spp.				14		130
Caloneis ventricosa						
Caloneis ventricosa var. *alpina*		7				
Caloneis ventricosa var. *subundulata*						
Caloneis ventricosa var. *truncatula*						
Caloneis lewisii					4	
Cocconeis placentula var. *lineata*						12
Cocconeis spp.				14		
Cyclotella comta						
Cyclotella meneghiniana			57			12
Cyclotella spp.		43		28		
Cymbella minuta					4	12
Cymbella minuta var. *silesiaca*						
Cymbella sinuata						
Cymbella spp.		14	28	7		
Fragilaria spp.						
Gomphonema acuminatum			14			
Gomphonema brebissonii						
Gomphonema parvulum		14	14		18	12
Gomphonema subtile var. *sagitta*						
Gomphonema spp.		14	14			
Gyrosigma acuminatum						

(Continued)

TABLE 8. Continued.

Species	Station 2 Month:	M	J	J	A	S
Meridion circulare		7				
Navicula angusta			14			24
Navicula arvensis				7		
Navicula capitata						
Navicula cryptocephala		43		28		12
Navicula menisculus var. *upsaliensis*		43	128			
Navicula minima						
Navicula pupula var. *rectangularis*						
Navicula radiosa						
Navicula rhynchocephala						
Navicula spp.		14	170	7		
Neidium affine var. *longiceps*						
Nitzschia acicularis		64				
Nitzschia amphibia var. *genuina*						
Nitzschia palea		7				
Nitzschia sigmoidea						
Nitzschia sigma		14				
Nitzschia vernicularis						
Nitzschia spp.		78	156	135	86	106
Pinnularia spp.						
Rhoicosphenia curvata						12
Rhopalodia gibba						
Rhopalodia gibba var. *ventricosa*			14			
Stauroneis anceps						
Surirella angusta						
Surirella spp.						
Synedra delicatissima					4	
Synedra ulna						12
Synedra spp.		21				35

(Continued)

TABLE 8. Continued.

Species	Station 2 Month:	M	J	J	A	S
Tabellaria flocculosa						
Cryptophyta						
Cryptomonas marssonii				7	4	
Cryptomonas spp.		14			11	
Rhodomonas minuta		7				
Pyrrophyta						
Peridinium inconspicuum						
Euglenophyta						
Euglena proxima						
Euglena spp.						
Lepocinclis acuta						
Trachelomonas dybowskii						
Trachelomonas intermedia						
Trachelomonas volvocina						
No. of Species		24	15	15	23	15
Total cells/ml		822	1290	388	760	721

(Continued)

TABLE 8. Continued.

Species	Station 3 Month:	M	J	J	A	S
Chlorophyta						
Actinastrum hantzschia				28		
Ankistrodesmus convolutus					18	18
Ankistrodesmus falcatus			71	71	35	24
Ankistrodesmus falcatus var. *acicularis*						71
Chlamydomonas spp.			22			
Chlorella sp.						
Coeloastrum microporum						
Cosmarium humile				7	53	
Cosmarium regnellii var. *minor*					18	
Cosmarium acerosum						
Cosmarium acutum						
Cosmarium spp.						
Dictyosphaerium ehrenbergianum						59
Dictyosphaerium pulchellum						
Franceia droescheri						
Lagerheimia wratislavensis						47
Oocystis borgei						
Oocystis crassa						
Oocystis parva						
Pandorina morum						
Pediastrum tetras			7		142	47
Scenedesmus bijuga			28		35	
Scenedesmus denticulatus			28			
Scenedesmus obliquus				28		
Scenedesmus serratus						
Tetraedron minimum						
Tetraedron muticum				7		

(Continued)

TABLE 8. Continued.

Species	Station 3 Month:	M	J	J	A	S
Cyanophyta						
Anabaena spp.				291		
Chroococcus dispersus				28		
Coelosphaerium kuetzingianum				568		
Lyngbya epiphytica						
Merismopedia glauca			57			
Oscillatoria agardhii						
Oscillatoria minnesotense						
Oscillatoria spp.						
Phormidium spp.						
Chrysophyta						
Class Chrysophyceae						
Bicoeca spp.						12
Chromulina spp.				50		
Chrysochromulina parva				7		
Chrysococcus rufescens		50		14	18	47
Dinobryon divergens				14		
Dinobryon sertularia		14	7			
Dinobryon sociale						
Epipyxis utriculus						
Kephyrion littorale		7				
Mallomonas akrokomonas		7				
Mallomonas sp.					18	
Ochromonas sp.				36		
Pseudokephyrion pseudospirale				21		12
Pseudokephyrion undulatissimum		7				
Pseudokephyrion striatum				7		
Pseudopedinella erkensis						
Synura petersenii			7			
Class Xanthophyceae						
Tribonema spp.						

(Continued)

TABLE 8. Continued.

Species	Station 3 Month:	M	J	J	A	S
Class Bacillariophyceae						
Amphipleura pellucida			7			
Achnanthes lanceolata						
Achnanthes linearis var. *curta*					89	
Achnanthes spp.			7	28	89	
Caloneis ventricosa						
Caloneis ventricosa var. *alpina*		7				
Caloneis ventricosa var. *subundulata*						
Caloneis ventricosa var. *truncatula*						
Caloneis lewisii						
Cocconeis placentula var. *lineata*					35	
Cocconeis spp.						
Cyclotella comta				28		
Cyclotella meneghiniana					35	
Cyclotella spp.			22			83
Cymbella minuta						
Cymbella minuta var. *silesiaca*						
Cymbella sinuata					18	
Cymbella spp.				7		
Fragilaria spp.						47
Gomphonema acuminatum						
Gomphonema brebissonii						
Gomphonema parvulum						
Gomphonema subtile var. *sagitta*						
Gomphonema spp.			14			
Gyrosigma acuminatum			7			

(Continued)

TABLE 8 . Continued.

Species	Station 3 Month:	M	J	J	A	S
Meridion circulare						
Navicula angusta		50	28		124	35
Navicula arvensis					53	413
Navicula capitata			7			
Navicula cryptocephala		21	57	92	283	236
Navicula menisculus var. *upsaliensis*						
Navicula minima						
Navicula pupula var. *rectangularis*						
Navicula radiosa			7			
Navicula rhynchocephala						
Navicula spp.		92	43	241	53	12
Neidium affine var. *longiceps*						
Nitzschia acicularis		178		28	18	35
Nitzschia amphibia var. *genuina*						12
Nitzschia palea					18	24
Nitzschia sigmoidea						
Nitzschia sigma			7	7	35	
Nitzschia vernicularis						
Nitzschia spp.		221	263	178	106	83
Pinnularia spp.		7				
Rhoicosphenia curvata						
Rhopalodia gibba						
Rhopalodia gibba var. *ventricosa*						
Stauroneis anceps						
Surirella angusta		7				
Surirella spp.						
Synedra delicatissima						
Synedra ulna		14		7		
Synedra spp.		14				

(Continued)

TABLE 8. Continued.

Species	Station 3 Month:	M	J	J	A	S
Tabellaria flocculosa						
Cryptophyta						
Cryptomonas marssonii						
Cryptomonas spp.		28	50	57	89	
Rhodomonas minuta					18	
Pyrrophyta						
Peridinium inconspicuum		14		7		83
Euglenophyta						
Euglena proxima						
Euglena spp.						
Lepocinclis acuta						
Trachelomonas dybowskii			7			
Trachelomonas intermedia		7		14		
Trachelomonas volvocina			7			12
No. of Species		18	23	27	23	21
Total cells/ml		751	760	1871	1400	1512

(Continued)

TABLE 8. Continued.

Species	Station 4 Month:	M	J	J	A	S
Chlorophyta						
Actinastrum hantzschia						
Ankistrodesmus convolutus				57		71
Ankistrodesmus falcatus		11	7		24	12
Ankistrodesmus falcatus var. *acicularis*				57		35
Chlamydomonas spp.		17		21	83	
Chlorella sp.						
Coeloastrum microporum						
Cosmarium humile						
Cosmarium regnellii var. *minor*						
Cosmarium acerosum						
Cosmarium acutum						
Cosmarium spp.						
Dictyosphaerium ehrenbergianum				128		142
Dictyosphaerium pulchellum						
Franceia droescheri						
Lagerheimia wratislavensis						12
Oocystis borgei						
Oocystis crassa						
Oocystis parva						
Pandorina morum						
Pediastrum tetras						
Scenedesmus bijuga						
Scenedesmus denticulatus						
Scenedesmus obliquus						
Scenedesmus serratus						
Tetraedron minimum		6		21		12
Tetraedron muticum						

(Continued)

TABLE 8 . Continued.

Species	Station 4 Month:	M	J	J	A	S
Cyanophyta						
Anabaena spp.						
Chroococcus dispersus						
Coelosphaerium kuetzingianum						
Lyngbya epiphytica						
Merismopedia glauca						
Oscillatoria agardhii						
Oscillatoria minnesotense						
Oscillatoria spp.						
Phormidium spp.						
Chrysophyta						
Class Chrysophyceae						
Bicoeca spp.				64		12
Chromulina spp.						
Chrysochromulina parva						
Chrysococcus rufescens		36				
Dinobryon divergens						
Dinobryon sertularia		8				
Dinobryon sociale						
Epipyxis utriculus				7		
Kephyrion littorale						
Mallomonas akrokomonas						
Mallomonas sp.						
Ochromonas sp.				21	12	
Pseudokephyrion pseudospirale						12
Pseudokephyrion undulatissimum					12	
Pseudokephyrion striatum						
Pseudopedinella erkensis					35	
Synura petersenii		11				
Class Xanthophyceae						
Tribonema spp.		11				

(Continued)

TABLE 8. Continued.

Species	Station 4 Month: M	J	J	A	S
Class Bacillariophyceae					
Amphipleura pellucida					
Achnanthes lanceolata				12	
Achnanthes linearis var. *curta*					
Achnanthes spp.				106	
Caloneis ventricosa	3		36		
Caloneis ventricosa var. *alpina*					
Caloneis ventricosa var. *subundulata*			7		
Caloneis ventricosa var. *truncatula*					
Caloneis lewisii					
Cocconeis placentula var. *lineata*					
Cocconeis spp.					
Cyclotella comta					
Cyclotella meneghiniana		14		12	
Cyclotella spp.			107		
Cymbella minuta					
Cymbella minuta var. *silesiaca*				12	
Cymbella sinuata					
Cymbella spp.			7		
Fragilaria spp.					12
Gomphonema acuminatum	3				
Gomphonema brebissonii	3				
Gomphonema parvulum				12	
Gomphonema subtile var. *sagitta*					12
Gomphonema spp.		7			
Gyrosigma acuminatum					

(Continued)

TABLE 8. Continued.

Species	Station 4 Month:	M	J	J	A	S
Meridion circulare						
Navicula angusta		20			35	35
Navicula arvensis					47	
Navicula capitata						
Navicula cryptocephala					35	59
Navicula menisculus var. *upsaliensis*						
Navicula minima						94
Navicula pupula var. *rectangularis*					12	
Navicula radiosa						
Navicula rhynchocephala					12	
Navicula spp.		11	71	85	12	
Neidium affine var. *longiceps*						12
Nitzschia acicularis		53			342	130
Nitzschia amphibia var. *genuina*						
Nitzschia palea					83	12
Nitzschia sigmoidea						
Nitzschia sigma					35	12
Nitzschia vernicularis					12	
Nitzschia spp.		81	57	114	330	106
Pinnularia spp.						
Rhoicosphenia curvata						
Rhopalodia gibba						
Rhopalodia gibba var. *ventricosa*						
Stauroneis anceps					12	
Surirella angusta						
Surirella spp.						
Synedra delicatissima						
Synedra ulna						12
Synedra spp.				7		

(Continued)

TABLE 8. Continued.

Species	Station 4 Month:	M	J	J	A	S
Tabellaria flocculosa				7		
Cryptophyta						
Cryptomonas marssonii				28		
Cryptomonas spp.		34		71	24	
Rhodomonas minuta					35	
Pyrrophyta						
Peridinium inconspicuum						
Euglenophyta						
Euglena proxima						12
Euglena spp.		6				
Lepocinclis acuta						12
Trachelomonas dybowskii						
Trachelomonas intermedia			7			
Trachelomonas volvocina		3				
No. of Species		17	6	18	24	21
Total cells/ml		317	163	845	1346	828

(Continued)

TABLE 8. Continued.

Species	Station 5 Month:	M	J	J	A	S
Chlorophyta						
Actinastrum hantzschia						
Ankistrodesmus convolutus				128	53	
Ankistrodesmus falcatus			71		496	94
Ankistrodesmus falcatus var. *acicularis*				36		47
Chlamydomonas spp.					159	
Chlorella sp.						
Coeloastrum microporum						94
Cosmarium humile						
Cosmarium regnellii var. *minor*						
Cosmarium acerosum						
Cosmarium acutum						
Cosmarium spp.			71			
Dictyosphaerium ehrenbergianum				43	212	
Dictyosphaerium pulchellum						
Franceia droescheri						
Lagerheimia wratislavensis						
Oocystis borgei						
Oocystis crassa						
Oocystis parva						
Pandorina morum					212	
Pediastrum tetras						
Scenedesmus bijuga						
Scenedesmus denticulatus					71	
Scenedesmus obliquus				7		24
Scenedesmus serratus					212	94
Tetraedron minimum				121	35	24
Tetraedron muticum						

(Continued)

TABLE 8. Continued.

Species	Station 5 Month:	M	J	J	A	S
Cyanophyta						
Anabaena spp.			391	170		
Chroococcus dispersus						
Coelosphaerium kuetzingianum						
Lyngbya epiphytica						95
Merismopedia glauca				57		
Oscillatoria agardhii						
Oscillatoria minnesotense						
Oscillatoria spp.						
Phormidium spp.						
Chrysophyta						
Class Chrysophyceae						
Bicoeca spp.						
Chromulina spp.						
Chrysochromulina parva					1982	
Chrysococcus rufescens						
Dinobryon divergens						
Dinobryon sertularia						12
Dinobryon sociale					177	
Epipyxis utriculus						
Kephyrion littorale						
Mallomonas akrokomonas						
Mallomonas sp.						
Ochromonas sp.						
Pseudokephyrion pseudospirale		99		7		
Pseudokephyrion undulatissimum						
Pseudokephyrion striatum						
Pseudopedinella erkensis						
Synura petersenii						
Class Xanthophyceae						
Tribonema spp.						

(Continued)

TABLE 8. Continued.

Species	Station 5 Month: M	J	J	A	S
Class Bacillariophyceae					
Amphipleura pellucida					
Achnanthes lanceolata					
Achnanthes linearis var. *curta*					
Achnanthes spp.	43	36	21	18	12
Caloneis ventricosa					
Caloneis ventricosa var. *alpina*					
Caloneis ventricosa var. *subundulata*					
Caloneis ventricosa var. *truncatula*					12
Caloneis lewisii					
Cocconeis placentula var. *lineata*					
Cocconeis spp.					
Cyclotella comta					
Cyclotella meneghiniana					47
Cyclotella spp.			149	18	
Cymbella minuta					
Cymbella minuta var. *silesiaca*					
Cymbella sinuata					
Cymbella spp.					12
Fragilaria spp.					
Gomphonema acuminatum					
Gomphonema brebissonii					
Gomphonema parvulum			21		
Gomphonema subtile var. *sagitta*					
Gomphonema spp.		71			
Gyrosigma acuminatum					

(Continued)

TABLE 8. Continued.

Species	Station 5 Month:	M	J	J	A	S
Meridion circulare						
Navicula angusta			178	28	35	24
Navicula arvensis				92		83
Navicula capitata						
Navicula cryptocephala			107	142		201
Navicula menisculus var. *upsaliensis*						
Navicula minima						
Navicula pupula var. *rectangularis*						
Navicula radiosa						
Navicula rhynchocephala						
Navicula spp.		241	71		18	
Neidium affine var. *longiceps*						
Nitzschia acicularis					53	12
Nitzschia amphibia var. *genuina*						
Nitzschia palea						12
Nitzschia sigmoidea					18	
Nitzschia sigma						
Nitzschia vernicularis						
Nitzschia spp.		185	391	99	53	35
Pinnularia spp.						
Rhoicosphenia curvata						
Rhopalodia gibba		14				
Rhopalodia gibba var. *ventricosa*						
Stauroneis anceps						
Surirella angusta						
Surirella spp.			36			
Synedra delicatissima						
Synedra ulna						
Synedra spp.						

(Continued)

TABLE 8. Continued.

Species	Station 5 Month:	M	J	J	A	S
Tabellaria flocculosa						
Cryptophyta						
Cryptomonas marssonii				28	18	
Cryptomonas spp.				156		
Rhodomonas minuta					407	
Pyrrophyta						
Peridinium inconspicuum				7		83
Euglenophyta						
Euglena proxima						
Euglena spp.						
Lepocinclis acuta						
Trachelomonas dybowskii						
Trachelomonas intermedia			284	7		24
Trachelomonas volvocina						
No. of Species		5	11	19	19	20
Total cells/ml		582	1707	1319	4247	1041

abundant group throughout the study period. The green algae increased in relative abundance from spring through summer and were most abundant in August. The blue-green and the golden-brown algae also increased seasonally and reached peak densities in July and August, respectively. Lesser groups such as the Euglenophyta and Cryptophyta reached their highest densities in the summer. They were most common at Stations 4 and 5.

Benthic Macroinvertebrates

Benthic macroinvertebrate data for lower Beaver Creek, the West Interceptor Ditch, and two feeder streams are summarized in Tables 9 to 15.

Lower Beaver Creek

Benthic macroinvertebrates in the restructured section of lower Beaver Creek (Figure 1), downstream from the North Starter Dyke, were sampled monthly from May to September in order to determine the extent of biological colonization in this new habitat.

Species Composition

The results (Table 9) indicate that this section was primarily colonized by oligochaetes (sludge worms) and chironomids (midges). In spring, only sludge worms were

FIGURE 5. Seasonal variations in phytoplankton diversity and density at the West Interceptor Ditch, May-September, 1977.

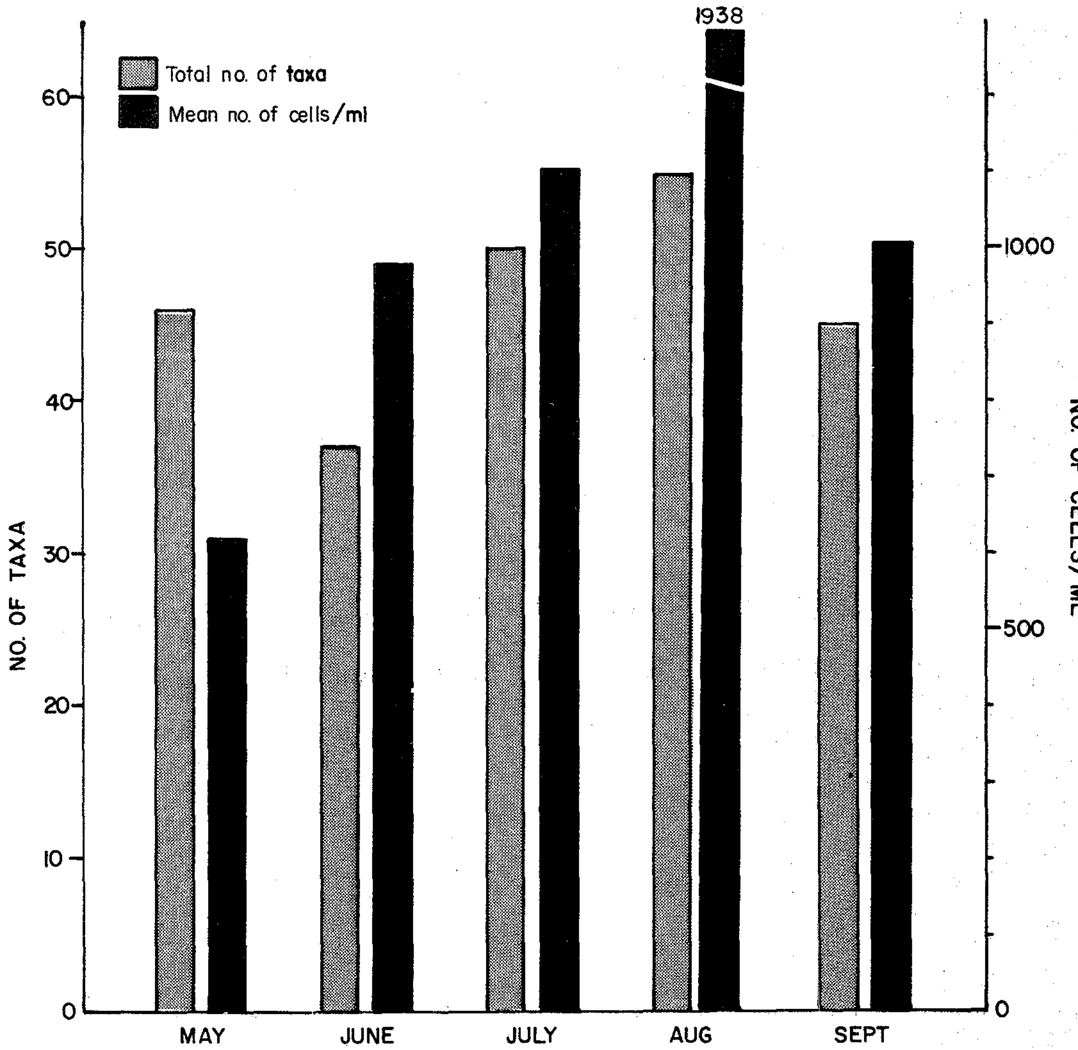

1938
Total no. of taxa
Mean no. of cells/ml
NO. OF TAXA
60
50
40
30
20
10
0
NO. OF CELLS/ML
1000
500
0
MAY
JUNE
JULY
AUG
SEPT

FIGURE 6. Seasonal variation in the percentage composition of the major phytoplankton taxa at the West Interceptor Ditch, May-September, 1977.

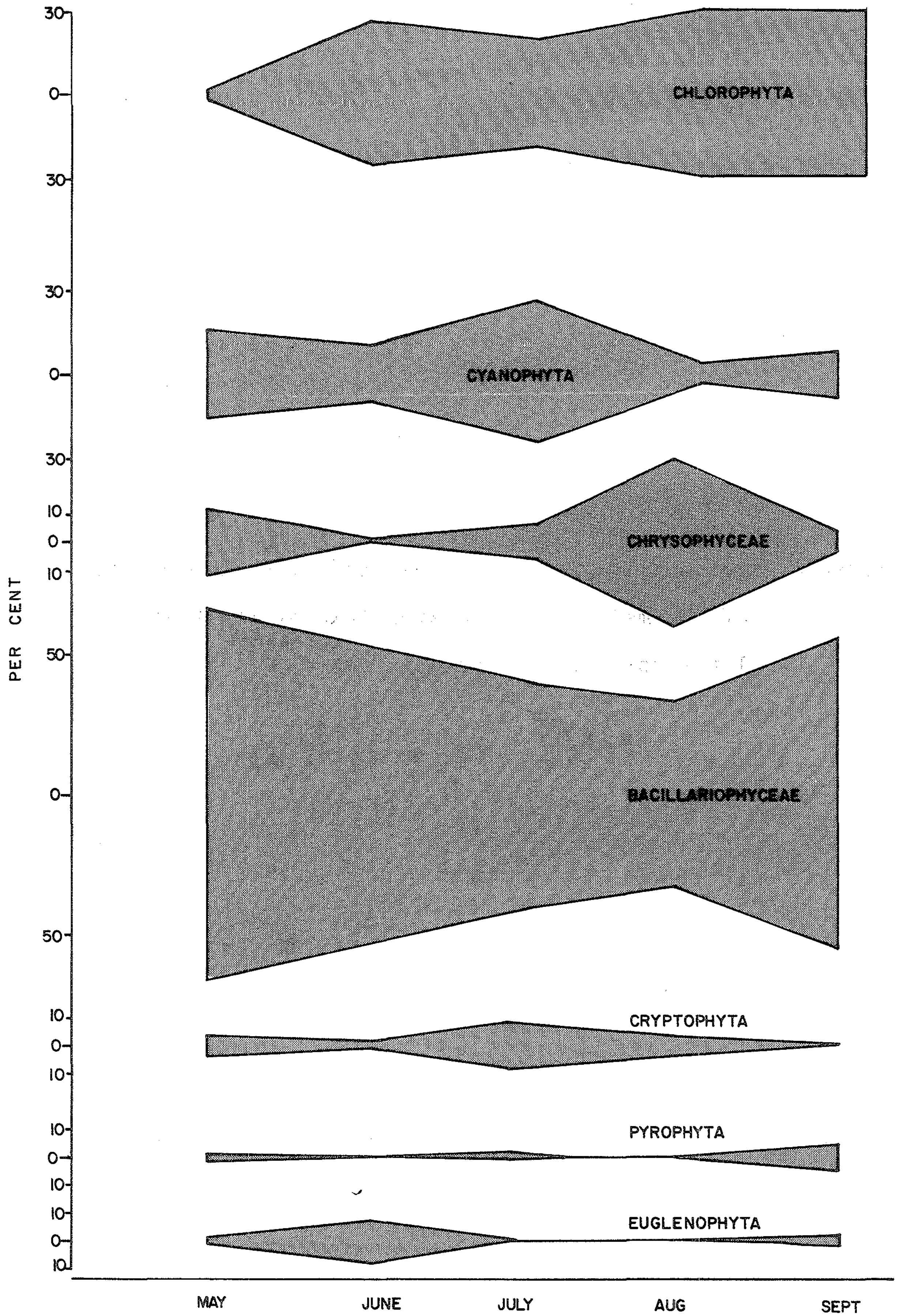

PER CENT
30
0
30
30
0
30
10
0
10
50
0
50
10
0
10
10
0
10
10
0
10
CHLOROPHYTA
CYANOPHYTA
CHRYSOPHYCEAE
BACILLARIOPHYCEAE
CRYPTOPHYTA
PYROPHYTA
EUGLENOPHYTA
MAY
JUNE
JULY
AUG
SEPT

TABLE 9. Benthic macroinvertebrates collected from lower Beaver Creek (Station 1), May-September, 1977.

Taxa	May No./m²	May %	June No./m²	June %	July No./m²	July %	August No./m²	August %	September No./m²	September %
Oligochaeta	433	100.00	50	3.03	450	96.43	550	80.48	650	99.00
Diptera				96.97		3.57		19.52		1.00
Chironomidae										
Chironomidae pupae			17	1.01						
Cladotanytarsus sp.			67	4.04						
Cricotopus sp.			900	54.55			50	7.32		
Orthocladiinae							17	2.44		
Orthocladius sp. A							50	7.32		
Orthocladius sp. B			550	33.33						
Procladius sp.			33	2.02			17	2.44		
Tanytarsus sp.					17	3.57				
Ceratopogonidae										
Bezzia group			17	1.01					17	1.00
Empididae sp.			17	1.01						
Total No. of Taxa	1		8		2		5		2	
Total No. of Organisms/m²	433		1651		467		684		1667	
Shannon-Weaver Species Diversity Index $\bar{d}$			1.66				1.07			
Equitability e			0.67				0.60			
Biomass cc/m²	not measurable		not measurable		1.67		1.67		6.67	

TABLE 10. Benthic macroinvertebrates collected from Station 2 of the West Interceptor Ditch, May-September, 1977.

Taxa	May No./m²	%	June No./m²	%	July No./m²	%	August No./m²	%	September No./m²	%
Oligochaeta	18	12.67	54	3.38	4	0.37	11	0.38		
Nematoda	4	2.82								
Turbellaria							4	0.14		
Hirudinea						1.66		0.14		
Helobdella sp.							4	0.14		
Placobdella					18	1.66				
Amphipoda						0.37		1.01		17.34
Hyalella azteca					4	0.37	29	1.01	400	17.34
Ephemeroptera		2.82		11.01		17.62		41.74		10.98
Baetis sp. A					158	14.58	470	16.39	50	2.17
Baetis sp. B			129	8.07			4	0.14		
Caenis sp.							101	3.52	136	5.90
Callibaetis sp.									17	0.74
Centroptilum sp.							488	17.01	50	2.17
Ephemera sp.							4	0.14		
Heptagenia sp.			22	1.38	22	2.03				
Paraleptophlebia sp.	4	2.82	25	1.56	11	1.01	4	0.14		
Parameletus sp.							122	4.26		
Stenonema sp.							4	0.14		
Trichoptera						2.40		1.64		
Arctopsyche sp.					4	0.37				
Cheumatopsyche sp.					4	0.37	22	0.77		
Glossosomatidae sp.					4	0.37				
Hydropsyche bifida					14	1.29				
Hydropsyche "Genus A" sp.							14	0.49		
Hydroptila sp.							11	0.38		

(Continued)

TABLE 10. Continued.

Taxa	May No./m²	%	June No./m²	%	July No./m²	%	August No./m²	%	September No./m²	%
Hemiptera				0.25		0.37		2.51		0.74
Corixidae sp.			4	0.25	4	0.37	72	2.51	17	0.74
Coleoptera				0.44		0.65		1.01		
Dytiscidae sp.			7	0.44	7	0.65	25	0.87		
Elmidae sp.							4	0.14		
Diptera		45.78		56.66		74.16		49.93		70.94
Chironomidae										
Chironomidae pupae	22	15.49								
Ablabesmyia sp.					118	10.89	43	1.50		
Chironomus sp.			79	4.94	11	1.01	147	5.12		
Cladotanytarsus sp.	14	9.86	36	2.25						
Corynoneura sp.							36	1.25		
Cricotopus sp.			86	5.38			14	0.49		
Glyptotendipes sp.					7	0.65				
Hydrobaenus sp.			7	0.44						
Micropsectra sp.					11	1.01				
Orthocladiinae sp.					7	0.65	4	0.14	167	7.24
Orthocladius sp. A	11	7.75			11	1.01	75	2.61		
Orthocladius sp. B							183	6.38	117	5.08
Polypedilum sp.			7	0.44			83	2.89	67	2.91
Procladius sp.			4	0.25					67	2.91
Psectrocladius sp.					7	0.65	36	1.25	584	25.33
Rheotanytarsus sp.	7	4.93			29	2.67	7	0.24		
Spaniotoma sp.							43	1.50		
Tanytarsus sp.			32	2.00	115	10.61	108	3.76	100	4.34
Thienemanniella sp.							502	17.50		
Thienemannemyia sp.							4	0.14	67	2.91
Ceratopogonidae										
Bezzia group							115	4.01	433	18.79
Culicinae			4	0.25						
Dolichopodidae			4	0.25			11	0.38		

(Continued)

TABLE 10. Continued.

Taxa	May No./m^2	%	June No./m^2	%	July No./m^2	%	August No./m^2	%	September No./m^2	%
Ephydridae										
Ephydra sp.			7	0.44						
Anthomyiidae										
Limnophora sp.			4	0.25						
Psychodidae sp.	4	2.82								
Simuliidae										
Simulium sp.	7	4.93	632	39.52	488	45.01	22	0.77	33	1.43
Tipulidae			4	0.25						
Mollusca		35.91		28.26		2.40		1.50		
Gyraulus sp.	4	2.82	366	22.89	18	1.66	32	1.12		
Lymnaea sp.	47	33.09	29	1.81	4	0.37	7	0.24		
Physa sp.			57	3.56	4	0.37	4	0.14		
Total No. of Taxa	11		22		25		38		15	
Total No. Organisms/m^2	142		1599		1084		2869		2305	
Shannon-Weaver Species Diversity Index $\bar{d}$	2.93		2.86		2.82		3.90		3.20	
Equitability e	1.00		0.45		0.40		0.58		0.87	
Biomass cc/m^2	6.10		15.43		6.82		17.22		21.67	

TABLE 11. Benthic macroinvertebrates collected from Station 3 of the West Interceptor Ditch, May-September, 1977.

Taxa	May No./m²	May %	June No./m²	June %	July No./m²	July %	August No./m²	August %	September No./m²	September %
Oligochaeta									50	1.14
Nematoda					17	2.17				
Hirudinea								0.22		
Helobdella sp.							17	0.22		
Amphipoda								5.14		6.43
Hyalella azteca							400	5.14	283	6.43
Ephemeroptera				0.15				28.05		18.57
Baetis sp. B							17	0.22		
Caenis sp.			17	0.15			2100	26.97	800	18.18
Centroptilum							67	0.86	17	0.39
Odonata								0.22		
Coenagrionidae sp.							17	0.22		
Hemiptera								0.42		0.75
Corixidae sp.							33	0.42	33	0.75
Megaloptera								0.22		
Sialis sp.							17	0.22		
Diptera		100.00		99.85		97.83		59.94		68.56
Chironomidae										
Brillia sp.									233	5.28
Chironomus sp.			4034	35.33			250	3.21	17	0.39
Cladotanytarsus sp.	50	59.52	2350	20.58						
Cryptochironomus sp.					83	10.59	533	6.85	50	1.14
Glyptotendipes sp.							67	0.86		

(Continued)

TABLE 11. Continued.

Taxa	May No./m²	May %	June No./m²	June %	July No./m²	July %	August No./m²	August %	September No./m²	September %
Harnischia sp.			183	1.60			150	1.93		
Monodiamesa sp.							83	1.07		
Orthocladius sp. A	17	20.24	183	1.60						
Orthocladius sp. B									67	1.52
Procladius sp.			2350	20.58			1184	15.21	333	7.57
Psectrocladius sp.			183	1.60	250	31.89			1467	33.33
Rheotanytarsus sp.					167	21.30	683	8.76		
Stictochironomus sp.							83	1.07	67	1.52
Tanytarsus sp.	17	20.24	2067	18.11	117	14.92	450	5.78	17	0.39
Thienemannemyia sp.							83	1.07		
Ceratopogonidae										
Bezzia sp.					17	2.17	1100	14.13	767	17.42
Dolichopodidae			17	0.15	83	10.59				
Simuliidae										
Simulium sp.			17	0.15	50	6.37				
Tipulidae			17	0.15						
Mollusca								5.79		4.55
Gyraulus sp.							217	2.79	117	2.66
Lymnaea sp.							150	1.93	83	1.89
Physa sp.							83	1.07		
Total No. of Taxa	3		11		8		22		16	
Total No. Organisms/m²	84		11418		784		7784		4401	
Shannon-Weaver Species Diversity Index d̄	1.37		2.26		2.59		3.38		2.90	
Equitability e	0.60		0.55		1.00		0.68		0.69	
Biomass cc/m²	not measurable		26.67		1.67		40.00		21.67	

TABLE 12. Benthic macroinvertebrates collected from Station 4 of the West Interceptor Ditch, May-September, 1977.

Taxa	May No./m²	May %	June No./m²	June %	July No./m²	July %	August No./m²	August %	September No./m²	September %
Oligochaeta	417	6.12	133	2.34	17	0.71	240	10.73	267	19.76
Nematoda	17	0.25	33	0.58	33	1.38			17	1.26
Hirudinea		1.48		0.30				0.81		
Helobdella sp.	50	0.74	17	0.30			18	0.81		
Placobdella sp.	50	0.74								
Amphipoda								0.18		
Hyalella azteca							4	0.18		
Ephemeroptera				0.58				22.49		7.40
Baetis sp. A			33	0.58			316	14.13		
Caenis sp.							4	0.18	100	7.40
Centroptilum sp.							183	8.18		
Trichoptera								0.49		
Cheumatopsyche sp.							7	0.31		
Hydropsyche slossonae							4	0.18		
Coleoptera										1.26
Halipus sp.									17	1.26
Diptera		91.41		96.20		97.91		65.30		67.88
Chironomidae										
Ablabesmyia sp.					33	1.38	32	1.43		
Brillia sp.					67	2.79			17	1.26
Chironomus sp.			67	1.18	183	7.62				
Cladotanytarsus sp.	1517	22.31	233	4.10						
Cricotopus sp.			300	5.28			492	21.99		
Cricotopus trifasciatus							32	1.43		
Cryptochironomus sp.			100	1.76	167	6.96	18	0.81		

(Continued)

TABLE 12. Continued.

Taxa	May No./m^2	%	June No./m^2	%	July No./m^2	%	August No./m^2	%	September No./m^2	%
Endochironomus sp.					17	0.71				
Harnischia sp.	83	1.22			467	19.44				
Micropsectra sp.	850	12.50	67	1.18			18	0.81		
Orthocladius sp. A	200	2.94	367	6.46						
Orthocladius sp. B	1400	20.59	533	9.38	50	2.08	18	0.81		
Polypedilum sp.			300	5.28	250	10.41				
Psectrocladius sp.	283	4.16					93	4.16	417	30.87
Rheotanytarsus sp.					50	2.08	165	7.38		
Stictochironomus sp.					100	4.17				
Tanytarsus sp.	1650	24.26	17	0.30	33	1.38	197	8.81	33	2.44
Ceratopogonidae										
Bezzia group	33	0.49			50	2.08	359	16.06	450	33.31
Dolichopodidae			17	0.30						
Simuliidae										
Simulium sp.	200	2.94	3467	60.98	884	36.81	32	1.43		
Tabanidae										
Tabanus sp.							4	0.18		
Mollusca		0.74								2.44
Gyraulus sp.	17	0.25								
Lymnaea sp.	33	0.49							33	2.44
Total No. of Taxa	15		15		15		20		9	
Total No. Organisms/m^2	6800		5684		2401		2236		1351	
Shannon-Weaver Species Diversity Index $\bar{d}$	2.86		2.19		2.92		3.30		2.29	
Equitability e	0.67		0.40		0.73		0.70		0.78	
Biomass cc/m^2	11.67		21.67		8.34		4.31		5.00	

TABLE 13. Benthic macroinvertebrates collected from Station 5 of the West Interceptor Ditch, May-September, 1977.

Taxa	May No./m²	May %	June No./m²	June %	July No./m²	July %	August No./m²	August %	September No./m²	September %
Oligochaeta	167	3.26	83	1.04			50	3.61	50	2.44
Nematoda	1050	20.52	100	1.25	33	0.42			33	1.61
Ephemeroptera						0.21		26.52		54.48
Caenis sp.					17	0.21	367	26.52	1117	54.48
Hemiptera						0.42		1.23		
Corixidae sp.					33	0.42	17	1.23		
Coleoptera				0.41						
Dytiscidae sp.			33	0.41						
Diptera		76.22		97.30		90.84		18.05		32.54
Chironomidae										
Ablabesmyia sp.					167	2.14				
Chironomus sp.			5201	65.16	867	11.12			33	1.61
Cladotanytarsus sp.	767	14.99	383	4.80						
Cricotopus sp.			17	0.21						
Cryptochironomus sp.	133	2.60								
Micropsectra sp.	250	4.88			333	4.27				
Orthocladius sp. A	667	13.03	100	1.25	167	2.14				
Orthocladius sp. B	1267	24.76	17	0.21	117	1.50				
Procladius sp.			633	7.93	583	7.47	50	3.61	100	4.88
Psectrocladius sp.	67	1.31	450	5.64	483	6.19			200	9.75
Rheotanytarsus sp.					617	7.91	33	2.38		
Tanypus sp.					350	4.49				
Tanytarsus sp.	117	2.29	900	11.28	3301	42.33	50	3.61	150	7.32
Ceratopogonidae										
Bezzia group	433	8.46			67	0.86	67	4.84	67	3.27
Dolichopodidae									17	0.83

(Continued)

TABLE 13. Continued.

Taxa	May No./m²	%	June No./m²	%	July No./m²	%	August No./m²	%	September No./m²	%
Psychodidae									17	0.83
Simuliidae									17	0.83
Simulium sp.	167	3.26	33	0.41						
Stratiomyidae									33	1.61
Tabanidae										
Tabanus sp.	33	0.64			33	0.42	50	3.61	33	1.61
Tipulidae			33	0.41						
Mollusca						8.11		50.59		8.93
Lymnaea sp.					633	8.11	700	50.59	183	8.93
Total No. of Taxa	12		13		16		9		14	
Total No./m²	5118		7983		7801		1384		2050	
Shannon-Weaver Species Diversity Index $\bar{d}$	2.97		1.86		2.89		2.11		2.45	
Equitability e	0.92		0.38		0.63		0.67		0.50	
Biomass cc/m²	13.34		38.34		25.00		11.67		18.34	

TABLE 14. Benthic macroinvertebrates collected from Station 6 of Feeder Creek #2, June, 1977.

Taxa	June No./m^2	%
Oligochaeta	111	28.45
Amphipoda		3.67
Hyalella azteca	14	3.67
Odonata		0.92
Somatochlora sp.	4	0.92
Diptera		66.96
Chironomidae		
Cricotopus sp.	43	11.01
Micropsectra sp.	11	2.75
Orthocladius sp. A	47	11.92
Orthocladius sp. B	11	2.75
Psectrocladius sp.	11	2.75
Rheotanytarsus sp.	65	16.51
Tanytarsus sp.	18	4.59
Simuliidae		
Simulium sp.	57	14.68
Total No. of Taxa	11	
Total No. of Organisms/m^2	392	
Shannon-Weaver Species Diversity Index $\bar{d}$	2.94	
Equitability e	1.00	
Biomass cc/m^2	1.44	

TABLE 15. Benthic macroinvertebrates collected from Station 7 of Feeder Creek #3, June, 1977.

Taxa	June No./m^2	%
Oligochaeta	140	11.75
Hirudinea		0.30
Helobdella sp.	4	0.30
Ephemeroptera		2.11
Baetis sp. A	22	1.81
Paraleptophlebia sp.	4	0.30
Odonata		1.20
Lestes sp.	4	0.30
Somatochlora sp.	11	0.90
Trichoptera		3.61
Limnephilus sp.	47	3.61
Diptera		78.62
Chironomidae		
Cricotopus sp.	47	3.61
Orthocladius sp. B	4	0.30
Polypedilum sp.	7	0.60
Rheotanytarsus sp.	18	1.51
Tanytarsus sp.	7	0.60
Ceratopogonidae		
Bezzia group	7	0.60
Simuliidae		
Simulium sp.	850	71.40
Mollusca		2.41
Gyraulus sp.	22	1.81
Physa sp.	4	0.30
Sphaerium sp.	4	0.30
Total No. of Taxa	17	
Total No. of Organisms/m^2	1192	
Shannon-Weaver Species Diversity Index $\bar{d}$	1.70	
Equitability e	0.23	
Biomass cc/m^2	8.61	

found, followed by a rapid development of midge populations in June. The dominant midge genera were *Cricotopus* and *Orthocladius*, which together constituted about 85% of the benthic community in June. The chironomid populations declined rapidly thereafter and the summer (July-August) and fall (September) faunas were again dominated by sludge worms.

Species Diversity

Only 10 benthic macroinvertebrate taxa were found, and species diversity ($\bar{d}$) and equitability (e) were low throughout the study period.

The Shannon-Weaver species diversity indices ($\bar{d}$) ranged from zero in May to 1.66 in June. The low and fluctuating $\bar{d}$ values probably indicate an unstable benthic community at the lower Beaver Creek study site (Station 1).

Standing Crop

Total density of the benthos was lowest in May ($433/m^2$) and highest in June ($1651/m^2$), and volume of biomass ranged from small, unmeasurable amounts in May and June to 6.67 cc/m^2 in September.

Biological Colonization

The rate of benthos colonization of this section of lower Beaver Creek was determined using a method similar to that of Dickson and Cairns (1972). The results are summarized in Table 16.

Initially, in spring and early summer, the colonization rate was high and the extinction rate was low. From mid-summer to fall, however, the colonization and extinction rates fluctuated greatly. This instability was partly caused by the emergence of chironomids with relatively short larval life spans. Also, the relatively homogeneous mud substrate at Station 1 did not offer the habitat diversity necessary to maintain a complex benthic community.

West Interceptor Ditch

Species Composition

A total of 68 benthic macroinvertebrate taxa was found in the West Interceptor Ditch (Tables 10-13). Of these, over 50% were dipterans, about 13% were mayflies (Ephemeroptera), and about 10% were caddisflies (Trichoptera). Considerable differences in species composition and dominance existed between the four sampling stations (Stations 2, 3, 4, and 5) since these stations were initially selected because they represented distinctly different substrate types within the West Interceptor Ditch (Table 1). Station 2 had an artificial stony substrate, whereas Stations 3, 4, and 5 had mud substrates.

TABLE 16. Total number of benthic macroinvertebrate species collected, number of new species, number of recurring species, and number of species eliminated on each sampling day at lower Beaver Creek, May-September, 1977.

Days	Total Number of Species	New Species	Recurring Species	Species Eliminated	Colonization Rate (species/day)	Extinction Rate (species/day)
1 (May)	1	1	0	0	1.0	0
35 (June)	7	6	0	0	0.17	0
64 (July)	2	1	0	6	0.03	0.20
103 (August)	5	2	2	1	0.10	0.02
140 (September)	2	0	1	4	0.02	0.10

Station 4 differed from Station 3 in having a higher percentage composition of gravels. Station 5 can almost be considered as a temporary pool, since most of the time it was shallow, lentic, and barely connected with the rest of the ditch. To compare the difference in species dominance at the four stations, Ulfstrand's method of dominance analysis was used (Ulfstrand, 1968). Based on percentage composition, species (or taxa) were classified with respect to their dominance in the community. Such an analysis is useful in gaining an overall impression of the benthic community composition at a particular station. Five categories of abundance were designated on the basis of percentage compositions:

1) Dominant Taxon (D)--at least 25%;
2) Sub-dominant Taxon (S)--at least 10%, but less than 25%;
3) Common Taxon (C)--at least 1%, but less than 10%;
4) Rare Taxon (R)--at least 0.1%, but less than 1%;
5) Incidental Taxon (I)--less than 0.1%.

To obtain a general impression of the relative dominance of the species collected, dominance indices were calculated by assigning arbitrary numerical values to each of the five categories:

D = 16

S = 8

C = 4

R = 2

I = 1

By adding up the values for each taxon at a particular station for the entire study period, an overall indication of the relative dominance of the taxon could be determined. Based on these values, the benthos at Stations 2-5 were grouped into dominance classes (Tables 17 to 20).

The results indicated that at Station 2 (Table 17) the dominant benthos were the blackflies *Simulium*, the mayfly *Baetis* sp. A, the midges *Psectrocladius* and *Tanytarsus*, and the snails *Gyraulus* and *Lymnaea*. There were more gravel and current associated taxa found at Station 2 (i.e., most of the mayflies and caddisflies). At Station 3 (Table 18) the dominants were mostly substrate-related organisms such as the pond mayfly *Caenis*, the midges *Chironomus*, *Psectrocladius*, and *Tanytarsus*. The carnivorous midge *Procladius* was common in the summer and the biting midge *Bezzia* was more abundant in late summer and fall. The silt and gravel substrate at Station 4 produced an association of dominants very similar to that at Station 3 (Table 19) with the exception that *Simulium*

TABLE 17. Grouping of the benthic macroinvertebrate taxa from Station 2 of the West Interceptor Ditch in dominance classes based on their dominance index values.

Index: 42	24-20	16-10	8-2	
Diptera	Ephemeroptera	Oligochaeta	Nematoda	Coleoptera
Simulium	*Baetis* sp. A	Amphipoda	Turbellaria	Dytiscidae
	Diptera	*Hyalella azteca*	Hirudinea	Elmidae
	Psectrocladius	Ephemeroptera	*Helobdella*	Diptera
	Tanytarsus	*Centroptilum*	*Placobdella*	*Corynoneura*
	Mollusca	*Paraleptophlebia*	Ephemeroptera	*Cricotopus*
	Gyraulus	Diptera	*Baetis* sp. B	*Glyptotendipes*
	Lymnaea	*Ablabesmyia*	*Caenis*	*Hydrobaenus*
		Chironomus	*Callibaetis*	*Micropsectra*
		Cladotanytarsus	*Ephemera*	Orthocladiinae
		Orthocladius A	*Heptagenia*	*Orthocladius* sp. B
		Polypedilum	*Paramaletus*	*Procladius*
		Rheotanytarsus	*Stenonema*	*Spaniotoma*
		Bezzia	Trichoptera	*Thienemanniella*
			Arctopsyche	*Thienemannemyia*
			Cheumatopsyche	Culicinae
			Glossosomatidae	Dolichopodidae
			Hydropsyche bifida	*Ephydra*
			Hydropsyche "Genus A" sp.	*Limnophora*
			Hydroptila	Psychodidae
			Hemiptera	Tipulidae
			Corixidae	Mollusca
				Physa

TABLE 18. Grouping of the benthic macroinvertebrate taxa from Station 3 of the West Interceptor Ditch in dominance classes based on their dominance index values.

Index:

36-30	26-20	16-10	8-2	
Diptera	Ephemeroptera	Diptera	Oligochaeta	Mollusca
Psectrocladius	*Caenis*	*Cryptochironomus*	Nematoda	*Gyraulus*
Tanytarsus	Diptera	*Orthocladius* sp.A	Hirudinea	*Lymnaea*
	Chironomus	*Rheotanytarsus*	*Helobdella*	*Physa*
	Cladotanytarsus	Dolichopodidae	Amphipoda	
	Procladius		*Hyalella azteca*	
	Bezzia		Ephemeroptera	
			Baetis sp. B	
			Centroptilum	
			Odonata	
			Coenagrionidae	
			Hemiptera	
			Corixidae	
			Megaloptera	
			Sialis	
			Diptera	
			Brillia	
			Glyptotendipes	
			Harnischia	
			Monodiamesa	
			Orthocladius sp. B	
			Sfictochironomus	
			Thiennemannemyia	
			Simulium	
			Tipulidae	

TABLE 19. Grouping of the benthic macroinvertebrate taxa from Station 4 of the West Interceptor Ditch in dominance classes based on their dominance index values.

Index:

40-30	26-24	18-10	8-2
Diptera	Oligochaeta	Nematoda	Hirudinea
Tanytarsus	Diptera	Ephemeroptera	*Helobdella*
Bezzia	*Psectrocladius*	*Baetis* sp. A	*Placobdella*
Simulium		Diptera	Amphipoda
		Cladotanytarsus	*Hyalella azteca*
		Cricotopus	Ephemeroptera
		Cryptochironomus	*Caenis*
		Harnischia	*Centroptilum*
		Micropsectra	Trichoptera
		Orthocladius sp. B	*Cheumatopsyche*
		Polypedilum	*Hydropsyche slossonae*
			Coleoptera
			Halipus
			Diptera
			Ablabesmyia
			Brillia
			Chironomus
			Cricotopus trifasciatus
			Endochironomus
			Orthocladius sp. A
			Rheotanytarsus
			Stictochironomus
			Dolichopodidae
			Tabanus
			Mollusca
			Gyraulus
			Lymnaea

TABLE 20. Grouping of the benthic macroinvertebrate taxa from Station 5 of the West Interceptor Ditch in dominance classes based on their dominance index value.

Index:

36-34	28-24	18-12	8-2
Ephemeroptera	Diptera	Oligochaeta	Hemiptera
Caenis	*Chironomus*	Nematoda	Corixidae
Diptera	*Orthocladius* sp. B	Diptera	Coleoptera
Tanytarsus	*Psectrocladius*	*Cladotanytarsus*	Dytiscidae
	Mollusca	*Orthocladius* sp. A	Diptera
	Limnaea	*Procladius*	*Ablabesmyia*
		Bezzia	*Cricotopus*
		Tabanus	*Cryptochironomus*
			Micropsectra
			Rheotanytarsus
			Tanypus
			Dolichopodidae
			Simulium
			Stratiomyidae
			Tipulidae

was more abundant at Station 4. The spring-summer faunas at Station 5 were mainly dominated by midges such as *Chironomus*, *Tanytarsus*, and *Orthocladius*. In late summer to fall, the benthic fauna was dominated by the mayfly *Caenis* and, to a lesser extent, by the midges *Psectrocladius* and *Procladius* (Table 20).

Species Diversity

A total of 55 benthic macroinvertebrate taxa was collected at Station 2, 32 at Station 3, 34 at Station 4, and 26 at Station 5 (Figure 7). Community diversity and evenness ($\bar{d}$ and e) followed a similar trend with Station 2 having the most, and Station 5 the least diversified community (Figure 7). Community diversities at these stations are clearly related to the nature of the substrate. The stability and sheltered crevices offered by the stony substratum at Station 2 were probably the main factors that led to the greater complexity and diversity of the benthic community (Hynes, 1970).

Seasonal variations in taxa and community diversities (Figure 8) indicate that, except for Station 5, August was the month of greatest diversity at all stations, preceded and followed by periods of low diversities in spring and fall.

FIGURE 7. Comparison of the total number of taxa collected (t), mean Shannon-Weaver Species Diversity Index ($\bar{d}$), and mean Equitability (e) for Stations 2-5 at the West Interceptor Ditch.

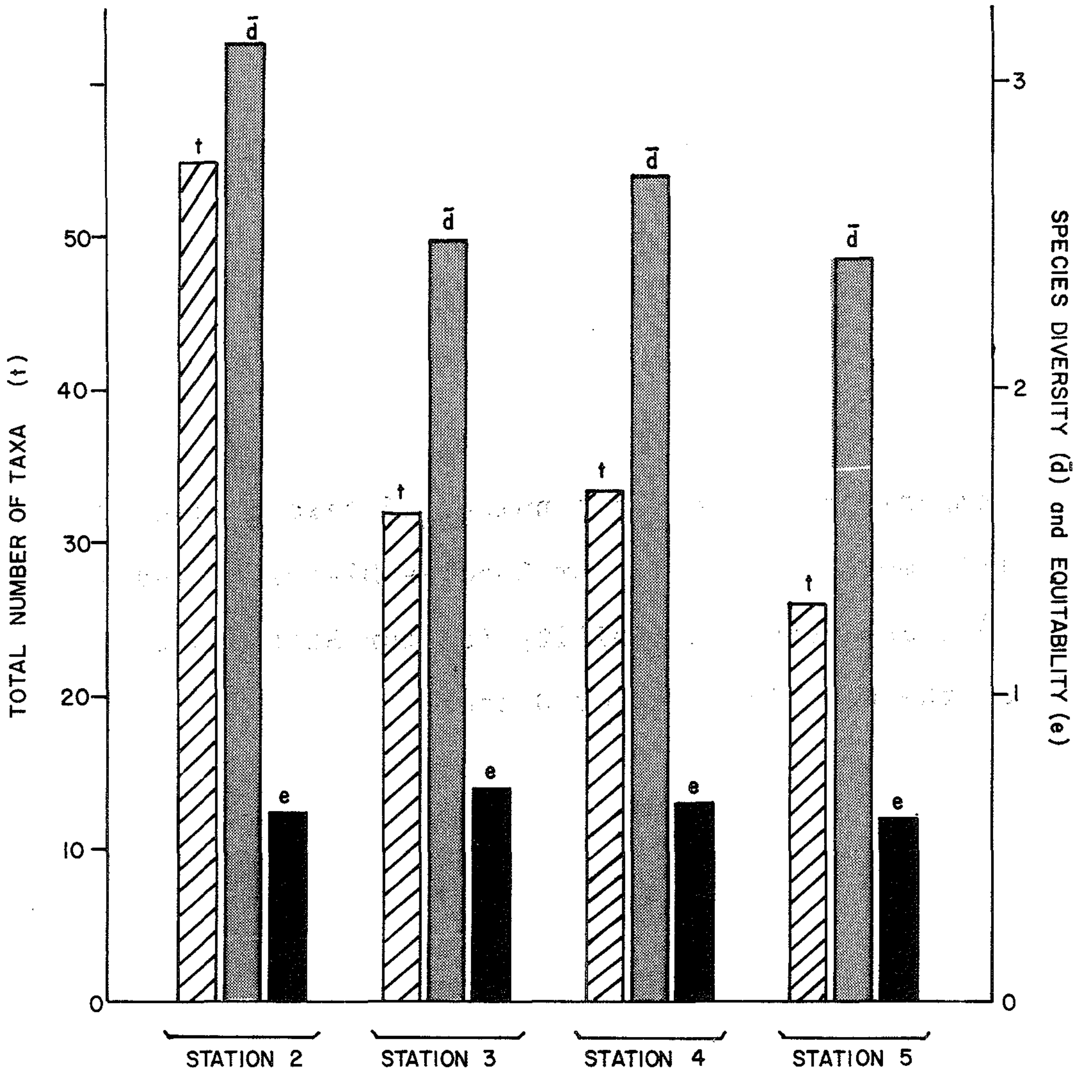
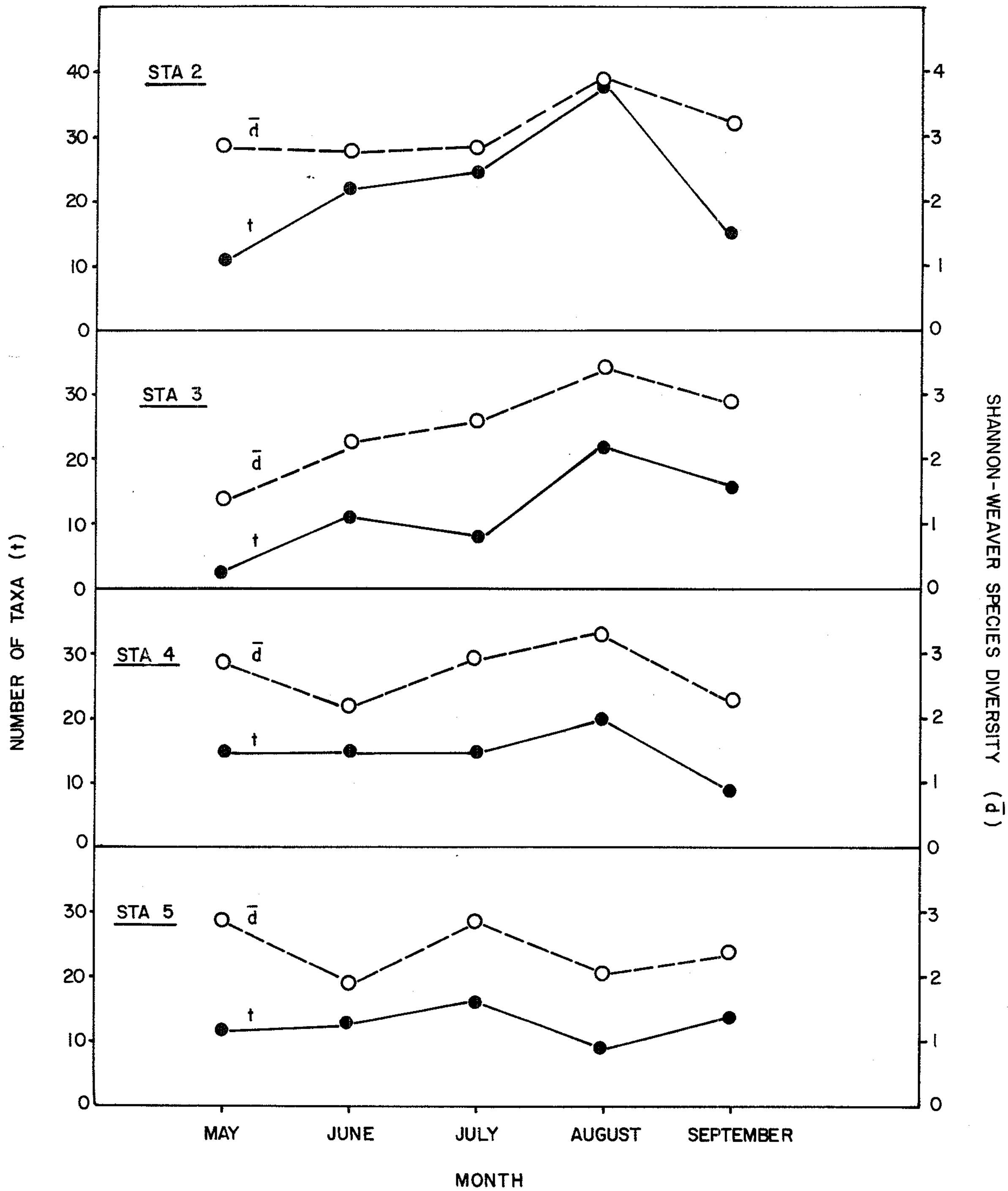

TOTAL NUMBER OF TAXA (t)
SPECIES DIVERSITY (d̄) and EQUITABILITY (e)
STATION 2
STATION 3
STATION 4
STATION 5
t
d̄
e
0
10
20
30
40
50
1
2
3

FIGURE 8. Seasonal variations in the number of benthic macroinvertebrate taxa (t) and the Shannon-Weaver Species Diversity Index ($\bar{d}$) at Stations 2-5 of the West Interceptor Ditch, May-September, 1977.



STA 2
STA 3
STA 4
STA 5
d̄
t
40
30
20
10
0
4
3
2
1
0
NUMBER OF TAXA (t)
SHANNON-WEAVER SPECIES DIVERSITY (d̄)
MAY
JUNE
JULY
AUGUST
SEPTEMBER
MONTH

Standing Crop

Benthos standing crop production at the ditch was measured in terms of both density (number per m^2) and total volume (cc). Table 21 compares benthos standing crop data for the West Interceptor Ditch.

The data indicate that mean density was highest at Station 3 and lowest at Station 2, whereas mean volume was highest at Station 5 and lowest at Station 4. On the whole, production seemed to be higher at the stations with mud and silt substrates (Stations 3, 4, 5) and lower at the station with stony substrate (Station 2). The higher densities and volumes at Stations 3 and 5 were mainly due to the large number of *Chironomus* larvae present in the early summer. It therefore appeared that muddy substrata may be low in taxonomic diversity although not in biomass.

Biological Colonization

One of the objectives of this study was to determine the extent of biological colonization of the West Interceptor Ditch since its completion about one year ago (May, 1976). Most studies of biological colonization indicate that, initially, new habitats are rapidly colonized by new species. At the same time, those species which become established have a low extinction rate (Paterson and Fernando, 1969; Williams and Hynes, 1976). As the new habitat matures, the

TABLE 21. Mean densities and mean volumes of benthic macroinvertebrates collected from Stations 2-5 of the West Interceptor Ditch, May-September, 1977.

Station	Mean Density (No./m^2)	Mean Volume (cc)
2	1599.0 (10.62%)	13.44 (21.34%)
3	4894.2 (32.50%)	18.00 (28.58%)
4	3694.4 (24.53%)	10.19 (16.18%)
5	4867.2 (32.33%)	21.33 (33.87%)

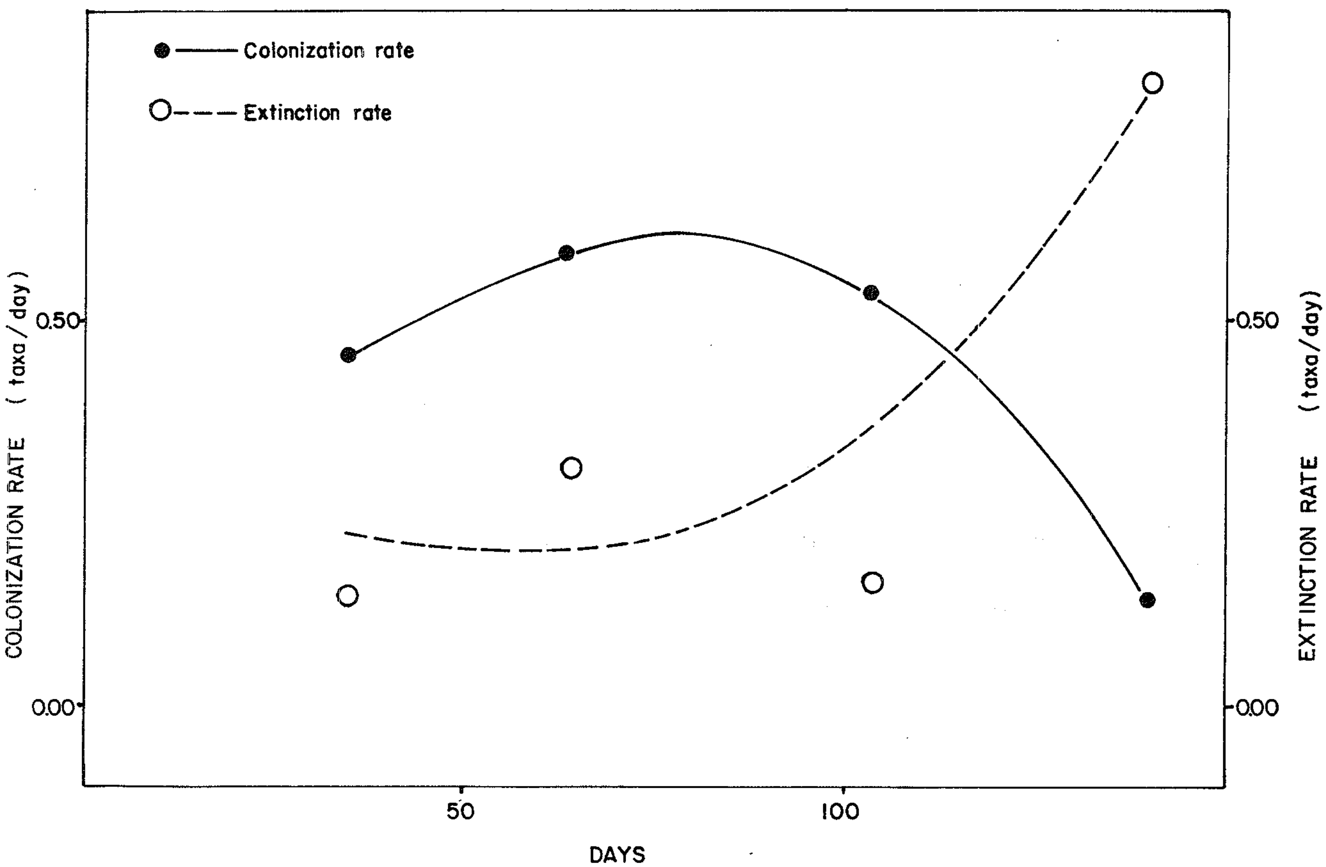
colonization rate decreases and extinction rate increases until an equilibrium is reached (MacArthur and Wilson, 1963). The present study was conducted at least one year after the ditch was constructed, however, and we are therefore not examining the biological colonization of a new and barren habitat. Instead, the results of this study depict the seasonal colonization and succession of benthic invertebrates in a small artificial waterbody. We have, in fact, observed the end result of various selection pressures exerted by the environments of a one-year old channel on its invertebrate inhabitants and colonizers.

Despite the fact that the West Interceptor Ditch is not a new, barren habitat, we have nonetheless determined colonization and extinction rates for benthic macroinvertebrates in a manner similar to that of Dickson and Cairns (1972). The results are summarized in Table 22 and Figure 9. The results indicate that the rate of colonization increased from spring to summer and decreased rapidly at the onset of fall. Conversely, extinction rate was low initially and increased rapidly in the fall. Most of the benthos in the ditch are univoltine and have a fast life cycle (Hynes, 1970) and this probably accounted for the observed pattern of colonization and extinction. Theoretically, the benthic community at the West Interceptor Ditch reached a dynamic equilibrium in late summer or early fall when its rates of

TABLE 22. Total number of benthic macroinvertebrate species collected, number of new species, number of recurring species, and number of species eliminated on each sampling day at the West Interceptor Ditch, May-September, 1977.

Days	Total Number of Species	New Species	Recurring Species	Species Eliminated	Colonization Rate (species/day)	Extinction Rate (species/day)
1 (May)	20	-	-	-	-	-
35 (June)	31	16	0	5	0.46	0.14
64 (July)	39	13	4	9	0.59	0.31
103 (August)	50	17	4	10	0.54	0.26
140 (September)	25	3	2	30	0.14	0.81

FIGURE 9. Colonization and extinction rates (taxa/day) of the benthic macroinvertebrates at the West Interceptor Ditch (Stations 2-5), May-September, 1977.



Colonization rate
Extinction rate
COLONIZATION RATE (taxa / day)
EXTINCTION RATE (taxa/day)
0.50
0.00
0.50
0.00
50
100
DAYS

colonization and extinction were equal.

Feeder Creeks

Benthic data for the two feeder creeks are summarized in Tables 14 and 15.

Species Composition

Twenty-one benthic macroinvertebrate taxa were collected in June. Both streams were dominated by dipterans, oligochaetes, and several other benthic taxa that are characteristic of slow brownwater streams, e.g., *Paraleptophlebia*, *Lestes*, and *Limnephilus*. Feeder Creek #2 had a higher percentage composition of oligochaetes than Feeder Creek #3, and the dominant dipteran species were *Rheotanytarsus* and *Simulium*. The benthic community at Feeder Creek #3 was dominated by *Simulium* (71%) and oligochaetes (11%).

Species Diversity

The mean species diversity index ($\bar{d}$) and equitability (e) at the feeder creeks were 2.32 (1.70-2.94) and 0.61 (0.23-1.00), respectively. In comparison, for the same period (June), mean species diversity index ($\bar{d}$) and equitability (e) at the West Interceptor Ditch were 2.29 (1.86-2.86), and 0.44 (0.38-0.55), respectively. This suggests that, for the month of June, the feeder creeks and the ditch were highly comparable in terms of their benthic community diversities and stabilities.

Standing Crop

The data suggest that, for the month of June, benthos production in the feeder creeks was lower than that of the West Interceptor Ditch. Mean density and mean volume of the benthos in the feeder creeks were $792/m^2$ (392-1192) and 5.02 cc/m^2 (1.44-8.61), respectively. In comparison, mean density of the benthos in the ditch was $6671/m^2$ (1599-11418) and mean volume was 25.52 cc/m^2 (15.43-38.43).

Potential Colonizers

Invertebrates from the feeder creeks are potential colonizers of the ditch. Except for two benthic taxa (*Somatochlora* and *Limnephilus*), all benthos found in the feeder creeks were also collected from the ditch. It can be anticipated that, as the habitats of the ditch mature, the benthic communities of the feeder creeks and the ditch will become more alike (Williams and Hynes, 1976).

Invertebrate Drift

An invertebrate drift study was performed on August 21-22, 1977, at Station 7 in order to determine the significance of the feeder creeks as suppliers of invertebrate colonizers to the West Interceptor Ditch. Results of the study are summarized in Tables 23 and 24.

During the drift study, the temperature of water at a nearby area (Station 4) was 14 C and oxygen concentration was about 10.4 mg/1. The channel at Station 7 was so narrow that the entire flow of the stream filtered through the drift net. Discharge was 0.004 m^3/sec.

Drift Composition

A total of 3201 invertebrates was collected in six one-hour drift samples over a period of 23.5 hours. Table 23 describes the total number of organisms collected and their percentage contribution to the drift fauna.

The results indicate that the drift fauna was mainly composed of planktonic copepods (43%) and ostracods (44%). The only benthic invertebrate taxa that occurred in any significant amounts were chironomids (6%), simulids (3%), and baetid mayfly nymphs (1%). In his study of the invertebrate drift from an intermittent muskeg stream,

TABLE 23. Total number of invertebrates collected from Station 7 and their percentage contributions to the drift composition, August 21-22, 1977.

Taxa	No. Collected	Per Cent
Oligochaeta	1	0.03
Nematoda	1	0.03
Hirudinea	1	0.03
Crustacea		
Copepoda	1401	43.76
Ostracoda	1415	44.20
Cladocera	13	0.40
Amphipoda	8	0.24
Ephemeroptera	29	0.90
Trichoptera	2	0.06
Hemiptera	12	0.37
Coleoptera	4	0.12
Diptera		
Chironomidae	199	6.21
Simuliidae	110	3.43
Hydracarina	4	0.12
Mollusca	1	0.03
TOTAL	3201	

TABLE 24. Total drift rates (numbers per hour) and drift densities (number per cubic metre) for the drifting invertebrates at Feeder Creek #3 (Station 7), August 21-22, 1977.

	Sample No. 1 August 21 1130-1230		Sample No. 2 August 21 1600-1700		Sample No. 3 August 21 2100-2200 (dusk)	
Time (MDT): Taxa	Rate	Density	Rate	Density	Rate	Density
Oligochaeta	-	-	-	-	1	0.06
Nematoda	-	-	-	-	-	-
Hirudinea	-	-	-	-	-	-
Crustacea						
Copepoda	3	0.2	1	0.06	169	11.73
Ostracoda	2	0.13	-	-	251	17.43
Cladocera	-	-	-	-	-	-
Amphipoda	-	-	-	-	2	0.13
Ephemeroptera	15	1.04	1	0.06	3	0.2
Trichoptera	-	-	-	-	-	-
Hemiptera	-	-	2	0.13	4	0.27
Coleoptera	-	-	1	0.06	1	0.06
Diptera						
Chironomidae	76	5.27	12	0.83	31	2.15
Simuliidae	95	6.59	6	0.41	4	0.27
Hydracarina	1	0.06	1	0.06	2	0.13
Mollusca	-	-	-	-	-	-
TOTALS	192	13.33	24	1.66	468	32.5

(Continued)

TABLE 24. Continued.

Time (MDT):	Sample No. 4 August 22 0100-0200		Sample No. 5 August 22 0500-0600 (dawn)		Sample No. 6 August 22 0900-1000	
Taxa	Rate	Density	Rate	Density	Rate	Density
Oligochaeta	-	-	-	-	-	-
Nematoda	-	-	-	-	1	0.06
Hirudinea	1	0.06	-	-	-	-
Crustacea						
Copepoda	1213	84.23	13	0.90	2	0.13
Ostracoda	1152	80.0	10	0.69	-	-
Cladocera	13	0.9	-	-	-	-
Amphipoda	5	0.34	1	0.06	-	-
Ephemeroptera	9	0.62	1	0.06	-	-
Trichoptera	1	0.06	1	0.06	-	-
Hemiptera	5	0.34	1	0.06	-	-
Coleoptera	2	0.13	-	-	-	-
Diptera						
Chironomidae	61	4.23	13	0.90	6	0.41
Simuliidae	2	0.13	1	0.06	2	0.13
Hydracarina	-	-	-	-	-	-
Mollusca	-	-	1	0.06	-	-
TOTALS	2464	171.11	42	2.91	11	0.76

Clifford (1972) also found that the drifting animals were a mixture of benthic and planktonic species, with the latter predominating (about 80%).

Drift Rate and Density

The mean drift rate (number of organisms/hour) during a single diel period (August 21-22) was 533.5 organisms/hour ranging from 11 organisms/hour to 2464 organisms/hour. Mean drift rate for night time (991.33 organisms/hour) was considerably higher than that for daytime sample periods (75.66 organisms/hour). In contrast, Clifford (1972) found that, for August, the daytime drift rate (162 organisms/20 min) was higher than nighttime (66 organisms/20 min).

At Station 7, the diel changes in drift densities (number of organisms/m^3) have a pattern similar to that of drift rates. Mean drift density during a diel period was 37.04 organisms/m^3, with a mean nighttime density of 68.84 organisms/m^3 and a mean daytime density of 5.02 organisms/m^3.

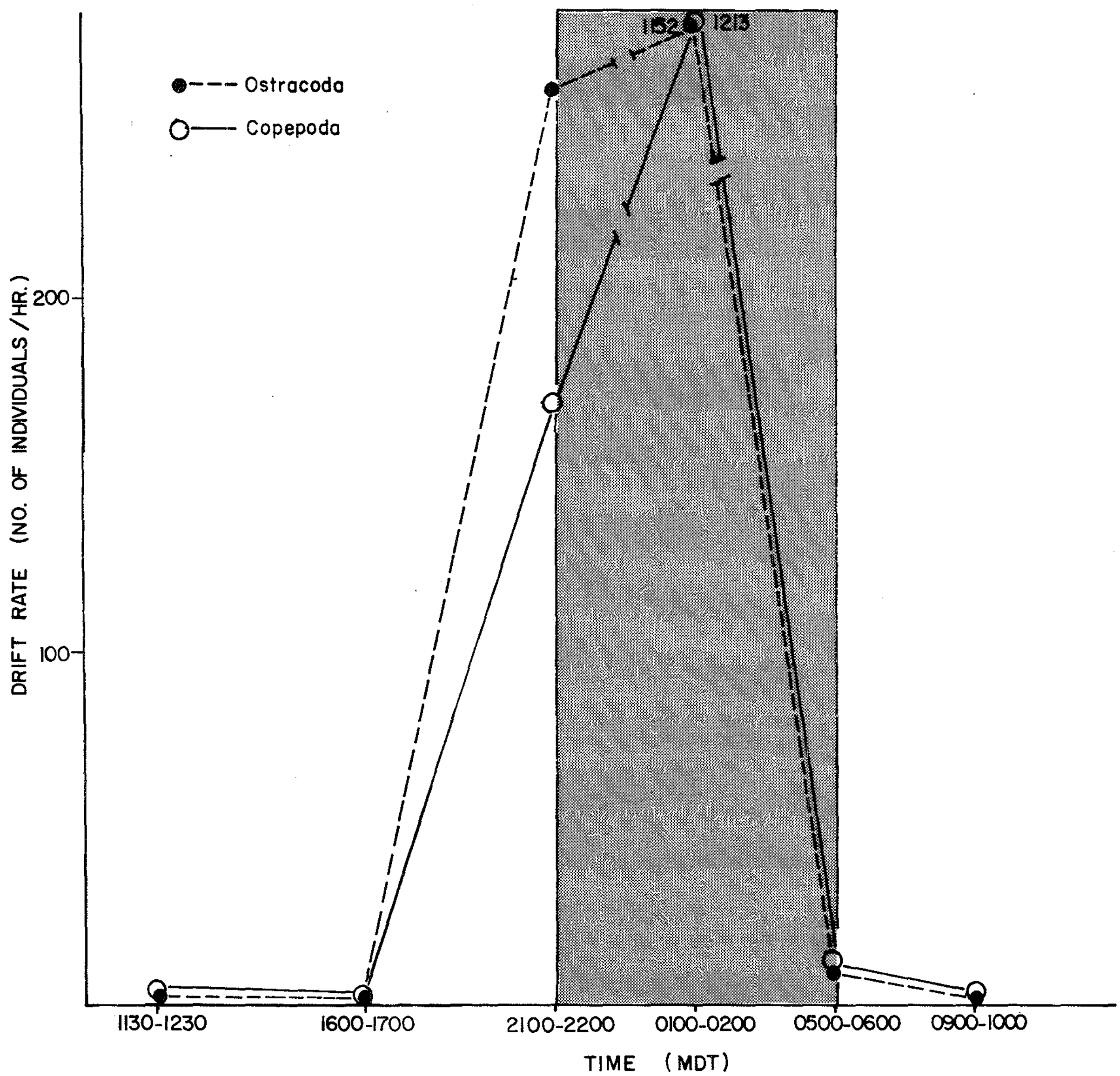
Drift Patterns of Certain Taxa

In general, the numerically dominant crustaceans such as the copepods and ostracods have higher drift rates at night than during the day (Figure 10). The diurnal drift pattern for the *Baetis* mayfly nymphs consisted of one peak during the day and a lesser one at night (Figure 11). Most studies, however, indicate that *Baetis* are night-active (Tanaka, 1960; Waters, 1962; Müller, 1963; Pearson and Franklin, 1968).

The chironomid larvae also appeared to have two peaks in their diurnal drift rates (Figure 12). A qualitative analysis of the drift samples indicated that *Orthocladius* spp. and *Thienemanniella* sp. were the dominant forms in both peaks. A study by Pearson and Franklin (1968) found that the numbers of drifting simulid larvae increased dramatically after sunset and that illumination accounted for a significant amount of variability in drift rates of simulid larvae. In this study, we found that the drift rates of simulid larvae were highest in the daytime and in fact decreased at night (Figure 12). These results concur with those of Clifford (1972).

It is evident from this study that the feeder creeks contribute a significant amount of potential colonizers to the ditch. The successful establishment of such colonizers will, however, be dependent on a) environmental conditions in the ditch, e.g., food, substrate (Fernando, 1958, 1959, 1963); and b) on their somatic plasticities and inter-specific competitive abilities (Lewontin, 1964).

FIGURE 10. Fluctuations in drift rates of Copepoda and Ostracoda during a 24 hour period at Station 7, Feeder Creek #3.



Ostracoda
Copepoda
1152
1213
DRIFT RATE (NO. OF INDIVIDUALS / HR.)
200
100
1130-1230
1600-1700
2100-2200
0100-0200
0500-0600
0900-1000
TIME (MDT)

FIGURE 11. Fluctuations in drift rate of *Baetis* sp. during a 24 hour period at Station 7, Feeder Creek #3.

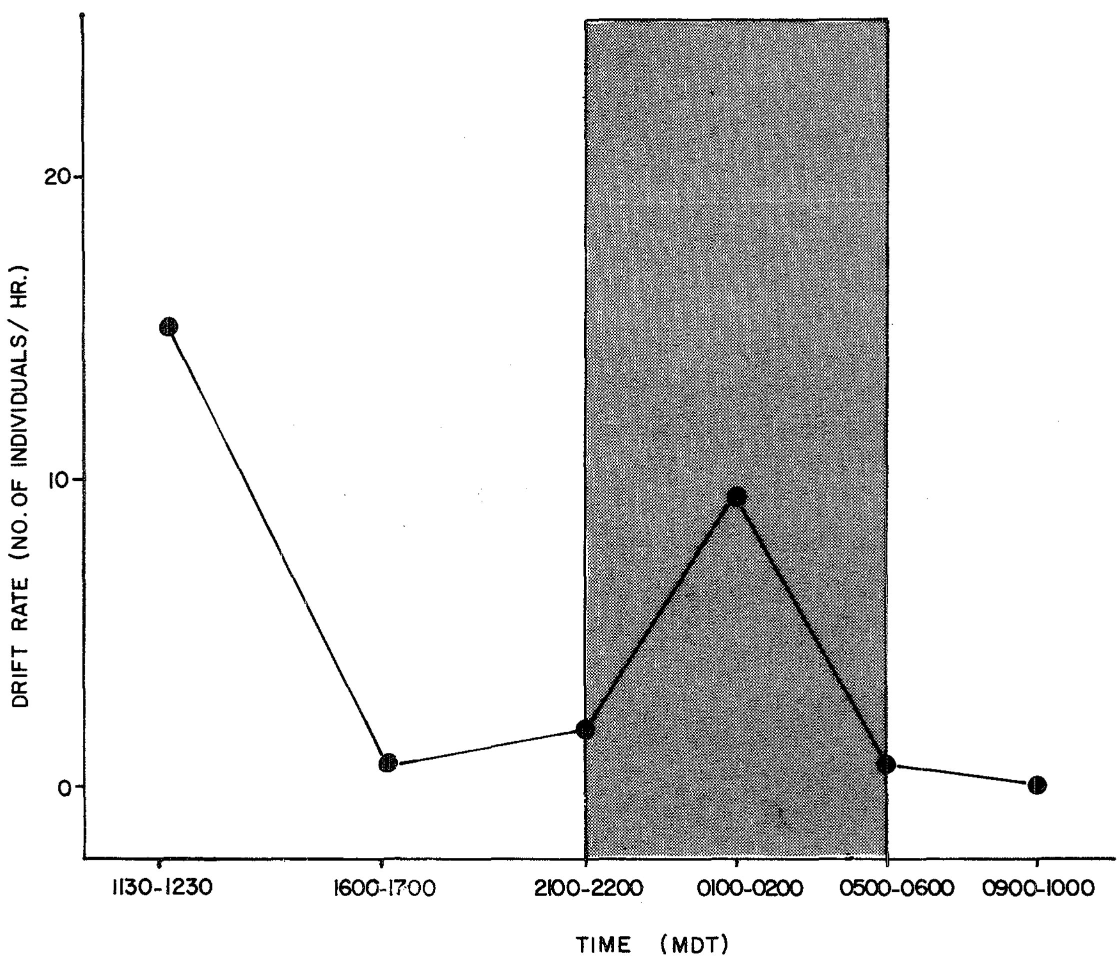
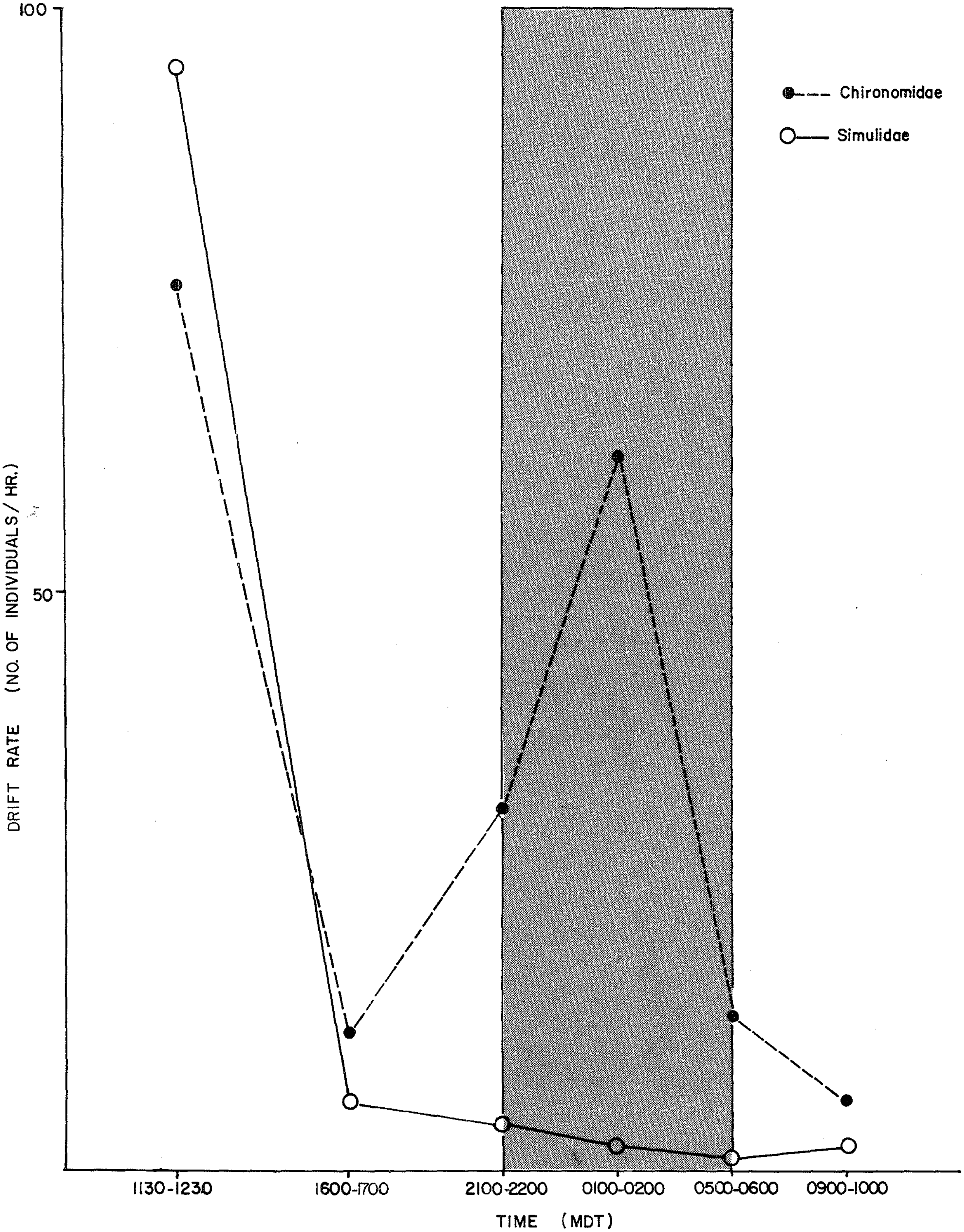

20
10
0
DRIFT RATE (NO. OF INDIVIDUALS/ HR.)
1130-1230
1600-1700
2100-2200
0100-0200
0500-0600
0900-1000
TIME (MDT)

FIGURE 12. Fluctuations in drift rates of Chironomidae and Simuliidae during a 24 hour period at Station 7, Feeder Creek #3.


100
50
DRIFT RATE (NO. OF INDIVIDUALS / HR.)
Chironomidae
Simulidae
1130-1230
1600-1700
2100-2200
0100-0200
0500-0600
0900-1000
TIME (MDT)

Aquatic Macrophytes

Species Composition

Data describing the identity and distribution of aquatic macrophytes in the West Interceptor Ditch, August 21, 1977, are summarized in Table 25. The sampling points or sections referred to in Table 25 are shown in Figure 13. In total, 19 species were identified of which 7 were either dominant within extensive stream segments or were locally dominant at the mouths of feeder creeks or erosion gullies. These included *Bidens cernua*, *Callitriche palustris*, *Caltha natans*, *Myriophyllum exalbescens*, *Potamogeton gramineus*, *Sparganium angustifolium*, and *Typha latifolia*. Three species (*B. cernua*, *Sium sauve*, *Sparganium* sp.) were a common feature of the bottom cover, occurring at almost every station, but were rarely dominant. Together with *Typha latifolia* as the dominant species, they were the principal components of the West Interceptor Ditch plant community. The remaining 10 species (*Caltha palustris*, *Carex* sp., *Impatiens capensis*, *Lemna minor*, *Polygonum coccineum*, *Potamogeton pectinatus*, *P. pusillus*, *Ranunculus circinatus* var. *subrigidus*, *R. gmelinii* var. *hookeri*, *Scirpus* sp.) were rare and restricted to isolated localities along the ditch.

Coverage

The average per cent coverage of macrophytes at various localities along the West Interceptor Ditch is illustrated

TABLE 25. Species composition, distribution, and per cent cover of aquatic macrophytes at sampling points along the West Interceptor Ditch, August 21, 1977. Sampling points along the ditch are as indicated in Figure 1.

Species	Sampling Points Distance (km)	1-2 0.5	2-3 0.4	3-4 0.4	4-5 0.1	5-6 0.4	6-7 0.3	7* 0.01
Bidens cernua L.			5				T**	T
Callitriche palustris L.								3
Caltha natans Pall.		T	2					10
C. palustris L.			5					
Carex sp.								
Impatiens capensis Meerb.								
Lemna minor L.								T
Myriophyllum exalbescens Fern.								
Polygonum coccineum Muhl.								
Potamogeton gramineus L.								
P. pectinatus L.								
P. pusillus L.								
Ranunculus circinatus Sibth. var. *subrigidus* (W. Drew) L. Benson								
R. gmelinii D.C. var. *hookeri* (D. Don) L. Benson								2
Scirpus sp.								
Sium sauve Walt.								
Sparganium angustifolium Michx.								
Sparganium sp.		T		T	2		T	
Typha latifolia L.		10	3	80	3	90	3	T
No. Species		3	4	2	2	1	3	5
% Coverage		10	15	80	5	90	5	20

* perennial stream or erosion gulley
**T=trace coverage

(Continued)

TABLE 25. Continued.

Species	Sampling Points Distance (km)	7-8 0.2	8* 0.01	8-9 0.2	9* 0.01	9-10 0.4	10* 0.01	10-11 2.0
Bidens cernua L.		T	2	T	T	T	T	T
Callitriche palustris L.		T	20	T	15	T	25	T
Caltha natans Pall.			5		2		5	T
C. palustris L.							T	
Carex sp.							5	
Impatiens capensis Meerb.								
Lemna minor L.					T		T	
Myriophyllum exalbescens Fern.								
Polygonum coccineum Muhl.								
Potamogeton gramineus L.								
P. pectinatus L.								
P. pusillus L.								
Ranunculus circinatus Sibth. var. *subrigidus* (W. Drew) L. Benson							T	T
R. gmelinii D.C. var. *hookeri* (D. Don) L. Benson			5		T		5	T
Scirpus sp.					T			
Sium sauve Walt.		T		T	T	T	T	T
Sparganium angustifolium Michx.							5	
Sparganium sp.		T		T		T	2	2
Typha latifolia L.		5	3	3	3	3	5	3
No. Species		5	5	5	8	5	12	8
% Coverage		5	35	3	20	3	52	5

* perennial stream or erosion gulley
**T=trace coverage

(Continued)

TABLE 25. Continued.

Species	Sampling Points Distance (km)	11-12 0.4	12* 0.01	12-13 1.3	13* 0.01	13-14 0.8	14* 0.01	14-15 0.5
Bidens cernua L.		T	T	T		T	2	
Callitriche palustris L.		T	3	5		5	3	T
Caltha natans Pall.		T	5	T		T	3	
C. palustris L.			T					
Carex sp.								
Impatiens capensis Meerb.								
Lemna minor L.							T	
Myriophyllum exalbescens Fern.			T	3		3	10	15
Polygonum coccineum Muhl.			T					
Potamogeton gramineus L.					T		5	
P. pectinatus L.							T	2
P. pusillus L.							2	3
Ranunculus circinatus Sibth. var. *subrigidus* (W. Drew) L. Benson						2	T	
R. gmelinii D.C. var. *hookeri* (D. Don) L. Benson		T						
Scirpus sp.							T	
Sium sauve Walt.		T	T				T	
Sparganium angustifolium Michx.			10				10	
Sparganium sp.			2	T		T	5	
Typha latifolia L.		T	5	2	20	2	20	T
No. Species		6	10	6	2	7	14	5
% Coverage		<1	25	10	20	12	60	20

* perennial stream or erosion gulley
**T=trace coverage

(Continued)

TABLE 25. Continued.

Species	Sampling Points Distance (km)	15-16 0.5	16* 0.01	16-17 1.8	17* 0.01	17-18 1.1	18-19 0.2	19-20 1.1
Bidens cernua L.					T		5	T
Callitriche palustris L.		T			T			
Caltha natans Pall.								
C. palustris L.								
Carex sp.								
Impatiens capensis Meerb.							T	T
Lemna minor L.								
Myriophyllum exalbescens Fern.		T						
Polygonum coccineum Muhl.								
Potamogeton gramineus L.			8	T				
P. pectinatus L.		T	2		2	T		T
P. pusillus L.								
Ranunculus circinatus Sibth. var. *subrigidus* (W. Drew) L. Benson								
R. gmelinii D.C. var. *hookeri* (D. Don) L. Benson								
Scirpus sp.								
Sium sauve Walt.							T	T
Sparganium angustifolium Michx.								
Sparganium sp.			T	T		T		
Typha latifolia L.		T	T	T	5	T	15	2
No. Species		4	4	3	4	3	4	5
% Coverage		<1	10	<1	7	<1	20	2

* perennial stream or erosion gulley
**T=trace coverage

in Figure 14. Also indicated are the dominant species in the main part of the ditch as well as at the mouths of feeder creeks. Coverage varied from zero to 90% at various sampling sites. Average per cent cover for the ditch was 10.6%. Areas of greatest coverage were within two kilometres of the origin (south end) of the ditch and within the influence of tributary streams. The reasons for this distribution are not clear but colonization from feeder creeks where populations of aquatic macrophytes are already established may be important. A comparison of taxonomic diversity (Table 26) indicates that while 18 species occurred at sampling sites near the mouths of streams, only 9 were identified in areas removed from the streams.

Differences in age of various localities of the ditch may also be significant. Since the ditch was constructed over a year period (May 1975 to May 1976), macrophyte communities in some areas of the ditch such as the south end may be a year older than the others.

While it is apparent that natural colonization has occurred in favourable areas, nearly 90% of the ditch remains uncovered. Colonization will undoubtedly continue but it is difficult to predict what the eventual state of colonization will be. Examination at yearly intervals is recommended in order to assess whether any improvements

FIGURE 13. Sampling areas for the aquatic macrophyte survey, August 21, 1977. Species identification and estimation of coverage were determined between numbered points except where these points corresponded to the mouths of streams or gullies formed by erosion.

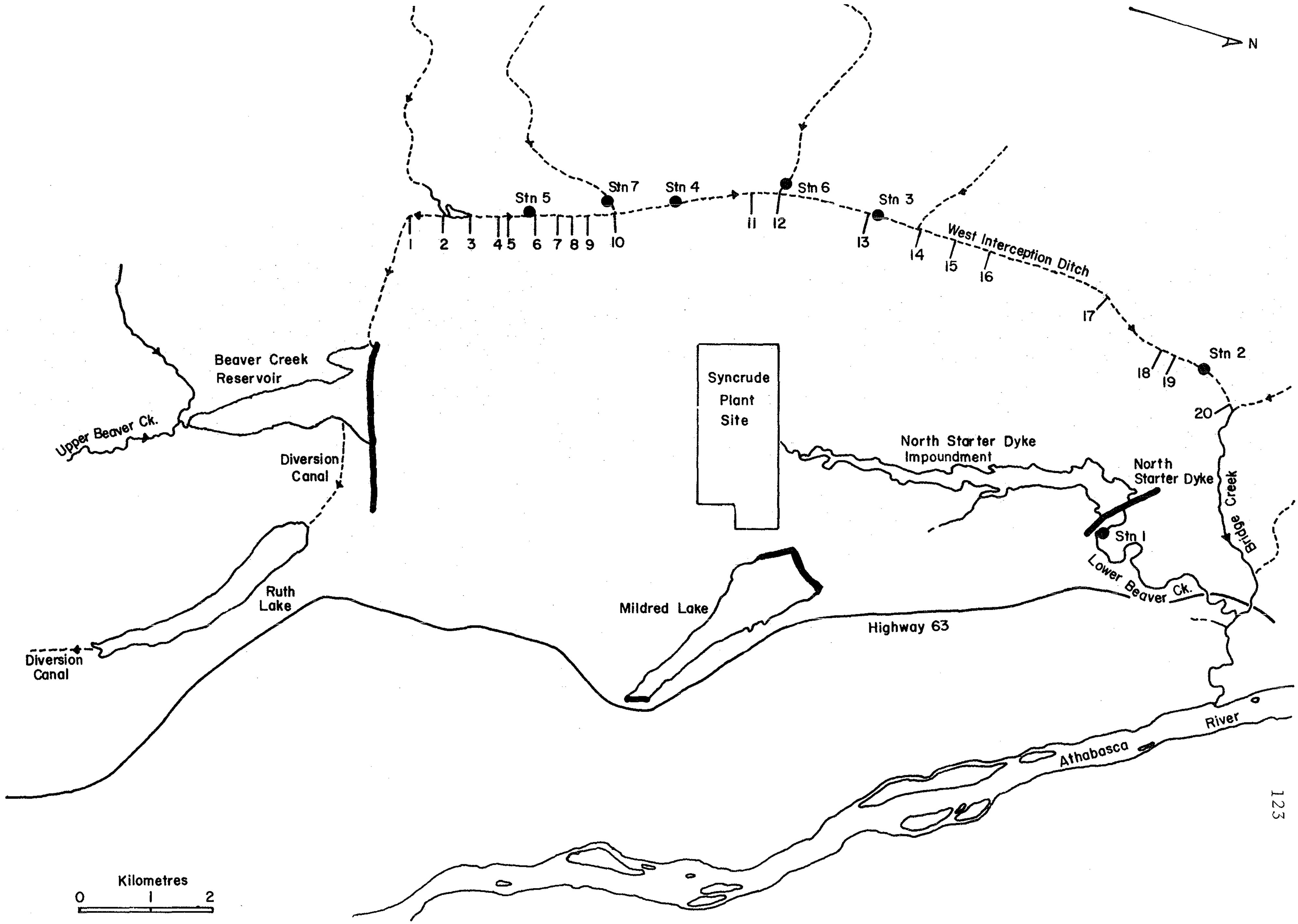
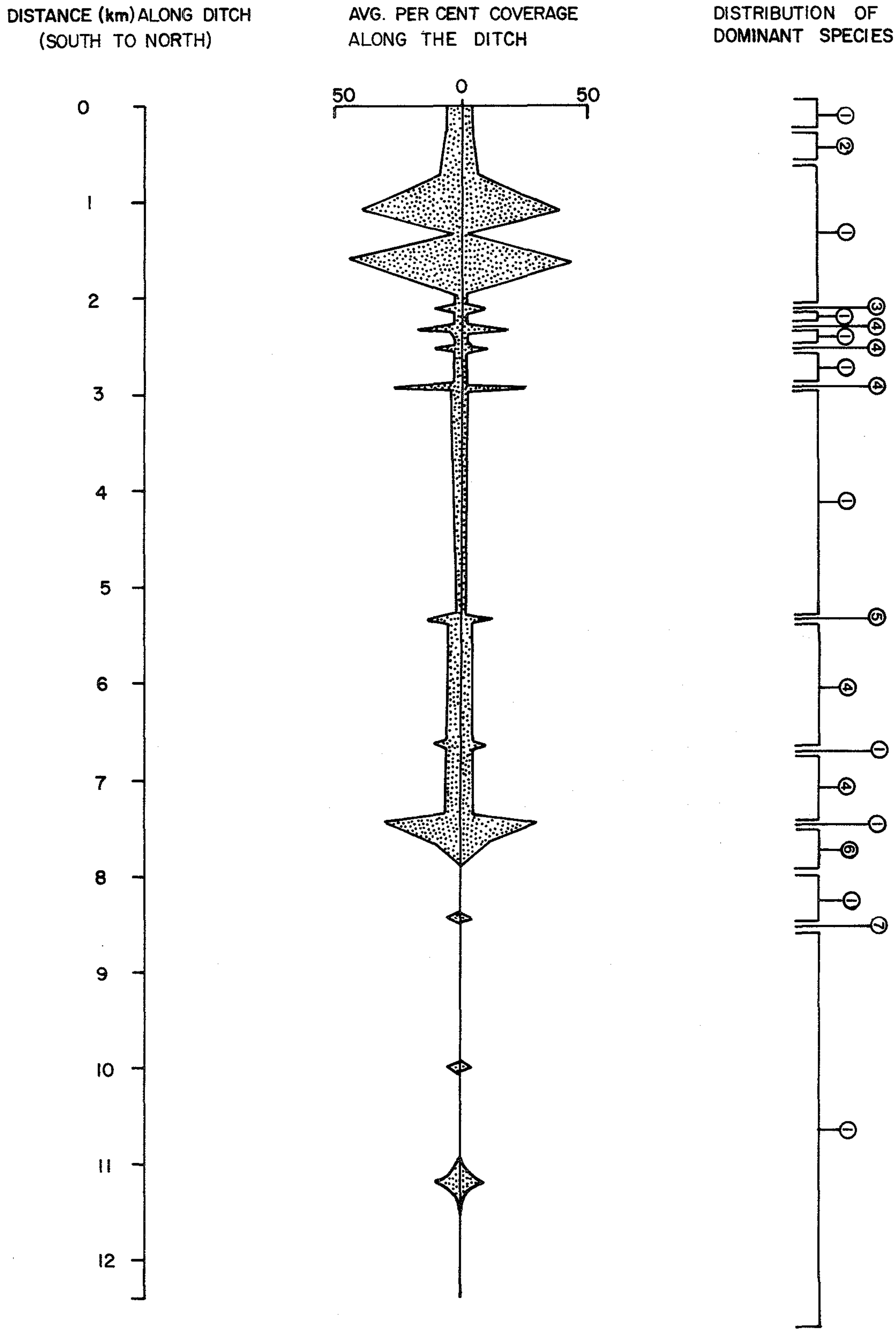

N
Stn 5
Stn 7
Stn 4
Stn 6
Stn 3
Stn 2
Stn 1
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
West Interception Ditch
Beaver Creek Reservoir
Upper Beaver Ck.
Diversion Canal
Syncrude Plant Site
North Starter Dyke Impoundment
North Starter Dyke
Bridge Creek
Lower Beaver Ck.
Ruth Lake
Mildred Lake
Highway 63
Diversion Canal
Athabasca River
Kilometres
0
1
2

FIGURE 14. Per cent substrate coverage and distribution of dominant macrophytes on the West Interceptor Ditch, August, 1977. Dominant species are as follows: 1: *Typha latifolia;* 2: *Bidens cernua;* 3: *Caltha natans;* 4: *Callitriche palustris;* 5: *Sparganium angustifolium;* 6: *Myriophyllum exalbescens;* 7: *Potamogeton gramineus.*



DISTANCE (km) ALONG DITCH (SOUTH TO NORTH)
AVG. PER CENT COVERAGE ALONG THE DITCH
DISTRIBUTION OF DOMINANT SPECIES
50
0
50
0
1
2
3
4
5
6
7
8
9
10
11
12

TABLE 26. Average per cent coverage by species of aquatic macrophytes in the entire West Interceptor Ditch, the Ditch excluding those macrophytes at the mouths of the streams and gullies, and at the mouths of streams only. T=trace coverage.

Species	Ditch Including Stream Mouths	Ditch Excluding Stream Mouths	Stream Mouths Only
Bidens cernua L.	0.2	0.2	0.4
Callitriche palustris L.	0.9		7.7
Caltha natans Pall.	0.1		3.3
C. palustris L.	0.2		T
Carex sp.	T		0.5
Impatiens capensis Meerb.	T	T	
Lemna minor L.	T		T
Myriophyllum exalbescens Fern.	1.1	1.0	1.1
Polygonum coccineum Muhl.	T		T
Potamogeton gramineus L.	T		1.4
P. pectinatus L.	0.1	0.1	0.4
P. pusillus L.	0.1	0.1	0.2
Ranunculus circinatus Sibth. var. *subrigidus* (W. Drew) L. Benson	0.1	0.1	T
R. gmelinii D.C. var. *hookeri* (D. Don) L. Benson	0.1		1.3
Scirpus sp.	T		T
Sium sauve Walt.	T	T	T
Sparganium angustifolium Michx.	T		2.8
Sparganium sp.	0.3	0.3	1.0
Typha latifolia L.	7.5	7.3	6.2
Total	10.6	9.1	26.3

such as bank stabilization resulting from artificial revegetation have had any beneficial effects.

Fish

Data describing the distribution and relative abundance of fish species captured in both Beaver Creek (Station 1) and at various locations in the West Interceptor Ditch (Stations 2-5) and its tributaries (Stations 6 and 7) are presented in Table 27. No fish were captured during the June sampling on Beaver Creek. However, longnose suckers had been observed spawning in May in the vicinity of the sampling station. Fry of this species had certainly emerged by the June sampling date. A possible explanation for their absence is the rapid downstream movement of recently emerged fry which is characteristic of this species (Geen *et al.*, 1966). The large catches in September (550/100 m) are probably the result of a reinvasion of the sampling area by young-of-the-year longnose suckers accompanied by white sucker fry, lake chub, and brook stickleback, a total of four species.

Only two species were taken in the West Interceptor Ditch and its tributaries, the brook stickleback and the fathead minnow. As in Beaver Creek, there was a seasonal disparity in catches. Only 5.0 fish/100 m were captured,

TABLE 27. Distribution and relative abundance of fish sampled in the West Interceptor Ditch and Beaver Creek, 1977. Catch per unit effort is catch per metre of stream x 100. Locations of sample sites are indicated in Figure 1 .

Station	Date	Method	Effort (m)	Lake Chub	Fathead Minnows	Longnose Sucker Fry	White Sucker Fry	Brook Stickleback	Total
1	June	S	20						0
	Sept	ES	20	250		550	350	50	1200
2	June	ES	40						0
	Sept	ES	35		66			26	92
3	June	S	50						0
	Sept	ES	75		3			25	28
4	June	S	50						0
	Sept	ES	60					8	8
5	June	S	50						0
	Sept	ES	50		74			6	80
6	June	ES	30		17			10	27
	Sept	ES	20					135	135
7	June	ES	20		5			15	20
	Sept	ES	20		95			125	220

S=minnow seines; ES=electroshocker.

all of them at tributary Stations 6 and 7, in June, but 60.4/100 m were captured in September. The latter included fish taken at both stations on feeder creeks (6 and 7) and at each of the four stations on the ditch itself (2-5). The fish taken in the Ditch in September may have moved either upstream from Bridge Creek or downstream from various tributaries to the Ditch. The latter seems the most likely possibility as the two species are common cohabitants of small drainages in the area.

Length frequencies for fathead minnows and brook sticklebacks from the West Interceptor Ditch are presented in Figure 15. The length range of the sample of fathead minnows (20 to 79 mm fork length) exceeds that of the brook stickleback (26 to 63 mm); however, the mean length of the latter (46.8, N=72) exceeds that of the former (38.3, N=87).

Growth data for the fathead minnow, based on scale readings, are presented in Table 28. These data are preliminary only, as it appeared that the majority of individuals did not form scales above their lateral line during their first year. A definitive description of growth must await larger samples. A few fathead minnows matured as early as their second summer (at age 1). The five age 3 fish were all males in distinctive breeding colouration. This, combined with the presence of young-of-the-year fathead minnows at Station 2, suggests that

FIGURE 15. Length-frequency of sticklebacks *(Culaea inconstans)* and fathead minnows *(Pimephales promelas)* from the West Interceptor Ditch, 1977.

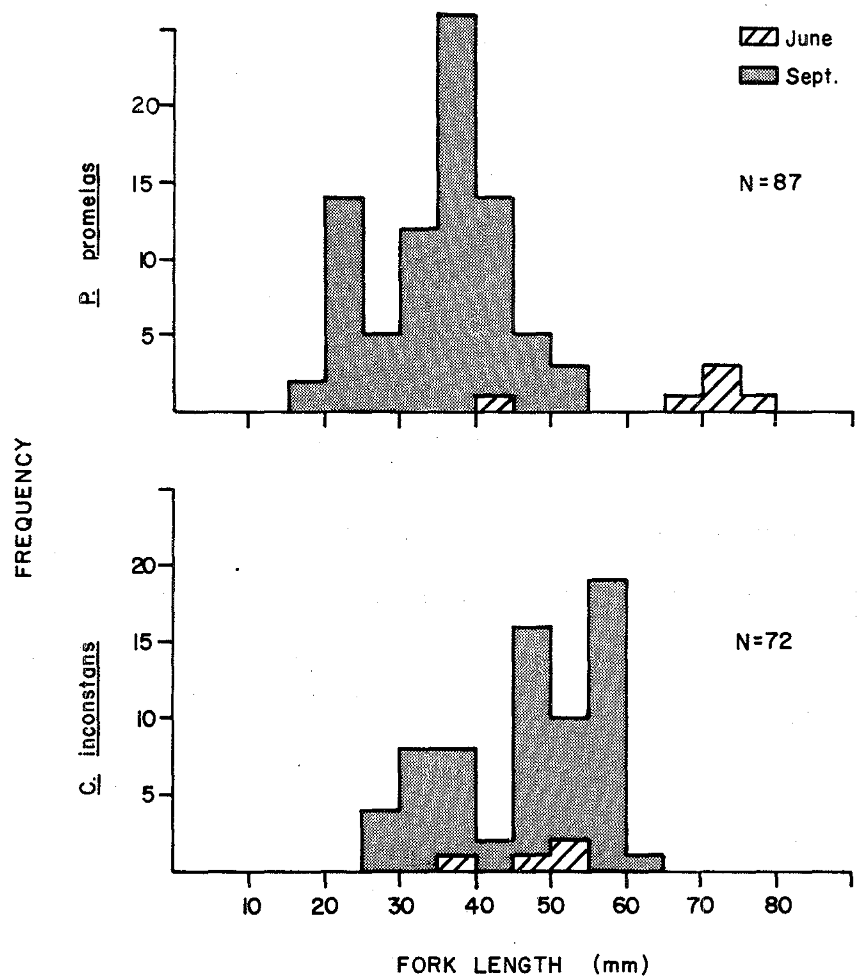

June
Sept.
N=87
P. promelas
FREQUENCY
C. inconstans
N=72
20
15
10
5
10 20 30 40 50 60 70 80
FORK LENGTH (mm)

TABLE 28. Observed age-length relationships and maturity for fathead minnows *(Pimephales promelas)* in the West Interceptor Ditch, 1977.

Age	N	Sampling Date	Fork Length (mm) $\bar{x}$	S.D.	Range	Per cent Mature
0 (scales absent)	18	Sept 27	23.9	2.2	20-27	0
1 (scales present)	10	Sept 27	38.8	5.4	35-53	30
2	1	June 14	44	-	-	-
3	5	June 14	73.4	4.4	67-79	100

some spawning occurred in the West Interceptor Ditch.

All the brook stickleback examined in detail (N=30, fork length range 26-63 mm) were mature.

Waterfowl and Shorebirds

The numbers of waterfowl and shorebird species encountered along the West Interceptor Ditch were recorded during each field trip. The results are summarized in Table 29.

A total of seven species of ducks was observed on or in the vicinity of the Ditch. Counts include some waterfowl flushed from the shallow ponds east of Station 4 and from the pond on Feeder Creek #2. The majority of ducks observed during these trips were males.

On June 14 a female mallard with 11 ducklings was seen near Station 6 retreating up Feeder Creek #2. On the same date a female green-winged teal with a brood of 8 was observed feeding near Station 3. These two sightings were the only evidence of the utilization of the ditch for rearing purposes.

Four species of shorebirds were observed in the vicinity of the ditch. No young were sighted. No explanation can

TABLE 29. Waterfowl and shorebird sightings along the West Interceptor Ditch from May to September, 1977. Numbers in brackets are ducklings.

Common Name	Scientific Name	May	June	July	August	September
Mallard	*Anas platyrhynchos*	4	8 (11)	-	16	-
Pintail	*Anas acuta*	2	1	-	8	-
Widgeon (Baldpate)	*Mareca americana*	-	1	-	-	-
Shoveller	*Spatula clypeata*	3	5	-	-	-
Green-winged teal	*Anas carolinensis*	-	4 (8)	-	1	-
Blue-winged teal	*Anas discors*	8	7	-	11	-
Bufflehead	*Bucephala albeola*	-	6	-	4	4
Spotted sandpiper	*Actitis macularia*	-	1	-	-	-
Solitary sandpiper	*Tringa solitaria*	-	3	-	-	-
Lesser yellowlegs	*Totanus flavipes*	2	3	-	13	-
Killdeer	*Charadrius vociferus*	6	-	-	6	-

be offered for the absence of both waterfowl and shorebirds on July 13.

Amphibians

Use of the West Interceptor Ditch by amphibians was restricted to breeding and the rearing of tadpoles. Tadpoles of the Dakota toad *(Bufo hemiophrys)* were abundant in June at Stations 4 and 5 as well as at the mouths of intervening tributary streams. Only two adult amphibians, a Dakota toad *(B. hemiophrys)* and a wood frog *(Rana sylvatica)* were collected during the course of the summer. Chorus frogs *(Pseudacris triseriata)* were present in adjacent ponds and marshy areas but were never observed in the ditch.

SUMMARY

1. Construction of the West Interceptor Ditch and lower Beaver Creek was completed in May, 1976, as part of Syncrude's plan to divert stream flow and surface runoff from their mine site. The present study was initiated in May, 1977, and completed in September, 1977. The objectives were to determine the environmental conditions and extent of biological colonization at the West Interceptor Ditch and a section of lower Beaver Creek.

2. The West Interceptor Ditch is a shallow, mud-bottomed channel with little flow in the summer. Peak discharge was recorded in June at Station 2, decreasing upstream. Revegetation of the banks was complete by August, 1977.

3. The West Interceptor Ditch water was slightly alkaline ($\bar{x}$ pH=7.5), with a mean alkalinity of 161.3 mg $CaCO_3$/l, a mean hardness of 172 mg $CaCO_3$/l, and a mean conductivity of 486.9 μmho/cm at 25 C.

4. Areas along the West Interceptor Ditch were fertilized with ammonium nitrate and phosphate. However, this treatment does not seem to have increased the macronutrient content of the water.

5. Lower Beaver Creek water was slightly basic with a mean pH value of 7.4, and relatively high in alkalinity ($\bar{x}$=193.7 mg $CaCO_3$/l), conductivity ($\bar{x}$=577 μmhos/cm at 25 C), and hardness ($\bar{x}$=236 mg $CaCO_3$/l).

6. Lower Beaver Creek had a MPN index of 10 per 100 ml for total coliform organisms and zero for faecal coliforms in May, 1977.

7. The zooplankton community of the ditch was dominated by copepods (>70%) during early spring followed by a general decline throughout the summer. Rotifers made up a minor part of the zooplankter community in spring but gradually replaced the copepods and became the numerically dominant group. Cladocera formed only a small portion of the zooplankton throughout the study period.

8. A total of 120 algal species was found in the Ditch, with diatoms being the most common with 56 species.

9. Sludge worms (Oligochaeta) and midges (Chironomidae) were the dominant benthos found at Lower Beaver Creek (Station 1). The relatively homogeneous mud substrate did not offer the habitat diversity necessary to maintain a complex and stable benthic community.

10. A total of 68 benthic macroinvertebrate taxa was found in the West Interceptor Ditch. Of these, over 50% were dipterans, about 13% were mayflies (Ephemeroptera), and about 10% were caddisflies (Trichoptera). Station 2, with the stony substrate, had the highest taxonomic diversity for benthos. However, the mud substrates at other stations, e.g., Stations 3 and 5, supported a higher standing crop of benthos.

11. The mean benthos colonization rate at the West Interceptor Ditch was 0.43 species/day and the mean extinction rate was 0.38 species/day. Colonization rates increased from spring to summer and decreased rapidly in fall. Conversely, extinction rate was slow initially but increased rapidly in fall.

12. A total of 21 benthic macroinvertebrate taxa was found in Feeder Creeks #2 and #3. Both streams were dominated by dipterans and oligochaetes.

13. Feeder Creek #3 had a mean benthic drift rate of 533.5 organisms/hour and a mean drift density of 37.04 organisms/m^3. The drift fauna was mainly composed of planktonic copepods (43%) and ostracods (44%).

14. A total of 19 species of aquatic macrophytes

was identified from the West Interceptor Ditch, August, 1977. Of these, *Typha latifolia* was the dominant species and, with *Bidens cernua, Sium sauve,* and *Sparganium* sp. formed the most common plant association. Total average per cent coverage was 10.6%, ranging from zero to 90%.

15. Both fathead minnows and brook sticklebacks inhabited the West Interceptor Ditch during the summer with some evidence of spawning by fathead minnows.

16. Use of the West Interceptor Ditch by amphibians and waterfowl was limited.

17. In lower Beaver Creek, peak flows were recorded in July and September but were negligible at other times. Sand shifting over the substrate at peak flows probably had a detrimental effect on the benthic fauna.

18. In addition to spawning by longnose suckers, lower Beaver Creek was used as a rearing and summer feeding ground by longnose sucker fry, white sucker fry, lake chub, and brook stickleback.

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