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WATER QUALITY CONSIDERATIONS OF INVERTEBRATE DRIFT IN THE NORTH SASKATCHEWAN RIVER AT EDMONTON

by

Robert Gray Ruggles

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE

STUDIES AND RESEARCH IN PARTIAL

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submitted by R.G. Ruggles

in partial fulfilment of the requirements for the degree of M.Sc. Environmental Science

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Date April 7, 1980

DEDICATION

This thesis is dedicated to my wife, Mary Rose, and my children, Lindsay and Shelley, for their patience and understanding during the course of the study.

ABSTRACT

Invertebrate drift was sampled in the North Saskatchewan River upstream and downstream of the City of Edmonton, Alberta on several occasions between October, 1975 and October, 1976. Wastewater discharges to the river had a measureable effect on the density and composition of the drift downstream of Edmonton. Upstream of the city, the drift fauna was dominated by "clean" water taxa, diel variation in total drift densities with night-time maxima were common and total drift densities were similar between midstream and near-shore locations. Downstream of Edmonton, drift densities were higher and the fauna dominated by organisms characteristic of a river environment affected by organic (nutrient) wastewater loading. Diel variations in total drift densities were not evident. Drift densities were significantly higher (p 0.01) near the south shore compared to the north shore because of incomplete lateral mixing of effluents at the downstream station. Flume experiments showed the drift sampler met the design criteria for isokinetic sampling of suspended particulates and thus insured quantitative sampling of drift. The sampling method was suitable for most river conditions throughout the year. The feasibility of sampling drift for routine environmental monitoring programs in rivers such as the North Saskatchewan was demonstrated.

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1.0 INTRODUCTION

In recent years water pollution has come to be recognized as part of the larger problem of water resources management. This is certainly the case in many of the southern prairie watersheds of western Canada where the growth of industry and population is placing an ever-increasing demand on this finite resource. The assessment of water pollution is essentially a biological problem because its primary effect is on living organisms; but it also requires a knowledge of the physical and chemical characteristics of the receiving water since standards for water quality are usually based on non-biological criteria.

In 1975, the Edmonton regional office of the Environmental Protection Service initiated a program to evaluate pollution in major prairie river basins (Hatfield, 1975). The project was designed to locate existing or potential water pollution problems in each basin, identify probable point sources of pollution causing the problem and to define the effects of such pollution sources on the biological community. This basin-oriented approach had not been attempted on western Canadian rivers. The North Saskatchewan River was selected as the first river basin for study. Several sampling stations were established along the entire river length, usually upstream and downstream from known pollution sources. At each station it was proposed to collect water samples for comprehensive chemical and bacteriological analysis, sediments for contaminant analysis, fish and aquatic invertebrates.

Early in the program, it was realized that standard techniques for collecting benthic invertebrates (e.g. Ekman and Ponar dredges, Surber sampler, hand nets, etc.) would not be suitable at all stations because of the rocky nature of the river bottom, relatively high current velocities and excessive depths. Therefore, a decision was made to sample invertebrates drifting in the water column, knowing that this sampling method could probably be applied at all stations and that the organisms collected would likely be representative of the benthic invertebrate fauna. The use of invertebrate drift was unique because it had not been applied to any previous surveys of this type.

The results of the benthic invertebrate component of the river basin program were important to the overall assessment of the study results. However, the method was new and required evaluation, so a detailed investigation of invertebrate drift in the North Saskatchewan River near Edmonton was undertaken in the Fall of 1975. This investigation is the subject of the study reported in this thesis. The specific objectives of the study were to:

a) investigate the effects of urban wastewater discharges from the City of Edmonton on the drifting invertebrate fauna of the North Saskatchewan River;

b) determine if sampling drift is a suitable method for collecting aquatic invertebrates in large rivers such as the North Saskatchewan for the purpose of environmental monitoring; and

c) determine if the sampler design is acceptable for collecting quantifiable samples of invertebrate drift.

2.0 DRIFT AND THE STREAM ENVIRONMENT

2.1 Aquatic Invertebrates and the Stream Ecosystem

Figure 1 (Hynes, 1970a) is a schematic representation of a river ecosystem in the rhithron zone. This zone is defined as that portion of a stream where monthly mean temperatures do not exceed 20^{0}C; the current velocity is high and flow is turbulent; dissolved oxygen concentrations are always high; the substrate is composed of rocks, stones or gravel with occasional sand or silty patches; the fauna is more or less cold stenothermic and characteristic of running water; and there is little or no true plankton. The North Saskatchewan River in the vicinity of Edmonton more or less fits into this classification.

In the rhithron, the main energy source is allochthonous material, with light playing a secondary role. Metabolic products released to the system tend to move downstream with little opportunity for local recycling. Any cycling which does occur is continually displaced in a downstream direction. Invertebrate drift is one of the components in Hynes' model which moves downstream.

From Figure 1 it can be seen that the benthic macroinvertebrates (insects and crustaceans) make up a large proportion of the biomass in such an ecosystem. The role of these organisms in terms of the structure and function of the ecosystem, as summarized by Cummins (1975), "is the conversion of reduced carbon compounds derived primarily from the surrounding land (allochthanous material), supplemented by in-stream carbon fixation (autochthanous material), into temporary storage in their own tissues and into carbon dioxide". Cummins (1973) has classified macroinvertebrates into four functional

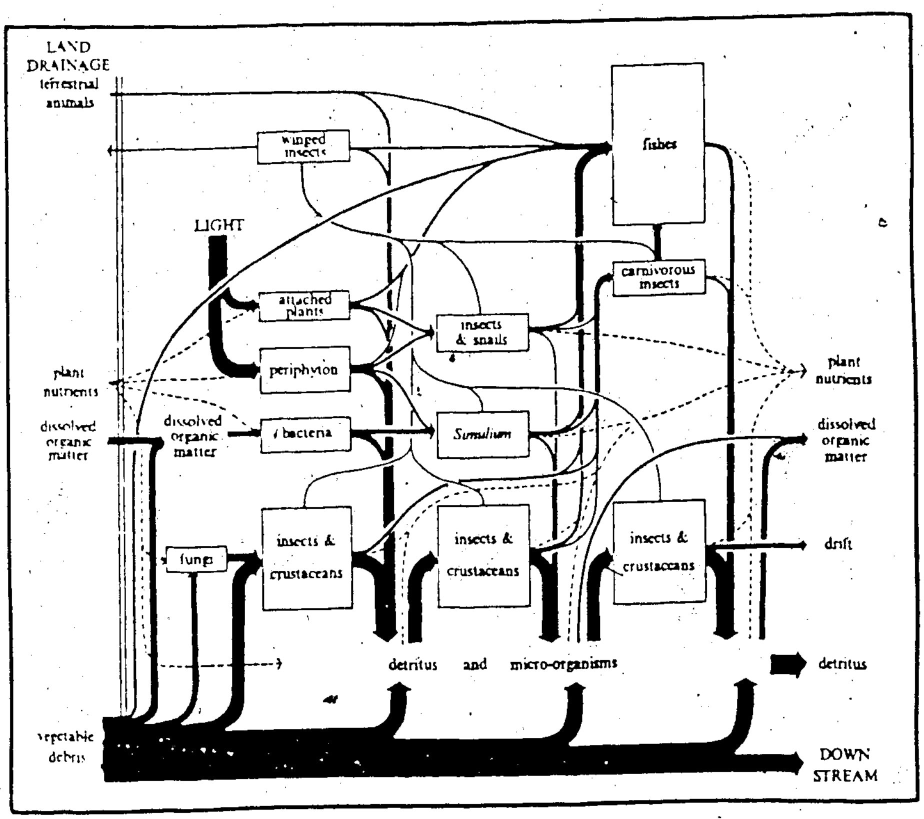


Figure 1 Diagrammatic representation of the trophic relationships of the ecosystem in the rhithron (from Hynes, 1970a).

categories based on feeding strategies, namely shredders, collectors, grazers and predators. Most aquatic insects do, however, occupy more than one category, a characteristic that enables them to adapt to various lotic habitats.

Since most of the organisms collected during this study were of the Class Insecta, a brief discussion on aquatic insect life histories is included here. Information specific to the North Saskatchewan River near Edmonton was not found in the literature.

Most aquatic insects spend the majority of their life in water in an immature form. The adult stage is short-lived and geared only towards reproduction. Mating usually takes place out of the water. The adults of some species have only vestigal mouth parts and/or digestive systems and do not feed at all. With the exception of one order (Hemiptera), aquatic insects undergo some type of metamorphosis from egg to adult.

Most aquatic insects in temperate streams have an univoltine life cycle, that is one generation per year (Hynes, 1970a). Eggs typically hatch in the summer and fall and the immature forms grow and develop over the winter and spring. The emergence of adults may start very early in the spring and continue through the summer, depending on the species and environmental conditions. There are exceptions to this pattern and these include species which take more than one year to complete the cycle (e.g. some Plecoptera) and species having more than one generation per year (e.g. some Simuliidae, Chironomidae and Baetis sp.).

Hynes (1970a) has distinguished three main types of life cycles. Non-seasonal cycles are those where individuals of all stages are present at all times because of long life histories or overlapping generations. Slow seasonal cycles are those in which the eggs hatch soon after laying and where growth occurs over a long period to maturity nearly a year later. Fast seasonal cycles have rapid growth after a long period of egg diapause or have one or more intermediate generations. A graphic presentation of seasonal fluctuations in biomass and numbers of insects in a stream is given in Figure 2. The applicability of this model to a river ecosystem is suggestive at best. Hynes (1970a) has stated that non-seasonal cycles are probably much more important in rivers than seasonal cycles.

Regardless of the type of life cycle, it is apparent that, except for periods of emergence, only the immature stages of aquatic insects will be captured in a study of drift.

2.2 The Drift Phenomenon

Simply defined, drift is the downstream movement of organisms in a running water system. Most commonly, these organisms are aquatic invertebrates but also included are fish (especially the juvenile stages), insects of terrestrial origin and algae. In North America, at least 50 species belonging to 40 genera of aquatic invertebrates have been collected in aquatic drift studies (Adamus and Gaufin, 1976). Invertebrate drift has been documented in rivers as large as the Mississippi (Berner, 1951) and in a Danish springbrook with a flow of one l/s (Iversen and Jessen, 1977). Drift sampling is now considered an integral part of any study on the ecology of stream invertebrates.

Waters (1965) subdivided the phenomenon of downstream invertebrate drift into three components: "behavioral" drift, a result of some behavioral characteristic of the animal; "catastrophic"

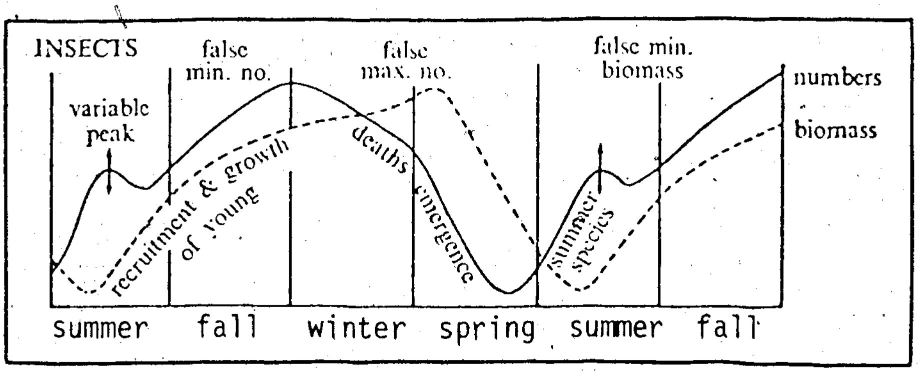


Figure 2 Diagrammatic representation of supposed seasonal fluctuations in numbers and biomass of insects in streams (from Hynes, 1970a).

Note: Points of false minimum and maximum numbers and false minimum biomass illustrate times where coarse-mesh sample nets may not represent actual conditions because they fail to collect the small individuals.

drift, which occurs as a result of floods or other physical or chemical disturbance; and "constant" drift of occasional individuals that for various reasons lose their hold on the bottom and drift in low numbers.

Non-catastrophic drift typically exhibits a diel pattern, first documented by Tanaka (1960) and also reported by others, including Waters (1961, 1962, 1965, 1966), Muller (1963), Elliott (1967a, b, 1968, 1977), Bishop and Hynes (1969), Clifford (1972), Cowell and Carew (1976), Armitage (1977), Iversen and Jessen (1977). This circadian rhythm is intimately connected to the state of activity of the invertebrate fauna. A low level of passive drift is to be expected but the nocturnal peak observed in drift is largely the result of a behavioral activity of the benthic animals. This change increases the propensity for detachment and transport by the current (Hynes, 1970a). Light intensity is considered the most important factor responsible for the circadian drift activity (Elliott, 1967a; Bishop and Hynes, 1969).

Most stream animals exhibit strong positive rheotaxis and thigmotaxis coupled with strong negative phototaxis. These mechanisms result in the firm attachment of most of the fauna to the underside of stones during the daytime (Bishop and Hynes, 1969; Odum, 1971). During darkness the activity of most benthic organisms increases and many move to the top of the substrate where they are more susceptible to the current forces. These nocturnal movements have been observed both in the field and in the laboratory (Elliott, 1967a; Bishop and Hynes, 1969; Chapman and Demory, 1963) and are probably associated with foraging for food that is more abundant on the tops of stones or in the case of filter feeders for the particulate material in the main current flow (Ulfstrand, 1967). Jostling for position and available food in this location results in the dislodging of some individuals and their recruitment to the drift. Movement to the upper substrate surface at night also reflects an important behavioral mechanism in reducing susceptibility to predation.

The night-time drift pattern typically peaks soon after sunset and again in the middle of the night or close to dawn. The pattern with the highest peak occurring early in the evening is termed bigeminous; that with the highest peak later in the night is called alternans (Aschoff, 1966). Typical patterns are illustrated in Figure 3.

The larvae of some Chironomidae, Simuliidae and Trichoptera are known to be positively phototactic and do not exhibit nocturnal drift peaks (Elliott, 1967a; Bishop and Hynes, 1969).

Nocturnal drift activity in the field and laboratory has been suppressed by the use of artifical light (Bishop, 1969; Elliott, 1967a; Holt, 1967). Anderson (1966) found that drift did not increase at all in a stream on the night of the full moon. Bishop and Hynes (1969) noted partial depression of the nocturnal drift maxima by moonlight. Critical levels of illumination for various mayfly species varied from one to 60 lux (Hynes, 1970a). In contrast Ulfstrand (1968) found the midnight sun in the Arctic does not completely suppress the diurnal rhythm. Hynes (1970b) summarized the importance of light on circadian drift rhythms by stating:

> "The rhythm is set by light, and that in some species it persists and is enhanced when the inhibitory effect of light is removed, but that in others the recurring stimulus of the change from light to dark is needed for the pattern to persist."

"Catastrophic" drift induced by heavy rainfalls has been described by Waters (1962); Elliott (1967a);and Anderson and Lehmkuhl

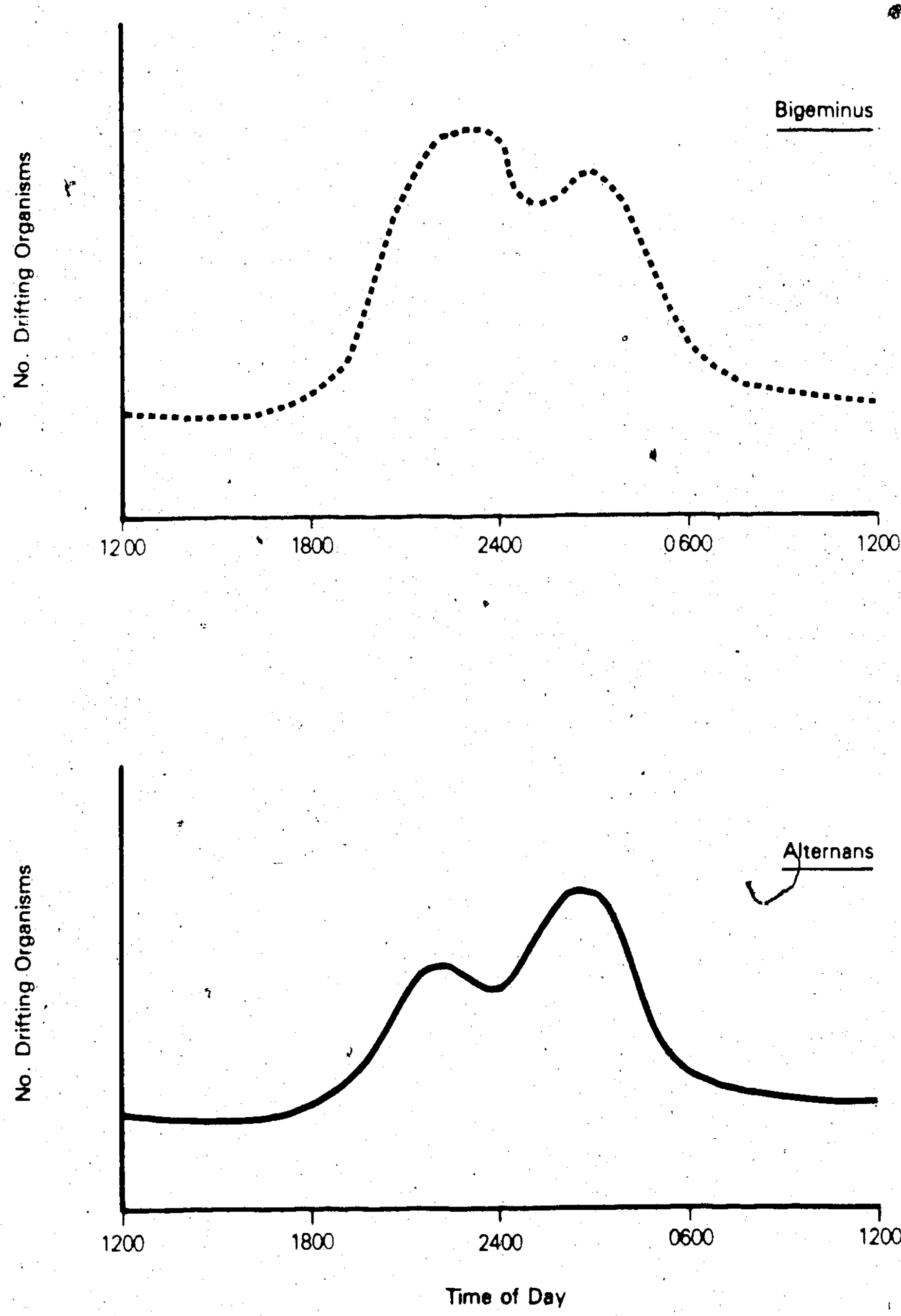


FIGURE 3
Typical Diel Patterns of Drifting Invertebrates
(from Aschoff, 1966)

(1968). In the last study a four to sixfold increase in stream discharge resulted in a fourfold increase in drift collections. Waters (1962) found the drift rate of Dixa sp. in Valley Creek, Minnesota increased 50-fold after a rainstorm. The term "catastrophic" may, however, be inappropriate in these cases since drift densities did not change significantly from pre-rainfall conditions. Also, Anderson and Lehmkuhl noted that many of the drifting invertebrates retained their characteristic nocturnal patterns even during periods of high discharge. The most classic cases of catastrophic drift are those resulting from direct or indirect applications of pesticides (Ide, 1957, 1967; Hatfield, 1969 and Wallace and Hynes, 1975). Treatment with methoxychlor of two small streams in Quebec caused a nearly 2000-fold increase in the numbers of drifting insects over a 24-hour period following application (Wallace and Hynes, 1975).

2.3 Significance of Drift to the Stream Environment

Four aspects of invertebrate drift which can be considered beneficial to the stream community include the rapid repopulation of denuded areas, the maintenance of a food supply of certain fish species, the removal of excess benthic production, and escape from inhospitable habitats.

Colonization of newly constructed stream channels was observed within four months by Leonard (1942) and Patrick (1959). Muller (1954) found that Chironomidae, Simuliidae, Ephemeroptera, Trichoptera and Plecoptera had moved into an area of a stream completely denuded by a bulldozer after only 11 days. Waters (1964) artifically cleared small areas of a stream and found two species, Baetis vagans and Gammarus limnaeus returned to their former abundance within four and one days respectively during the fall. Coutant (1962) observed winter recolonization by stream invertebrates in sections of the Delaware River where summer water temperatures were increased beyond tolerance limits by a power generating station. Recolonization attributed to drift in streams affected by insecticide applications has been noted by Dimond (1967).

Many species of fish (most notably salmonids) are known to feed on drifting organisms. In four Idaho streams, Griffith (1974) found that members of five insect orders (Ephemeroptera, Coleoptera, Diptera, Plecoptera and Trichoptera) which comprised the bulk of drift made up an average of 92 percent of the diet of brook trout (Salvelinus fontinalis) and cutthroat trout (Salmo clarki) of all age groups. Drifting Chironomidae (both larvae and emerging adults) comprised 70 percent of the diet of coho salmon fry (Oncorhynchus kisutch) in an artificial stream in British Columiba (Mundie, 1971). Insects of terrestrial origin which drift on the surface made up nearly 50 percent of the diet of brook trout in a Colorado stream (Reed and Bear, 1966). The exploitation of drift for increasing production of salmon in nursery streams has been proposed by Mundie (1974). Possibilities include the collection of nocturnal drift and subsequent release during the daytime, percolation of an air-water mixture through the gravel of riffle areas to dislodge the benthos and attraction of terrestrial insects to the water surface by suspended lights. Mundie (1973) also demonstrated the potential for field culturing fish food organisms by adding cereal grain to promote higher benthic invertebrate production. These organisms could then be made available to fish via the drift.

Waters (1961 and 1966) has argued that drift represents excess production from the benthic habitat. His studies of the mayfly (Baetis vagans) suggested drift was a function of production rate at or above the point at which the carrying capacity is reached. Dimond (1967) also found that invertebrate drift was not significant in streams in Maine previously affected by aerial DDT spraying until the carrying capacity of the benthos was achieved. Here the drift component recovered two to three years after the bottom fauna. The dependence of drift on benthic density was also shown by Pearson and Franklin (1968). Waters (1966) estimated the production rate of Baetis vagans using two methods; drift and instantaneous growth rate, and population densities of the benthos but found more confidence could be placed in the latter.

This relationship between drift and density of the benthos was not found by Elliott(1967a) or Bishop and Hynes (1969). In both studies the proportion of benthos in the drift never exceeded 0.0086 and 0.0004 percent respectively. In addition, the benthos probably never reached carrying capacity due to seasonal spates and cultural interferences. Such small percentages make it impossible to estimate benthic production rates using drift alone. Armitage (1977) found the proportion of benthos in the drift varied from 0.02 to 4.73 percent in two English streams with the highest proportions occurring in July and the lowest in January.

The final consideration is that of escape. This is especially important in streams with fluctuating shorelines caused by hydroelectric power generation. Brusven and MacPhee (1976) found that drift served as one of the prime ways by which aquatic insects can avoid stranding and possible demise when colonizing habitats were subjected to stage fluctuations. Certain groups such as ephemeropterans, plecopterans, and trichopterans would tend to drift rather than seek out cover deeper in the substrate.

2.4 Invertebrate Drift as a Measurement of Environmental Change

2.4.1 The Use of Aquatic Invertebrates for Water Quality Assessment

Biological monitoring plays an important role in a pollution monitoring program by providing information not available from physical and chemical tests alone. In rivers, benthic invertebrates have long been recognized as organisms particularly suited to pollution surveys (e.g. Richardson, 1928; Patrick, 1950; Gaufin and Tarzwell, 1952; Beck, 1955; Wartz, 1955; Hynes, 1960; Dean and Burlington, 1963; and Klein, 1962). The assemblage of bottom organisms in a river is a reflection of the quantity and quality of wastes entering the waterway. Chemical analyses alone only describe water quality at the time of sampling and may not coincide with the period of most critical conditions to the organisms. In contrast, the composition of the bottom fauna is determined by single or recurring critical conditions and reflects the environmental conditions which prevailed during its development. Even a short-term exposure to a particular pollutant will result in the loss of those organisms intolerant of the stress.

There are several reasons why benthic invertebrates are selected for study. First, they are usually abundant in rivers and streams during all seasons. Second, they are differentially sensitive to pollutants of various types and respond quickly (Cook, 1976). Third, they typically have a life cycle of a year or longer and if at any time during their life cycle environmental conditions are outside the tolerance limits, they die (Cairns and Dickson, 1971). Fourth, they are relatively immobile and cannot easily escape unfavourable environmental conditions. Finally, they are easy to collect and identify.

The response of the benthic invertebrate community to pollution varies with the nature of the waste. Typical responses to two types of wastes, organic and toxic, are described here. In the case of organic wastes such as a sewage treatment plant effluent, important successional changes occur in the downstream direction. Immediately below the outfall, there may be a zone where the dissolved oxygen concentration is reduced due to oxygen demanding substances in the waste and the substrate blanketed with organic solids, sewage fungus or algae. Here only those organisms which can tolerate low dissolved oxygen concentrations and utilize the altered habitat will be found. Tubificid worms and certain midge larvae typically are very abundant in this zone because of the abundant food supply and lack of interspecific competition. This group of organisms actually assists in processing complex organic wastes through their feeding and burrowing activities which help return the waters to their natural state. Secondary waste treatment processes such as activated sludge, trickling filters and rotating biological contactors also utilize characteristic communities of organisms to process wastes (Hawkes, 1963). As conditions improve downstream, the more tolerant forms decline in number and the more sensitive groups gradually re-appear until the benthic community returns to something like that which existed upstream of the discharge.

Unlike sewage, toxic wastes such as pesticides, heavy metals, acids, etc. generally affect nearly all kinds of benthic invertebrates. As the concentration of the waste is reduced downstream, different species successively begin to reappear, depending on their tolerance. Toxic substances are of minor direct benefit to only a few organisms so large increases in the numbers of such species are not usually found.

There are two common approaches to measuring the response of benthic organisms to waste input, be it continuous or intermittent. The first involves the use of benthic invertebrates as indicator organisms whereby certain taxonomic groups are classified according to whether they occur in clean water, polluted water or some intermediate range between these extremes (Gaufin and Tarzwell, 1952; Beck, 1955; Sladacek, 1973). Numerical indices based on these classifications have been developed by many researchers but they generally apply to specific types of waterbodies or types of pollution (Beck, 1955; Woodiwiss, 1964; Chandler, 1970; Beak, 1972; Chutter, 1972). The breakdown of taxonomic groups in this manner is somewhat subjective, since the tolerance of the same organism may vary under a different set of environmental conditions (Cairns et al., 1973). Also, it is very important to identify organisms to the species level because different species have different ranges of tolerance to the same stress (Resh and Unzicker, 1975).

The second approach involves the examination of the structure and organization of the benthic invertebrate community (i.e. community diversity). The community response to pollution is usually a reduction in the number of species present and either a reduction or increase in the numbers of those species remaining. This change in diversity can be measured by means of a mathematical expression called a diversity index which describes the distribution of individuals among species at a particular location. Many kinds of diversity indicies have been developed (e.g. Simpson, 1949; Burlington, 1962; Brillouin, 1960; Pielou, 1966; Wilhm and Dorris, 1968; Odum, 1971; Cairns and Dickson, 1971; Hurlbert, 1971; Harkins and Austin, 1973). All are based on the assumption that clean water communities have high diversity, stability and predictability and any pollutional stress will decrease diversity. In most cases, maximum diversity occurs when each individual belongs to a different species and minimum diversity occurs when all individuals belong to one species.

Both approaches have been followed in assessing the effects of waste discharges on the benthic invertebrate fauna of the North Saskatchewan River near Edmonton. These are discussed more fully in Section 4.1.3.

Most commonly benthic invertebrates are collected from their normal habitat (i.e. the river substrate) by either removing a known area of bottom with a dredge or coring device and sorting the organisms from other debris or by stirring a known area of bottom and collecting the dislodged organisms in a downstream net. The organisms collected are then analyzed and comparisons made between each sampling site using one or both of the approaches discussed above. A well recognized problem associated with bottom sampling is that of collecting a representative sample at a particular location. Benthic invertebrates are typically distributed in a clumped or contagious pattern on the stream bottom and regardless of the sampling method used, the variances of the samples collected are very large (Hynes, 1970a). This problem is compounded when several stations at different points on a stream are sampled. If drifting benthic organisms are distributed more or less randomly in the water column, then the problem of large sample variance may be partly overcome by sampling drift.

2.4.2 The Use of Invertebrate Drift for Water Quality Assessment

Benthic invertebrate drift has seldom been used routinely in the study of water pollution. Important exceptions are studies related to the aerial application of pesticides (see Section 2.2) and the works of Larimore (1974); Ball, et al., (1973); Rosenberg and Snow (1975); and Zimmer and Bachmann (1978). Larimore collected drift and benthos samples from a stream receiving domestic and industrial wastes in Illinois and found both methods useful in delineating polluted zones. He also discussed the pros and cons of collecting drift for water quality assessment. The advantages of collecting drift instead of benthos were:

a) the drift collection represents a wide spectrum of habitats and a single drift sample may suffice in place of several benthic samples.

b) drift collection requires much less effort.

c) drift nets are inexpensive.

d) drift collection may include emerging forms.

The disadvantages were:

a) certain organisms such as molluscs, decapods and fish occur only sporadically in the drift.

b) collections should be made at night.

c) floating debris, ice, etc. can interfere with nets.

d) abundance and composition of drift varies seasonally.

e) drift collection may not reflect very localized habitat disruption.

f) the origin of the drifting organism is not known precisely.

Ball, et al., (1973) studied drift in three Michigan rivers and found the numbers of drifting invertebrates increased as the level of human disturbance (forest clearing, municipal discharges, etc.) increased. Diurnal variations in the drift were also more pronounced in the more disturbed streams. They suggested that drift may be useful as a sensitive indicator of deteriorating stream conditions, and may signal the future occurrence of more severe changes.

Rosenberg and Snow (1975) examined the effects of controlled sediment additions on macroinvertebrate drift in the Harris River, N.W.T. These experiments were conducted to assist in the prediction of impacts of northern highway and pipeline construction on freshwater biota. Positive increases in drift were shown at all concentrations (10 mg/l to 500 mg/l) for macrobenthic organisms but not zooplankton, verifying the usefulness of the macroinvertebrate community as an indicator of sediment pollution. The maximum percentage of the resident macrobenthic population caused to drift by a 15-minute period of sediment addition was estimated to be 2.6. The minimum was 0.04.

Zimmer and Bachmann (1978) compared drift densities in natural and channelized streams in Iowa and found densities were higher in the former. They showed mean drift weights and counts were significantly (P = .05) correlated with stream sinuosity, suggesting channelization reduced habitat diversity.

3.0 DESCRIPTION OF THE STUDY AREA

3.1 The North Saskatchewan River at Edmonton

The North Saskatchewan River orginates in the Rocky Mountains of Banff National Park, 530 km west of Edmonton, Alberta. It flows a total of 850 km in an easterly direction across Alberta and into Saskatchewan where it joins with the South Saskatchewan River to form the Saskatchewan River. The waters of the Saskatchewan drain into Hudson Bay via Lake Winnipeg and the Nelson River. The North Saskatchewan River basin area at Edmonton is approximately 27,200 km^2, about 29 percent of the total basin area (Nwachukwa, 1972).

In the vicinity of Edmonton, the North Saskatchewan River valley is generally 1 to 3 km wide and from 30 to 90 m deep. The valley is believed to have been cut entirely in postglacial time and contains several alluvial terrace levels (Westgate, 1969). The river channel is partly confined and meanders irregularly. The channel location is fairly stable and bank erosion is very localized in nature and proceeds at a slow rate.

The river bed is composed primarily of gravel. An analysis of bed material at the High Level Bridge and Clover Bar is given in Table 1. The former location is immediately downstream from the University of Alberta cooling water discharge and the latter is immediately upstream of the Celanese Canada Limited discharge (see Figure 4). The bed in these areas is underlain by approximately 1.5 m of gravel followed by shale. The bank material is generally silty sand.

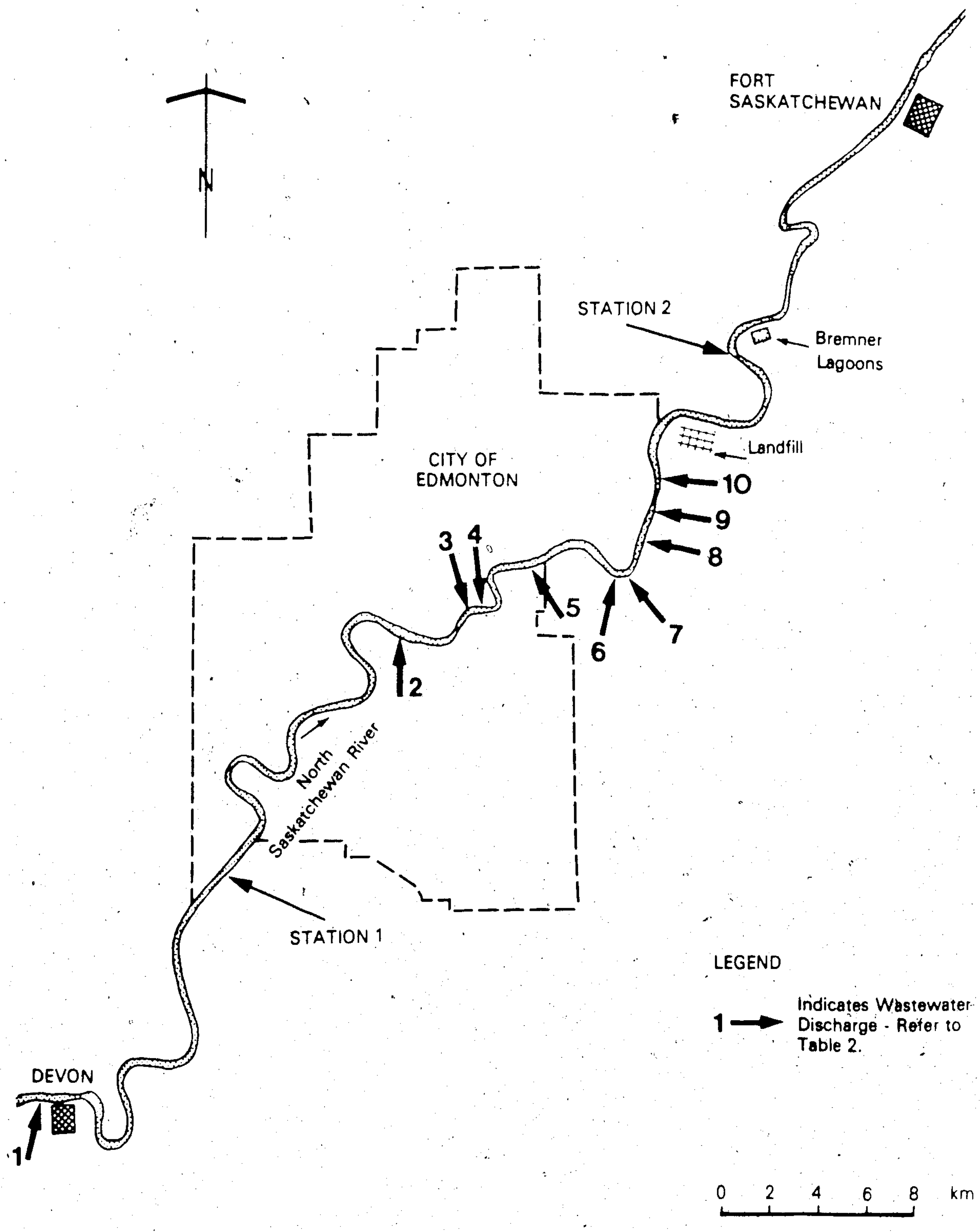


FIGURE 4
Map of the Study Area

TABLE 1

(from Halferdahl, 1969)

Analysis of Bed Material Samples

Location	Total Sample (mm) D_{50}	Total Sample (mm) D_{90}	Portion of Sample >8 mm D_{50}	Portion of Sample >8 mm D_{90}	Upper Range of Largest Size (mm)
High Level Bridge	23	95	35	97	128
Clover Bar	16	90	31	97	128

Discharge has been measured on the North Saskatchewan River at Edmonton since 1911. Figure 5 shows the flow in the river during the study period. The mean flow in 1975 was 140 m^3/sec and in 1976 it was 167 m^3/sec (Water Survey of Canada data). The river stage typically fluctuates over a 24-hour period, due to upstream influences such as the hydroelectric power dam on the Brazeau River, a major tributary of the North Saskatchewan River. Examples of these fluctuations during some of the sampling periods of this study are illustrated in Figure 6.

The river is generally ice-covered for five months of the year. During this study the river froze over on November 9, 1975 and broke up on April 11, 1976.

3.2 Drift Sampling Locations

Two sampling stations were established for this study, one upstream of the City of Edmonton (Lat. 53° 27', Long. 113° 37'; 10 km upstream of the city limits) and one downstream (Lat. 53° 37', Long. 113° 18'; 10 km downstream of the city limits). These are

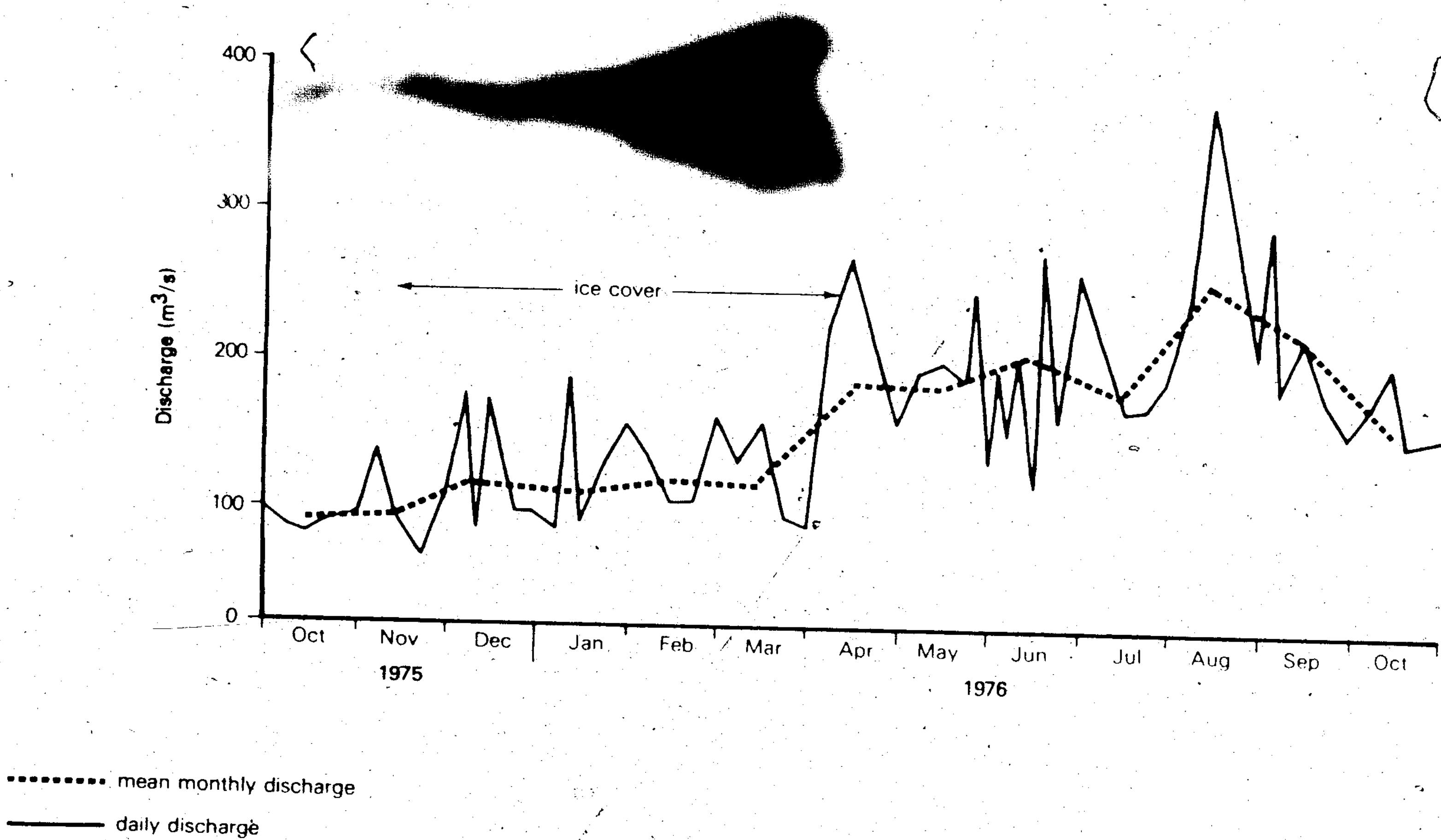


FIGURE 5
Discharge of the Nprth Saskatchewan River
at Edmonton: October 1975 - November 1976

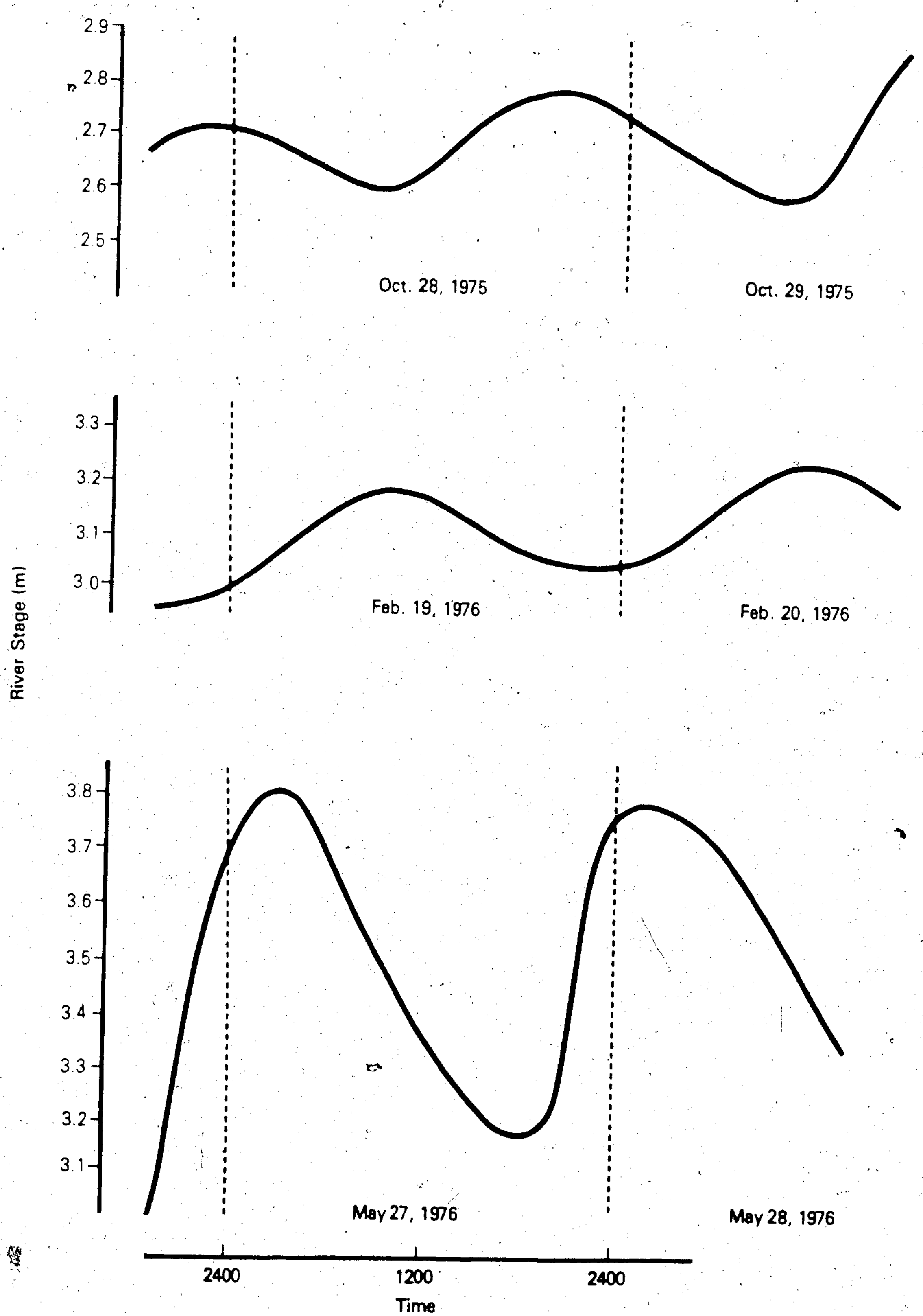


FIGURE 6
Stage Fluctuations in the North Saskatchewan River at Edmonton

shown on Figure 4. The upstream station (hereinafter called station 1) was chosen to represent a portion of the river relatively unaffected in terms of wastewater loadings. The nearest continuous effluent discharge came from the municipal sewage treatment plant at Devon, 23 km upstream of station 1. This effluent is subjected to secondary treatment and chlorination prior to discharge to the river. The ratio of this discharge to the mean discharge of the North Saskatchewan River (1975 and 1976) was approximately 1:86400.

The downstream station (hereinafter called station 2) was selected to represent a portion of the river strongly affected by a wide variety of wastewater loadings. Direct discharges to the river between stations 1 and 2 include urban storm runoff, cooling water from two power generating stations and the University of Alberta, alum and lime sludge from the Edmonton water treatment plant, treated sewage from the Edmonton Gold Bar Wastewater Treatment Plant and effluents from a number of industries including oil refineries and chemical plants. A brief description of these discharges is given in Table 2. Most are located on the south side of the river except the Rossdale generating station and water treatment plant.

The major continuous wastewater discharge was that of the Edmonton Gold Bar Wastewater Treatment Plant located on the south shore at 50 Street, 18 km upstream of station 2. The average daily discharge from the plant was approximately 1.42×10^6 m^3/day. The ratio of this discharge to the mean discharge (1975 and 1976) of the North Saskatchewan River was approximately 1:58. Average

TABLE 2

Summary of Effluent Discharges to the
North Saskatchewan River Upstream of Station 2
(source: Alberta Environment, 1976)

Source	Number on Fig. 4	Type of Discharge and Treatment
Town of Rocky Mountain House		Domestic sewage (lagoon)
Town of Drayton Valley		Domestic sewage (lagoon)
Town of Devon	1	Domestic sewage (secondary treatment and chlorination)
Imperial Oil, Devon		Surface run-off (lagoon)
University of Alberta	2	Cooling water
Edmonton Power Rossdale Generating Station	3	Cooling water
Edmonton Water Treatment Plant	4	Lime and alum sludge
Edmonton Gold Bar Waste-water Treatment Plant	5	Domestic sewage (secondary treatment)
Imperial Oil Enterprises (Edmonton)	6	Refinery wastewater (aerated lagoon)
Texaco Canada Limited	7	Refinery wastewater (API separator)
Gulf Oil Limited	8	Refinery wastewater (lagoon)
Celanese Canada Limited	9	Industrial waste-water (lagoon)
Edmonton Power Cloverbar Generating Station	10	Cooling water

daily mass loading of major pollutants from this plant to the North Saskatchewan River in 1975 are given in Table 3 (Coutts, 1976).

TABLE 3

1975 Average Daily Loadings from the Edmonton Gold Bar Wastewater Treatment Plant to the North Saskatchewan River (from Coutts, 1976)

Flow	2×10^5 m^3/day
Suspended Solids	7881 kg/day
Biochemical Oxygen Demand	5740 kg/day
Grease	2864 kg/day
Total Coliforms	3×10^6/100 ml
Phenols	1×10^{-2} mg/l

The Edmonton Power Company Limited generating stations at 105 Street and Clover Bar continually discharge once-through cooling water to the North Saskatchewan River. The waste heat contained in these and other discharges was sufficient to maintain an open water channel in the river between 105 Street and Fort Saskatchewan during the winter 1975-76. At station 2, the river was ice free from shore to shore. Snow from street clearing operations in the City of Edmonton was dumped on the banks of the river at several locations within the city limits during the winter of 1975-76.

River habitat similarity was the major criteria in selecting the exact station locations. Ease of access by vehicle during all seasons was also an important consideration. Both stations were similar in terms of river width, depth and slope. Cross-sectional profiles of each station are illustrated in Figure 7. Bed material at both stations consisted of gravel. Exposed gravel bars were more numerous at station 1. Aquatic macrophyte growth was very limited at both stations, being generally restricted to back eddies along the shoreline. Current velocities measured at both stations during this study ranged from 0.5 to 1.1 m/s.

3.3 Previous Environmental Studies

The deterioration of water quality in the North Saskatchewan River downstream of Edmonton has been recognized since at least the early 1950's. Prior to the construction of upstream reservoirs and the establishment of suitable controls on wastewater discharges, dissolved oxygen concentrations in the river during periods of ice cover typically dropped to levels considered critical for fish survival. Atton (1954) reported river dissolved oxygen concentrations of less than 1.0 mg/l between Two Hills (160 km downstream of Edmonton) and the South Saskatchewan River confluence during the winter of 1953-54. At Prince Albert, Saskatchewan (780 km downstream of Edmonton) live fish placed in cages under the ice died after only five hours of exposure (Atton, 1954). In March, 1957, dissolved oxygen concentrations at Borden (430 km downstream of Edmonton) and Prince Albert were 1.2 and 1.4 mg/l respectively (Reed, 1962).

Since the construction of the Brazeau Dam and Reservoir in 1962, the Alberta Department of Health and subsequently Department of Environment have monitored the chemical and bacteriological quality of the river during the winter months (Ferguson

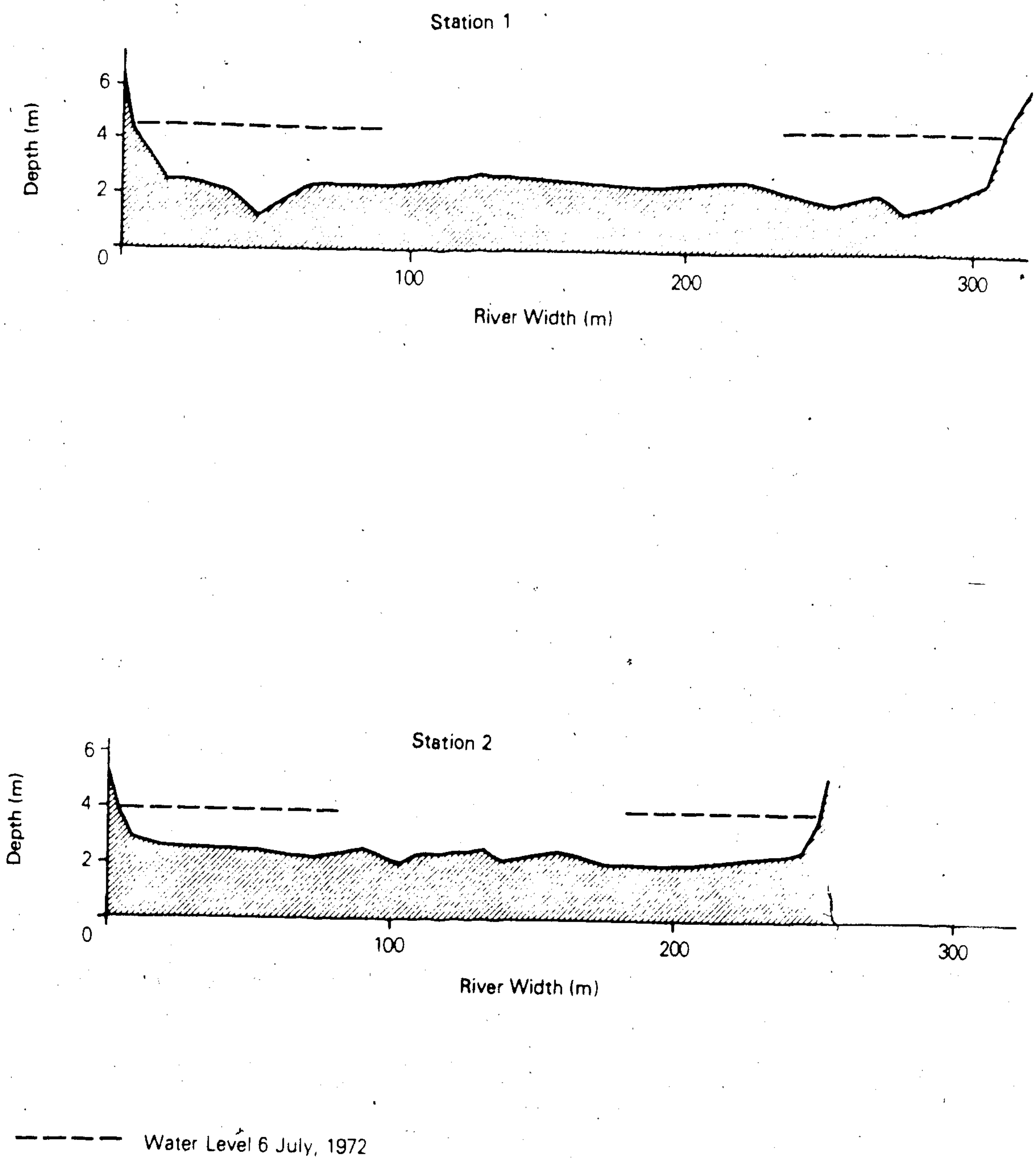


FIGURE 7

Cross-Sectional Profiles of the North Saskatchewan River at Station 1 and 2 (from Alberta Environment, 1972)

1965; Krishnaswami, 1966; Kupchanko, 1967, 1968, 1969, 1970; and Masuda, 1971, 1972). Dissolved oxygen concentrations in the river since 1962 have improved substantially although sags are still evident at the Alberta-Saskatchewan border. Other chemical parameters which increased in concentration downstream of Edmonton included ammonia nitrogen, total phosphorus, nitrate nitrogen, oil and grease, phenols, chlorides and carbon chloroform extracts. Bacterial densities in the river (including total coliforms, fecal coliforms and standard plate counts) also increased downstream of Edmonton and tended to remain elevated at the Alberta-Saskatchewan border.

Coleman, et al. (1974) found bacterial densities in the North Saskatchewan River increased due to the discharge from the Edmonton Gold Bar Wastewater Treatment Plant for a distance of 480 km downstream. Densities of fecal coliforms in the river increased by two orders of magnitude below the sewage plant discharge.

More recently, an intensive bacteriological and chemical water quality survey of the river was conducted by the Environmental Protection Service in 1975 and 1976 (Zaal et al., 1979 and Bell, 1977). The study area extended from station 1 upstream of Edmonton to a point 225 km downstream. The results showed that below the Edmonton Gold Bar Wastewater Treatment Plant, chemical and bacterial levels in the river exceeded recommended standards for potable water supplies and recreational use for a distance of 121 km downstream. Large numbers of salmonella serotypes were also isolated from water samples collected in the same stretch of river.

In order to characterize the chemical and bacteriological quality of the North Saskatchewan River at stations 1 and 2 during the present study, some of the data from Zaal et al. (1979) have been summarized in Tables 4 and 5. The data reported for station 2 were actually collected approximately two km upstream but is considered representative since there were no wastewater discharges in the intervening length of river and lateral mixing was thought to be minimal. Recent studies by the Alberta Research Council have shown that the mixing capacity of the river below Edmonton is indeed weak (Beltaos and Anderson, 1979). Of particular interest are the lateral differences in water quality at station 2. Fecal coliform, fecal streptococci and heterotrophic bacteria densities were an order of magnitude higher in the south shore samples in comparison to the north shore. Similarly, the concentrations of total Kjeldahl nitrogen, ammonia nitrogen, nitrate nitrogen, total phosphorus, sodium, potassium and chloride were much higher in the south shore samples.

Beginning in 1960, there have been several biological investigations carried out on the North Saskatchewan River to assess the impact of wastewater inputs on the benthic invertebrate fauna. Beak (1960) characterized the river downstream of Edmonton as being organically polluted for a distance of at least 60 km based on large numbers of Oligochaetes and Chironomid larvae found at the downstream stations in comparison to a station near the present Quesnel bridge (6 km downstream from station 1). He collected the samples with a Petersen dredge from both gravel and mud substrates near the shore. Paterson (1966) and Paterson and Nursall (1975) found a similar situation existing in the

TABLE 4

Water Chemistry of the North Saskatchewan River at Stations 1 and 2 in 1976

(from Zaal et al., 1979)

Parameter (mg/l)	Station 1	Station 2 North	Station 2 Midstream	Station 2 South
Total Carbon	35	35	35	38
Inorganic Carbon	30	31	31.5	32
Organic Carbon	5	4	3.5	6
Total Kjeldahl Nitrogen	0.15	0.13	0.23	2.60
Ammonia Nitrogen	0.01	0.02	0.01	1.95
Nitrate-Nitrite Nitrogen	0.01	0.01	0.01	0.04
Total Phosphorus	0.01	0.01	0.03	0.19
Sodium	4.2	4.6	4.8	9.8
Potassium	0.8	0.8	0.8	1.5
Calcium	58	58	59	55
Chloride	0.4	0.4	0.3	4.0
Magnesium	12.9	13.5	13.2	13.7
Zinc	0.015	0.036	0.016	0.033

Note: Values are averages of three samples collected in May, June and September, 1976.

TABLE 5

Bacteriological Quality of the North Saskatchewan River at Stations 1 and 2 in 1976

(from Bell et al., 1977)

Parameter	Station 1	Station 2 North	Station 2 Midstream	Station 2 South
Coliform MF per 100 ml	100	1700	3800	46000
Fecal Coliform MF per 100 ml	6	150	260	6300
Fecal Streptococci MF per 100 ml	3	52	310	3700
Heterotrophs	4100	6000	7400	54000

Note: Values are geometric means of three samples collected in May, June and September, 1976 benthic fauna of the river during a limnological investigation conducted between 1961 and 1965. The clean water fauna found upstream of the city were either absent or found in very low numbers downstream of the Edmonton Gold Bar Wastewater Treatment Plant. Several genera of mayflies, stoneflies and caddis flies were completely absent from stations along the south shore near effluent outfalls. Paterson attributed this absence of clean water fauna chiefly to habitat disruption and not to toxic substances. The organic nature of the sewage discharge would enhance algal and bacterial growth on the river substrate and clog the interstices between rocks - a situation intolerable to many species of stone-flies, mayflies and caddis flies. Samples were taken from the near-shore areas only with an Ekman dredge and Surber sampler.

Paterson also studied the fish fauna of the river using gill and seine nets. Catches along the north side of the river were similar throughout the study area; however, no fish were taken at south shore stations two and ten kilometers down-stream of the Edmonton Gold Bar Wastewater Treatment Plant.

Paetkau (1970 and 1971) initiated a regular biological monitoring program on the North Saskatchewan River in 1969 by collecting handnet samples of benthos at five stations in the fall and spring of that year. During 1969-70 and 1970-71 he found the benthic community downstream of Edmonton did not recover to up-stream conditions for a distance of at least 160 km. This program has been continued by the Alberta Department of the Environment, with some modification in sampling techniques, station locations, and data analysis. The 1973-74 monitoring results reported by

Reynoldson (1974) showed the benthic community had not recovered to upstream conditions at a point 250 km downstream of Edmonton. Diversity indicies computed for a station upstream of Edmonton (one kilometer upstream of station 1) and stations 18, 65, 200, and 250 km downstream were 2.681, 0.251, 1.810, 2.129 and 1.990, respectively. Samples were collected near the shore using a modified Hess sampler. Table 6 lists the benthic invertebrates collected from the North Saskatchewan River during the 1973 study.

Two additional biological studies have been conducted in the river in the vicinity of the present study area but are more site-specific in nature. During the winter of 1973-74, the impact of snow dumping on river quality was investigated (Renewable Resources Consulting Services Ltd., 1974). No adverse affects were found in the benthic community downstream of a snow dump located on the north shore of the river near the Low Level bridge. The effects of the once-through condenser cooling water discharge from the Edmonton Power Clover Bar Generating Station on river biota was studied in 1972 and 1974 (Western Research and Development Ltd., 1974) but no obvious impact was found. The study did, however, indicate a difference in benthic communities between the north and south shores similar to that reported by Paterson in 1966.

No studies reporting on invertebrate drift in the North Saskatchewan River have been located in the literature.

TABLE 6

Benthic Invertebrates Collected from the North Saskatchewan River in 1973

(from Reynoldson, 1974)

Taxon	Station 1 (Big Island)	2 (Beverly Bridge)	3 (Vinca Bridge)	4 (Duvernay Bridge)	5 (Elk Point Bridge)
Ephemeroptera					
Ephemerella sp.			2	3	1
Heptagenia sp.	2		19	2	10
Baetis sp.	15	3	10	348	10
Ameletus sp.					2
Leptophlebia sp.					2
Plecoptera					
Nemoura sp.					4
Isogenus sp.	6		1	21	
Alloperla sp.			1		
Trichoptera					
Hydropsyche sp.	3	15	1170	11	3
Hemiptera					
Corixidae	16	36	323		24
Lepidoptera		1			
Diptera					
Tanypodinae		6	191	60	40
Orthocladiinae	3	3	205	282	260
Rhagionidae			2		
Pupae	3	2	3	112	5
Oligochaeta	2	2141	15	26	11
Gastropoda			1		32
Pelecypoda					1
Nematomorpha	1				
Total No. Organisms	54	2207	1943	865	405
Diversity Index	2.681	0.251	1.810	2.129	1.990

4.0 METHOD[illegible]

4.1 L[illegible] Review of Drift Sampling Techniques

A [illegible]ety of techniques have been developed for sampling inve[illegible]rate[illegible] in lotic systems. Many are described in a review paper [illegible] Elli[illegible] (1970). The most common approach has been the placement o[illegible] nets [illegible] various dimensions and mesh sizes directly into a stream. [illegible]er approach is to pass a portion of the stream discharge through [illegible]be which empties into a filtering net above the water surface. [illegible]th can be equipped with flow meters to record the volume of water fil[illegible]ed. Pearson and Kramer (1969) used a waterwheel to sample drift. Sma[illegible] buckets were attached to the perimeter of the wheel and as it rotated the buckets would fill underwater and empty into a trough which in turn emptied into a net. More recently, Armitage (1977) has sampled drif[illegible] pumping river water through a filter. The majority of inverteb[illegible] drift studies have been conducted on streams with a relatively small flow. Some examples include: Rold Kilde Spring, Denmark, 0.027 m^3/s (Iversen and Jensen, 1977); Valley Creek, Minnesota, 0.14 m^3/s (Waters, 1966); River Tees, England, 3.98 m^3/s (Armitage, 1977); Blackwater Creek, Florida, 2.86 m^3/s (Anderson and Ledmkuhl, 1968); Stream M.26, Quebec, 2.36 m^3/s (Wallace and Hynes, 1975); Biogray River, Alberta, 2 m^3/s (Clifford, 1972); Red Cedar River, Michigan, 5.4 m^3/s (Ball et al., 1973). Some workers have even been able to block the entire cross-section of a stream and collect all the drifting fauna at that location (Minshall and Winger, 1968; Anderson and Lehmkuhl, 1968). In all the above examples, the streams were shallow (usually less than 0.5 m) and could be easily traversed by foot.

In contrast Burton and Flannagan (1976) and Northcote et al.

(1976) studied drift in two large Canadian Rivers - the Athabasca (mean discharge 430 m^3/s) and the lower Fraser (mean discharge 3650 m^3/s. In the former study, nets were suspended from surface buoys. Nets in the latter study were towed upstream behind a boat parallel to the shore. Both rivers were relatively deep (i.e. >5 m).

4.2 Criteria for Drift Sampler Design

None of the techniques reviewed in the literature prior to undertaking the present study were considered entirely suitable for year-round drift sampling in the North Saskatchewan River based on the following criteria:

(a) The nets could be placed at any location and depth along a river cross-section.

(b) The nets must not clog after one or two hours of operation.

(c) The nets must be operational under freezing temperatures.

(d) The time involved in retrieving and replacing the nets and their contents during a 24-hour sampling period is minimized.

(e) The nets must be operational under varying river discharges and velocities.

(f) The mesh size of the net must be small enough to retain most macro-invertebrates yet large enough to prevent rapid clogging.

(g) The nets must filter a representative volume of river water and provide isokinetic sampling of particulates.

(h) The flow of river water through the mouth of the net should be unobstructed to ensure reliable estimates of the volume of water filtered over a given period of time.

(i) The cost of materials must be minimized.

(j) The nets must be durable enough to be re-used many times.

4.3 Sampler Design and Rationale

The net and associated apparatus constructed to meet these design criteria are described below and illustrated in Figure 8. The rationale for some of the major aspects of the design follows.

The Drift Net

The front of the net was supported by a 15 cm length of PVC pipe with an inside diameter of 7.5 cm and outside diameter of 8.1 cm. The pipe wall at the upstream end was bevelled from the outside to the inside a distance of 1 cm around the entire circumference to provide a sharp leading edge to reduce flow resistance. Half way along the length of the pipe were two holes directly opposite each other through which a length of aluminum rod (1.27 cm outside diameter) could be inserted. This rod secured the net to the surface float, its length depending on the depth of sample required. Two retaining clips placed a short distance away from the PVC pipe held the rod firmly to the PVC pipe and also permitted the pipe to rotate and maintain a position parallel to the river flow.

The net itself was made of Nitex nylon monofilament screen cloth with a mesh opening of 333 microns. It was 90 cm long and tapered slightly from 8.1 cm in diameter at the upstream end to 6.5 cm in diameter at the downstream end. Canvas collars were sewn at each end of the net to facilitate attachment to the PVC pipe and collection bucket using standard hose clamps, and also to prevent fraying of the mesh with repeated use.

The collection bucket was made from a wide mouth nalgene jar

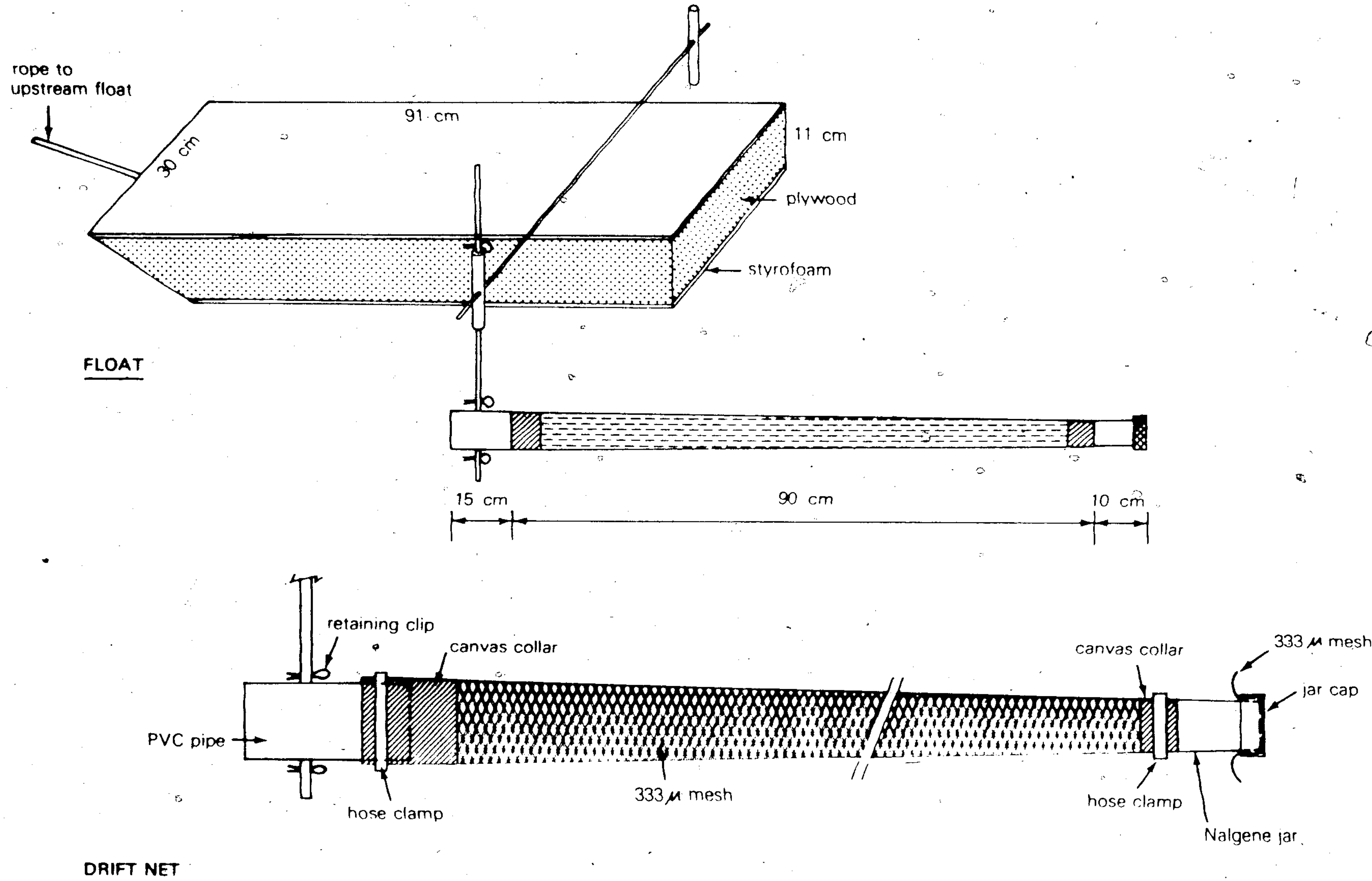


FIGURE 8
Diagram of Apparatus Used to Sample Drift
in the North Saskatchewan River

of 251 ml capacity with the bottom of the jar and top of the screw-on cap cut out. The jar was 10 cm long and 7 cm in diameter. The bottom of the jar fitted into the canvas collar at the downstream end of the net. A piece of nylon mesh identical to the netting material was placed over the threaded (downstream) end of the jar and secured by screwing on the topless jar cap. The net components are shown in Plate 1.

The Floats

Each float was made of styrofoam covered on top and bottom with 6.4mm plywood. Two eyebolts held the styrofoam and plywood together and also served as points of attachment for the anchor line and downstream float line. The front of the float was tapered inward from top to bottom a distance of 15 cm to reduce flow resistance. The float measured 91 cm long, 30 cm wide and 11 cm thick. An aluminum rod 100 cm long was bolted to the top surface of the downstream float so that it extended out over the water the same distance from each side of the float.

At each end of the rod, a 15 cm length aluminum tubing (inside diameter 1.6 cm) was fastened using a right-angle clamp so that the tubing sat perpendicular to the river surface. The aluminum rod extending upwards from the PVC pipe of the drift net was then inserted through this tubing and secured from above with a retaining clip. In this way, the desired sampling depth could be set quickly (Plate 2).

Rationale

Considering the relatively large size of the North Saskatchewan River, it was decided to suspend the drift nets from surface floats. Access to all but the near-shore portions of the river was feasible only by boat and attempts to drive steel stakes into the substrate

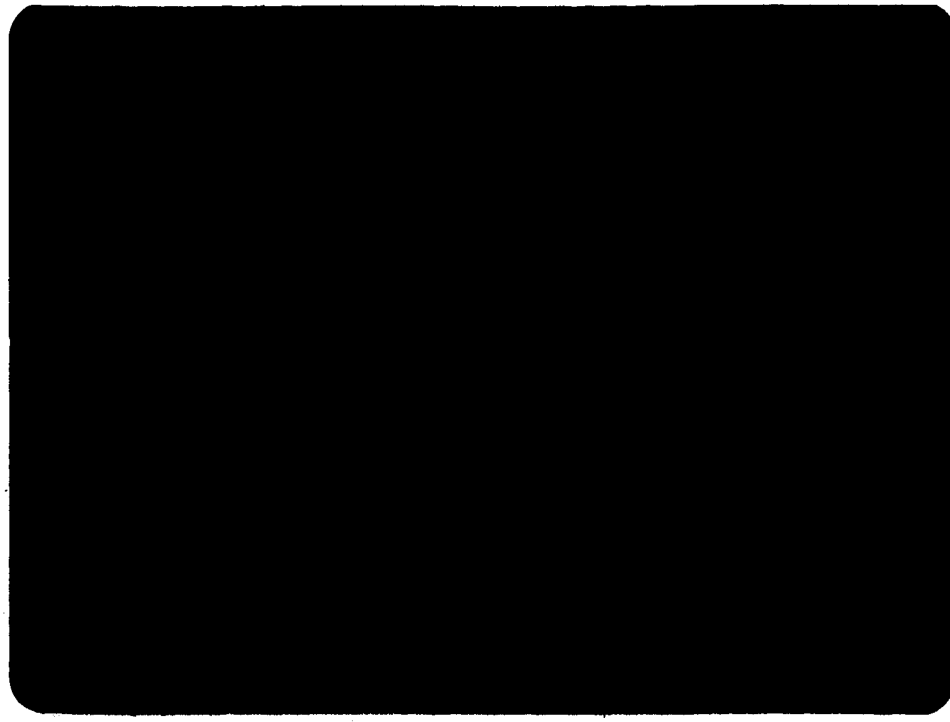


Plate 1 Components of the Drift Net

Plate 2 Float with Drift Nets Attached

failed due to the rocky nature of the river bottom.

The size of the net opening chosen (60.8 cm^2) was quite small in comparison to equipment used by other workers. (For example: 81 cm^2, Clifford (1972); 336 cm^2 Elliott (1967a); 670 cm^2 Griffith (1974) and 929 cm^2, Waters (1962). The small net opening was considered essential for this study to reduce the bulk of material collected by the net during sampling. Preliminary testing of the nets in June and July, 1975 indicated large quantities of organic debris were carried in the river during periods of rainfall and increased discharge and the nets clogged very quickly. The smaller net would present less surface area on which floating twigs and branches could catch and impede the flow of water through the net. Tending the nets to remove such material on a continuous basis would be virtually impossible, especially during the hours of darkness. A small net mouth was also considered advisable based on the very large numbers of drifting Chironomid larvae and Corixids collected at station 2 during preliminary testing. Such large numbers would increase the laboratory time spent on sorting and identification.

Most drift nets described in the literature have a mesh size close to 0.5 mm (Elliott, 1970) although meshes as small as 0.145 mm and as large as 1.0 mm have been reported (Ulfstrand, 1968 and Northcote, 1976). Zelt (1972) has suggested any bottom sampling net with a pore size greater than 0.3 mm misses over half of the fauna (by numbers) and a net of plankton mesh size is required to collect the early instars of some insect species. The mesh size chosen for the present study was 0.333 mm based on advice from Dr. H. Clifford of the Department of Zoology, University of Alberta. Dr. Clifford used a mesh size of 0.32 mm during his study of invertebrate drift in the Bigoray River of west-central Alberta (Clifford, 1972).

The loss of invertebrates through a coarse mesh has been measured by placing a fine mesh plankton net behind the drift net (Elliott, 1970 and Lane, 1974). Elliott, however, found that a drift net of 0.44 mm mesh size retained most invertebrates, chiefly insects and amphipods. This check on drift retention was not attempted during the present study.

The drift nets adopted were one meter long. Preliminary field testing showed this length was adequate to prevent clogging interference with the flow of water through the net mouth.

4.4 Method of Operation

During this study, two drift nets were suspended (one on each side) from the downstream float. This arrangement provided stability and also permitted the collection of drift samples at two different depths, 10 cm below the surface and 10 cm above the river bottom. The downstream float was tied to the anchored upstream float so that the floats were 10 m apart. By approaching the downstream float by boat and from the rear it was found that the nets (complete with aluminum rod) could be attached to and removed from the float quickly and without disturbance of the river bottom.

The material clinging to the inside of the net was washed into the collection bucket by pulling the net through the water a few times, taking care to keep the mouth of the net above the surface. The cap at the end of the collection bucket was then unscrewed and the piece of mesh along with the bucket contents were emptied into a suitable container for preservation with 80 percent ethyl alcohol.

During the period of ice cover at station 1, the operation of the nets was much simpler. A 30 cm diameter hole was first drilled through the ice at each sampling site. The two drift nets were mounted on a single aluminum rod which was lowered through the hole and held in place from the surface by a block of wood laid over the hole. After the nets were positioned, the hole was filled with snow to minimize light penetration. The ice was 40 cm thick on February 18, 1976 and was covered by 20 cm of snow.

River velocities were measured at both depths of each sampling site during every sampling interval throughout the entire study using a hand-held Gurley current meter (Model 622AA). At each point of measurement, three readings were recorded and the results averaged. Readings were usually taken at the mid-point of the drift sampling interval (e.g. for the 1530 - 1630 sample, velocity readings were made at 1600).

4.5 Sampling Efficiency of the Drift Net

4.5.1 Isokinetic Sampling

The flow pattern of a fluid is described by a set of streamlines (lines drawn through the flow field such that the velocity vector at all points on the streamline is tangent to the streamline at that instant). In a steady flow, the flow path corresponds to the streamline pattern. When an object like a drift net is submersed in the flow, the streamline may be distorted as the flow diverts around the leading edge of the net mouth. Sharpening the leading edge of the sampler helps to minimize this distortion.

Particles (including aquatic invertebrates) suspended in the flow possess mass and therefore inertia. The inertia has a directional component identical to the particles' velocity (i.e. along the streamlines). If these streamlines are diverted around the outside of the net mouth, the suspended particles may not follow the streamline but instead leave the streamline and enter the net. This would result in the collection of more particles per unit volume of water than actually existed in the water column and bias the drift density calculations. Only when the velocity inside the net mouth equals the approach velocity of the river flow will the streamline patterns remain undistorted and the correct proportion of suspended particles be collected by the drift sampler. This condition is called isokinetic (equal velocity) sampling (Hrudey, 1977).

4.5.2 Flume Tests

Velocity measurements were always made outside the drift net mouth during this study. In order to determine if these velocity readings accurately represented velocities inside the net mouth (and ensured isokinetic sampling), tests were conducted in a flume at the T. Blench Hydraulic Laboratory. The effects of net clogging and the importance of bevelling the leading edge of the net mouth were also briefly investigated. The experimental set-up is depicted in Figure 9.

Flow in the flume was regulated by varying the height of the weir at the downstream end. During each test, the water depth was maintained at 40 cm and the drift sampler positioned 20 cm below the surface. Velocities were measured using two Kent Miniflow low-speed velocity probes (Model 265-3, propellor-type). The probes were connected to a chart recorder calibrated in Hertz. The chart recordings were later converted to

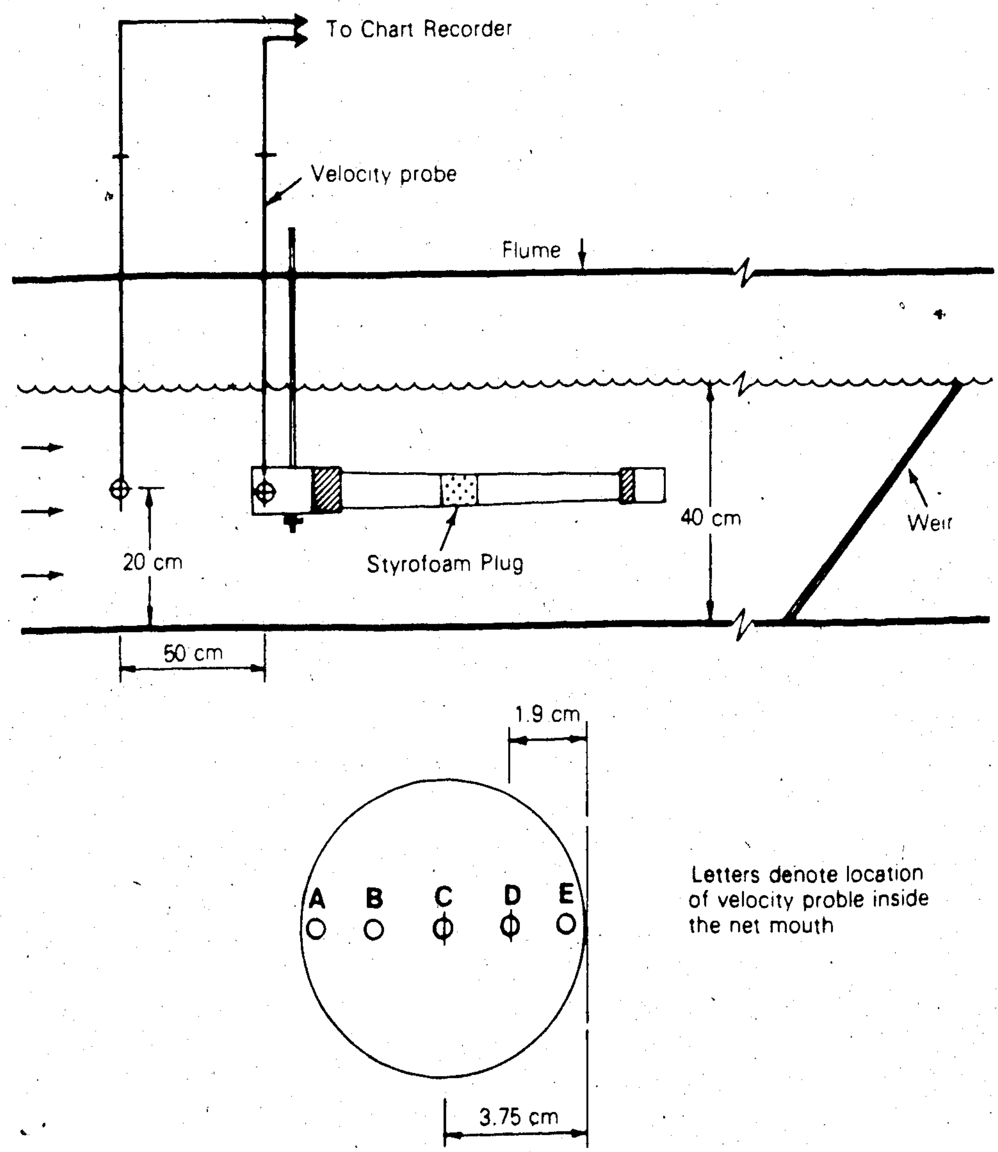


FIGURE 9
Apparatus for Testing Drift Sampler Efficiency

velocity readings using graphs supplied with each velocity probe. Velocities outside the net were always measured 50 cm upstream of the probe located inside the net mouth. Because only one chart recorder was available, velocities were measured outside then inside, outside, inside, etc. until the required number of replications were obtained. Each reading lasted 60 seconds.

In test number one, ten velocity readings were made with the inside probe always at location "C". In test number two, five velocity readings were made at each of locations "A", "B", "C", "D", and "E". In test number three, the net was artificially plugged with a styrofoam block at distances of 55, 35, 25, and 20 cm behind the mouth of the sampler. Five velocity readings were made for each plug location. The inside probe was always positioned at location C.

Differences in the mean velocities measured inside and outside the net were tested for significance using the one-way analysis of variance for two groups with equal sample sizes.

A visible dye was injected near the leading edge of both bevelled and non-bevelled samplers suspended in the flume to observe any flow disruptions around the front of the net.

The results of the flume tests are summarized in Table 7. The velocity data and ANOVA calculations for each experiment are contained in Appendix I, Tables 1 to 10. In test number one, the mean inside and outside velocities were significantly different at the $p < 0.01$ level but not at the $p < 0.001$ level. In test number two, mean velocity differences were significant only at location C (centre of the net mouth).

TABLE 7

Summary of Flume Test Results

Test No.	Location of Inside Velocity Probe	Location of Styrofoam Plug (distance behind net mouth in cm)	No. of Replicates	Mean Velocity Outside Net V_O (cm/s)	Mean Velocity Inside Net V_I (cm/s)	$\frac{V_I}{V_O} \times 100$	F(Degrees of Freedom)
1	C		10	58.8	58.2	98.9	11.00 (1, 8)
2	A		5	59.2	59.6	100.7	1.57 (1, 8)
	B		5	58.8	59.6	101.4	10.67 (1, 8)
	C		5	59.2	58.1	98.1	45.00 (1, 8)
	D		5	59.0	59.1	100.2	0.18 (1, 8)
	E		5	59.3	59.5	100.3	0.42 (1, 8)
3	C	55	5	59.7	58.1	97.3	25.13 (1, 8)
	C	35	5	59.3	59.5	100.3	0.40 (1, 8)
	C	25	5	59.4	54.4	91.6	203.22 (1, 8)
	C	20	5	59.7	43.2	72.4	3573.59 (1, 8)

$F_{.01}$ (1, 18) = 8.28 $F_{.001}$ (1, 18) = 15.4 $F_{.01}$ (1, 8) = 11.3 $F_{.001}$ (1, 8) = 25.4

The inside velocities in both cases of significance were slightly (1.1 and 1.9 percent) less than the velocities measured in front of the net. Conversely, the inside velocities measured at locations "A", "B", D" and "E" were slightly greater (0.2 to 1.4 percent) than the outside velocities. These small cross-sectional changes in velocity may have been caused by the bevelled leading edge of the drift sampler which reduced the flow area, thereby causing the velocity to increase. A similar effect was observed in the first experiment of test number three but not in the second experiment. The net effect of these differences in terms of the accuracy of field velocity readings was probably negligible since the high and low measurements would tend to cancel each other out.

Three obvious sources of experimental error in calculating the velocities were the averaging of the points on the chart paper for each 60 second reading (the flow in the flume was always turbulent); the conversion of H_z to cm/s using graphs; and the use of two separate velocity probes. Therefore, for the purposes of this study, the river current velocities measured in the field during each sampling interval were acceptable for drift density calculations. Also, since the inside and outside velocities were identical, the sampler met the criteria for isokinetic sampling of particulates.

Visible observations of the dye injections did not reveal any obvious flow diversions around the mouth of either the bevelled or non-bevelled nets. Turbulence in the flume dispersed the dye too quickly to discern disruptions in the flow pattern.

The results of the artificial clogging experiments are depicted graphically in Figure 10. Clogging did not affect the inside velocity until the plug was between 20 and 25 cm behind the net mouth (i.e. 70 to 80 percent of the net would have to be full of drift material). Decreased sampling efficiency due to clogging was never a problem during this study since the nets were never more than an estimated 20 percent full after any sampling interval.

4.6 Sampling Schedule

Drift samples were collected at the upstream station 1 near the south shore (1A) and at midstream (1B). No samples were taken near the north shore since lateral differences in water quality were not evident in the river at this location. At the downstream station 2, three sample points were established; one near the south shore (2A), one at midstream (2B) and one near the north shore (2C). The near-shore sample points were usually about 10 m out from the shoreline where depths were similar to those at midstream and where substrate exposure due to fluctuating discharges never occurred.

Seven samples were taken at evenly spaced intervals over the 24-hour period. Initially, the nets were placed in the water for two hours at a time (i.e. 1130 - 1300, 1530 - 1730, ... 1130 - 1330) but this was later reduced to one hour (i.e. 1130 - 1230, 1530 - 1630, ... 1130 - 1230) because of the extremely large number of organisms collected at station 2 and the greater chance for debris to catch on the nets.

The dates on which complete or nearly complete 24-hour samples were obtained are summarized in Table 8.

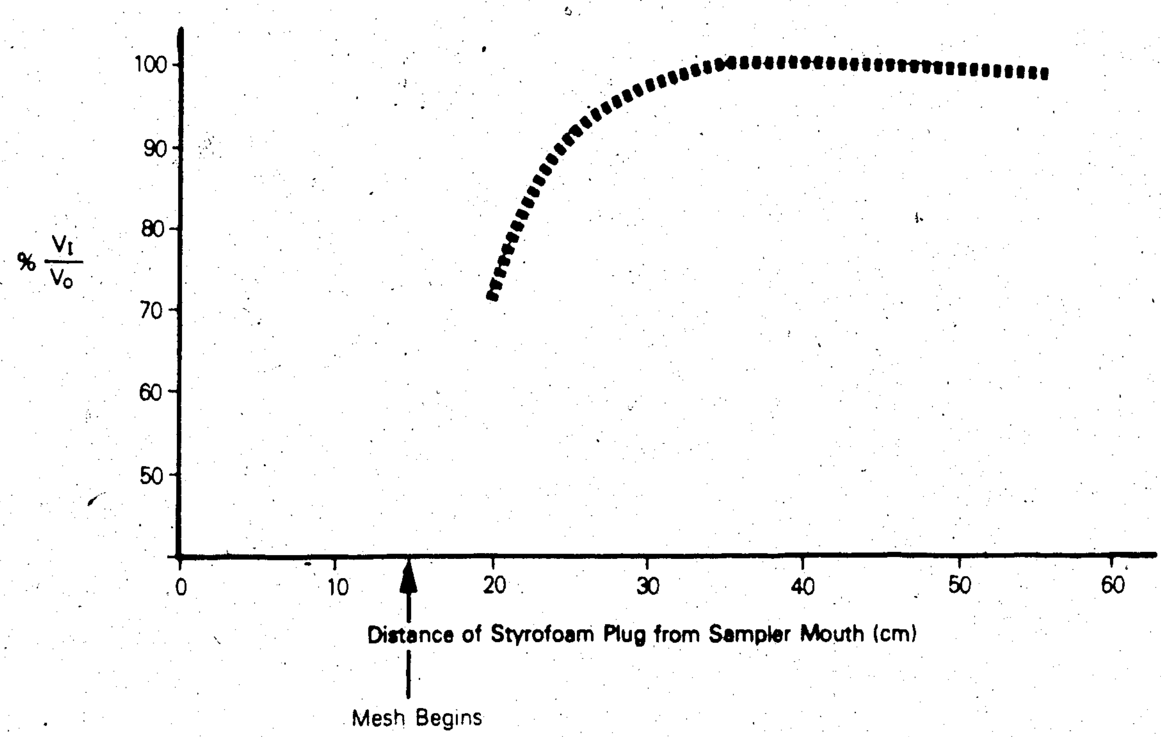


FIGURE 10
Effect of Not Clogging on Sampling Efficiency of the Drift Net

TABLE 8

Dates of Collection for 24-Hour Drift Samples

Station 1	Station 2
28 - 29 October, 1975	9 - 10 November, 1975
18 - 19 February, 1976	9 - 10 March, 1976
21 - 22 June, 1976	28 - 29 June, 1976
21 - 22 July, 1976	22 - 23 September, 1976
10 - 11 October, 1976	

Incomplete collections were made at station 1 on April 19, 28, and 29 and May 19, 1976; and at station 2 on April 19 and May 19, 27 and 28, 1976.

4.7 Drift Sample Analysis

All preserved sample analysis was done in the laboratory. The material collected by the nets was examined at 12X magnification and the organisms picked out and placed in clean vials containing 80 percent ethyl alchol. The organisms were then counted and identified using the keys of Pennak (1953); Edmondson (1959); Ross (1944); Hungerford (1948); and Scott and Crossman (1973).

Identifications were usually taken to the generic level whenever possible. Some of the fish larvae were submitted to Dr. D. Faber of the National Museum of Canada for identification.

Drift densities (number of organisms per 100 m^3 of water) were calculated by first determining the volume of water filtered by the net over a given sampling period.

$$V = Atv \quad \text{where } V = \text{volume of water filtered } (m^3)$$

A = area of net opening (m^2)

t = time net was in water (s)

v = river velocity (m/s)

The number of organisms caught in Vm^3 of water was then multiplied by the appropriate factor $(\frac{100}{V})$ to give the number of organisms per 100 m^3 of water.

4.8 Analysis of Spatial and Temporal Variations in Drift Catches

Elliott(1970) investigated spatial variations in drift catches in a small English stream by studying both the vertical and horizontal distributions of drift rate. He concluded that the drifting invertebrates were randomly distributed in the water column because catches at different depths and, in some cases, at different points across the stream followed a poisson distribution. Elliott also found drift rate to be proportional to the volume of water filtered and concluded that variations in drift density were due to random causes, and drift density could be treated as a poisson variable. In those experiments, a large proportion of the water column was sampled. Clifford (1972) studied the vertical distribution of drift densities in the Bigoray River, Alberta and found no significant ($p < 0.05$) difference in the catches of entomostracans and immature aquatic insects between surface and near-bottom nets.

In the present study samples were always collected at two depths at a given sample point in accordance with Clifford (1972). Possible differences in the total drift densities between top and bottom nets were assessed using the t-test for comparison of means. The total drift densities calculated for the upper and lower nets were paired for each sample interval at each sample point over the entire study period and the t value computed using the formula

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2 + s_2^2}{n}}}$$

$\bar{x}_1$ = mean drift density in the upper net catches

$\bar{x}_2$ = mean drift density in the lower net catches

$\frac{s^2}{n}$ = standard error of the means

n = number of paired samples

The null hypothesis tested was that both upper and lower drift catches came from the same population and had the same means.

Two methods were used to analyze horizontal variations in total drift densities. First, a series of experiments were conducted to determine how the drifting organisms were distributed across a small (1.5 m) section of river. The type of distribution (e.g. regular, random or contagious) must be known before applying parametric statistical tests. Also, it was important to know if a single pair of nets collected a representative drift sample at a given point in the river. Nine nets, each 10 cm apart were placed in the river, 20 cm below the water surface. The nets were suspended from an aluminum rod supported at each end by a stake driven into the substrate. Tests were conducted at station 1A on September 14, 1976 (2030 - 2130) and September 15th (0830 - 0930) and at station 2A on September 9, 1976 (1130 - 1230 and 2330 - 0030). The net contents were analyzed in the same manner as the regular samples. The distributions of the drift catches were tested using the chi-square test (variance to mean ratio) for randomness (Elliott, 1970) using the formula $\chi^2 = \frac{s^2}{\bar{x}} - 1$

s^2 = sample variance; $\bar{x}$ = sample mean. The null hypothesis was that the sample variance equalled the sample mean. Although desirable, a similar experiment across an entire width transect of the river was not considered practical.

The second approach was to compare total drift catches at different points on the same river transect over each 24-hour sampling period. In this case differences in drift densities between near-shore and mid-stream stations and differences in drift densities between sampling intervals were assessed. The test chosen was the two-way analysis of variance (AVOVA). The null hypotheses were that total drift densities at different sampling points were the same and that total drift densities at different sample intervals over a 24-hour period were the same. The two-way ANOVA permitted independent testing of these two hypotheses. Tests were run on each set of 24-hour data (five sets for station 1 and four sets for station 2) using a Wang Laboratories Limited Model 700 programmable calculator.

5.0 RESULTS AND DISCUSSION

5.1 Drift Density Analyses

5.1.1 Vertical Distribution of Drift Densities

There was no statistically significant difference ($p < 0.01$) in total drift densities between the upper and lower nets for all paired samples collected during this study ($n = 160$, $df = 159$, calculated $t = -0.92$, $t_{.01}(159) = 2.61$ for a two-sided test). The absolute value of the calculated t indicated a probability of only 35 percent that the samples came from different populations. Therefore, the null hypothesis was accepted and it was assumed that the drifting organisms at stations 1 and 2 were distributed evenly in the water column. This finding was consistant with the shallow and turbulent nature of the river flow at both locations. Drift catches in the upper and lower nets were combined and treated as one sample for all other analyses and presentations.

5.1.2 Variations in Drift Catches Across a Small (1.5 m) River Section

The results of the four experiments are summarized in Table 9. Details of the catches of drifting organisms are given separately in Appendix II, Tables 1 and 2. All the calculated chi-square values fell within the one percent significance levels for eight degrees of freedom (from Pearson and Hartley, 1966, Table 8). Therefore, the null hypothesis was accepted in each test and it was assumed the catches of drifting organisms did not vary significantly ($p < 0.01$) from a poisson distribution. Based on these results it was assumed that drift densities at stations

TABLE 9

Results of the Horizontal Drift Variation Experiments

Sample Location and Date	Net Number (total number of organisms collected per net) 1	2	3	4	5	6	7	8	9	N	$\bar{x}$	s^2	X^2
Station 1A 14 Sept. 76 2030 - 2130	985	975	940	1006	964	1077	988	937	949	8821	980.1	1858.1	15.17 n.s.
Station 1A 15 Sept. 76 0830 - 0930	189	226	188	219	205	187	194	164	153	1725	191.7	551.5	23.02 n.s.
Station 2A 9 Sept. 76 1130 - 1230	25	20	22	20	23	17	15	23	15	180	20	13.23	5.3 n.s.
Station 2A 9 Sept. 76 2330 - 0030	11	13	1	11	14	10	9	15	6	90	10	18.75	15 n.s.

N = total number of organisms

$\bar{x}$ = mean number of organisms per net

s^2 = variance

X^2 = calculated chi-square = $\frac{(n-1)s^2}{\bar{x}}$

1% significance levels for X^2 with 8 degrees of freedom: upper 26.125, lower 1.344

n.s. - not significant

1 and 2 were fairly constant (at least over short time periods), that variations were due to random causes and that drift density could be treated as a poisson variable. The results also suggested that one pair of nets probably collected a representative drift sample at a particular point in the river during periods of high drift density (as occurred at station 1A) and low drift density (station 2A).

5.1.3 Horizontal and 24-Hour Variations in Drift Densities Between Points on the Same River Transect Station 1

Average total drift densities recorded at stations 1A and 1B for each sample interval and each sample period are presented graphically in Figure 11. The results of the two-way ANOVAS are given in Appendix III, Tables 1 to 5. Since the ANOVA is a parametric test, all average drift density values had to be transformed to ensure normally distributed data. The square root transformation was used in all cases because there were no zero values (Sokal and Rohlf, 1969).

On all five occasions, the variations in drift densities between stations 1A and 1B were not significant ($p < 0.01$). Therefore, the first null hypothesis (sample location drift densities are the same) was accepted. At station 1, then, drift density was probably quite uniform across the entire river section. This was expected given the very uniform conditions of river depth, velocity, substrate and chemical quality at that station.

Variations in drift densities due to time of sampling (i.e. sample interval) at station 1 were significant ($p < 0.01$)

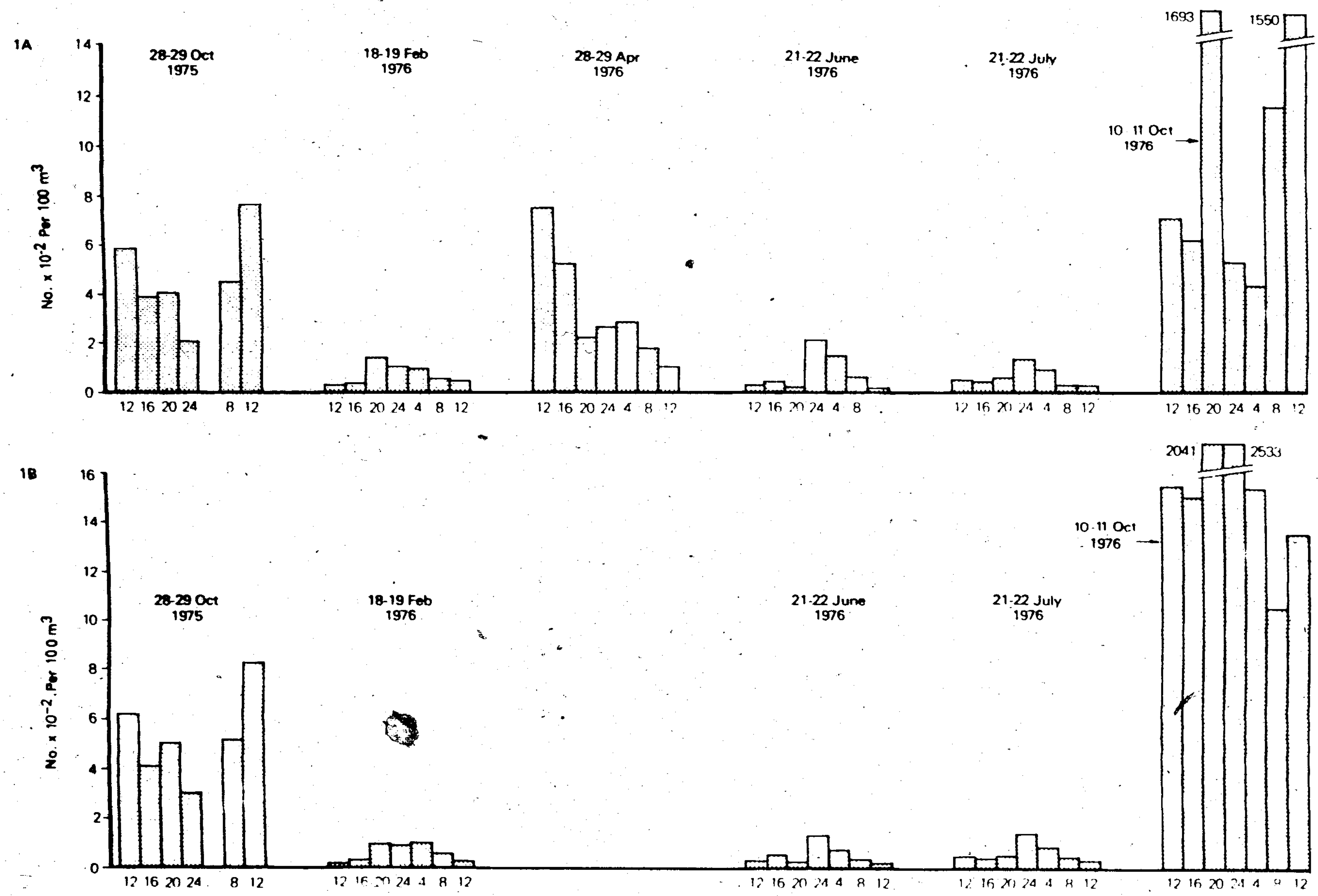


FIGURE 11
Average Total Drift Densities Per 24 Hour Sampling Interval at Station 1

during all but the October, 1976 sample period. Therefore, the second null hypothesis (sample interval drift densities were the same) was rejected. Three of the sample periods (February, June, and July, 1976) showed obvious diel patterns in drift density (Figure 11), with the highest densities occurring during the hours of darkness. Behavioral drift (discussed in Section 2.2) probably accounted for these variations. Variations in drift density between sampling intervals during October, 1975 were also significant but with no apparent diel pattern. These samples and the October, 1976 samples were characterized by high drift densities and large numbers of Corixids which masked behavioral drift patterns associated with other less abundant immature aquatic insects.

Station 2

Average total drift densities recorded at stations 2A, 2B and 2C for each sample interval and sample period are presented graphically in Figure 12. The results of the two-way ANOVAS using transformed values are given in Appendix III, Tables 6 to 9. Drift density variations across the river transect were significant ($p<0.01$) on three of four occasions. On the fourth occasion (June, 1976) the variations were significant at the five percent level but not at the one percent level. Therefore, the first null hypothesis (no difference in sample location drift density) was rejected. In all cases drift densities were much lower at station 2C in comparison to stations 2A and 2B. This result was opposite to the station 1 results where such variations were not significant.

Drift density variations between sample intervals were not significant ($p<0.01$) during three of the four periods

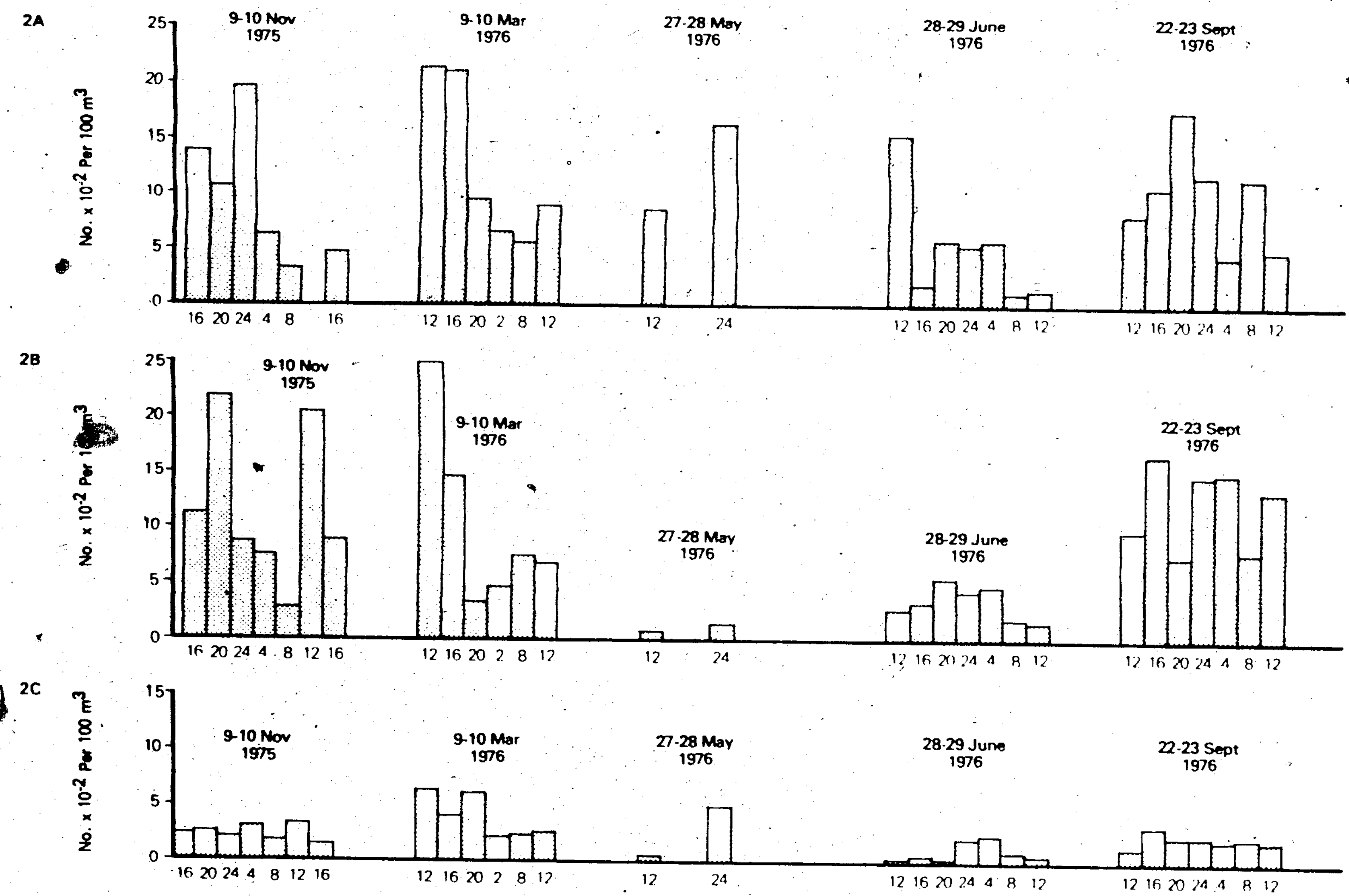


FIGURE 12
Average Total Drift Densities Per 24 Hour Sampling Interval at Station 2

analyzed, again in contrast to the situation found at station 1. The fourth period (March, 1976) did exhibit significant variations in drift density over the 24-hour sample period but no pattern was evident. Thus the second null hypothesis (no difference in sample interval drift density) was accepted. Drift densities were generally high at station 2 during all sampling periods and the catches were mainly comprised of organisms known to exhibit no particular diel drift pattern (e.g. chironomids, oligochaetes and corixids).

5.1.4 Significance of Drift Density Analyses to Water Quality Assessment in the North Saskatchewan River

The results above have clearly demonstrated important differences in the drift characteristics between the two stations during the period of study. These can be summarized as follows:

Characteristics	Station 1	Station 2
Local distribution of drifting organisms	Random	Random
Drift density variations between sample points across river cross-section	Not Significant ($p < 0.01$)	Significant ($p < 0.01$)
Drift density variations between sample time intervals	Significant ($p < 0.01$)	Not significant ($p < 0.01$)

Considering only drift densities (without regard to species composition) a quantitative method for assessing differences in water quality has been demonstrated. Station 1 located upstream of the City of Edmonton was selected as a control to represent river conditions not affected by large wastewater loadings. Drift densities did not vary between the near-shore and midstream sample points during all seasons. Significant night-time peaks in drift densities were observed during most seasons. These were a result of behavioral activities of immature aquatic insects generally associated with clean-water conditions. The drift patterns at station 1 were typical of those reported by others in studies of smaller streams not affected by pollution (eg. Waters, 1965; Bishop and Hynes, 1969; Elliott, 1970; and Clifford, 1972).

Station 2 was situated downstream of most of the major sources of wastewater loadings from the City of Edmonton. The drift patterns at this station were reversed from those at station 1. Drift densities on the north (station 2C) side of the river were consistently less than those at midstream or near the south shore, suggesting the full impact of wastewater discharges had not yet reached the north shore at station 2. Chemical and bacteriological analyses (Tables 4 and 5, Section 4.3) certainly indicated this to be the case. Diel variations with night-time maxima in total drift densities were never apparent at station 2 during the study. The constant drift of large numbers of oligochaetes and chironomids (taxa which are characteristic of organically enriched environments and were very rare in the drift catches at station 1) overshadowed any behavioral drift patterns.

Average total drift densities over the entire study period (only 24-hour sample periods considered) were higher at station 2 (n = 12, mean = 706.1, range 88 - 1217) in comparison to station 1 (n = 11, mean = 392.9, range 54 - 957). No attempt was made to statistically evaluate these differences or seasonal differences because the samples were not collected at closely corresponding time periods. If, however, it were possible to collect drift samples at different stations at the same time or at least within one or two days, during different seasons, an addition ANOVA could be run to test variations between stations and between seasons. Larimore (1974) was able to collect drift samples in this manner at five stations in the Salt Fork Basin, Illinois, during four different months of the year, but he did not statistically analyze the results.

Although only two river transects were sampled during this study, the addition of several more transects upstream and downstream of station 2 would have provided a more complete analysis of the extent (both lateral and horizontal) of water quality deterioration (nutrient enrichment) in the North Saskatchewan River. Again, using only drift density data, it should be possible to identify where lateral mixing of pollutants is complete and also the point where the river returns to upstream control conditions.

5.2 Drift Characteristics of Selected Taxa

5.2.1 Composition of the Drifting Fauna - Summary

A total of 49 taxa representing seven phyla were identified in the drift catches during this study (Table 10). Aquatic insects accounted for 37 (75 percent) of these taxa and in terms of total numbers of drift organisms collected, comprised 96 percent of the catches at station 1 and 84 percent of the catches at station 2. The only non-aquatic organisms collected were two spiders (O. Araneae) caught at station 2B in November, 1975. Invertebrates of terrestrial origin are usually found in drift collections where the nets sample the water surface and

TABLE 10

Taxonomic List of Drift Organisms
Collected During the Entire Study

	Station 1	Station 2
Phylum Arthropoda		
Class Arachnoidea		
O. Araneae		x
O. Hydracarina	x	
Class Insecta		
O. Coleoptera		
F. Dytiscidae		
Dytiscus sp.	x	
Hydroporinae	x	
Hydrovatus sp.	x	x
F. Elmidae	x	
O. Collembola		
F. Isotomidae		x
O. Diptera		
F. Ceratopogonidae	x	x
F. Chironomidae	x	x
F. Simuliidae	x	
F. Tabanidae	x	
Atherix sp.		x
Chrysops sp.	x	
Tabanus sp.		x
O. Ephemeroptera		
Ameletus sp.	x	x
Baetis sp.	x	x
Caenis sp.		x
Ephemerella sp.	x	x
S.F. Heptageniinae	x	x
Hexagenia sp.	x	
Leptophlebia sp.	x	x
Pseudocleon sp.	x	
Rhithrogena sp.	x	x
Stenonema sp.		x
Tricorythodes sp.		x
O. Hemiptera		
F. Corixidae	x	x

TABLE 10 (continued)

Taxonomic List of Drift Organisms
Collected During the Entire Study

	Station 1	Station 2
O. Plecoptera		
Acroneuria sp.	x	
Brachyptera sp.	x	x
Capnia sp.	x	x
Hastaperla sp.	x	
Isogenus sp.	x	x
Isoperla sp.	x	
Nemoura sp.		x
O. Trichoptera		
Agapetus sp.	x	x
Arctopsyche sp.	x	x
Brachycentrus sp.	x	x
Cheumatopsyche sp.	x	x
Hydropsyche sp.	x	x
Psychomyia sp.	x	
Phylum Annelida		
Class Oligochaeta	x	x
Phylum Bryozoa		
Plumatella sp.	x	
Phylum Coelenterata		
Hydra sp.		x
Phylum Nematomorpha		
Gordius sp.	x	x
Phylum Mollusca		
Class Gastropoda		
Ferrissia sp.		x
Lymnaea sp.	x	x

TABLE 10 (continued)

Taxonomic List of Drift Organisms
Collected During the Entire Study

	Station 1	Station 2
Phylum Chordata		
Class Pisces		
F. Catastomidae		
Catastomus sp.	x	x
F. Cyprinidae		x
F. Cottidae		x
F. Gadidae		
Lota lota	x	x

where overhanging bankside vegetation is present. They sometimes comprise a large proportion of the total drift catch (Elliott, 1967a; Bishop and Hynes, 1969; and Clifford, 1972). In the present study, the river surface was not sampled and bankside vegetation was very sparse or non-existent at stations 1 and 2. Therefore, organisms of terrestrial origin were never an important component of the drift.

The major groups of aquatic invertebrates collected from the North Saskatchewan River near Edmonton in other studies (Paterson and Nursall, 1975; and Reynoldson, 1974) were also collected in this study. Comparisons of the taxonomic composition between these studies is difficult because of differences in sampling methods, sample locations, date of collection and level of taxonomy used. However, following the level of taxonomy used in this study, the drift method collected 42 aquatic invertebrate taxa as compared to nine (Reynoldson, 1974 - samples collected with a modified Hess sampler) and 18 (Paterson and Nursall, 1975 - samples collected with a Surber sampler and Ekman dredge). From this, it is apparent the drift catches did not misrepresent the faunal composition of the bottom community. Benthic invertebrates, not likely to be collected in the drift such as Pelecypoda (clams), Gastropoda (snails) and stone-cased Trichoptera larvae have not been reported as abundant in this section of the North Saskatchewan River.

All but one aquatic taxon collected in this study are included in the synopsis of Nearctic drift taxa prepared by Adamus and Gaufin (1976). The exception was the burbot (Lota lota).

The detailed analyses of each drift sample are given in Appendices IV and V. Average total drift densities over each 24-hour sample interval were discussed in Section 5.1 and illustrated in Figures 11 and 12. Before discussing selected taxa in more detail, a general description of the drift fauna composition, at each station, is presented here. The percentage composition of the major drift taxa in the 24-hour samples collected at stations 1A, 1B, 2A, 2B and 2C is summarized in Tables 11 to 15.

The total densities and taxonomic composition of the drift at stations 1A and 1B were very similar throughout the study. Highest densities were recorded in October, 1975 and October, 1976 when Corixids dominated the catches (94.5 to 98.1 percent). Drift densities in the winter and summer at these stations were much lower and the composition distributed more evenly among several groups including mayflies (Ephemeroptera), stoneflies (Plecoptera), caddis flies (Trichoptera) and chironomids. Burbot fry accounted for 66 percent of the drifting organisms collected at station 1A in April, 1976. From Tables 11 and 12, those taxa (excluding Corixids and fish), which comprised by numbers at least ten percent of the total drift on one date or one percent on two or more sampling dates, included Chironomidae, _Baetis_ sp.; _Ephemerella_ sp.; _Rhithrogena_ sp.; _Brachyptera_ sp.; _Isogenus_ sp.; _Capnia_ sp.; _Brachycentrus_ sp.; and _Cheumatopsyche_ sp.

Drift densities at stations 2A and 2B were always similar and much higher than densities at station 2C. In contrast to the upstream station, three groups, chironomids, oligochaetes and corixids dominated the drift catches, the first two being

TABLE 11

Percentage Composition of the Major Drift Taxa Occurring in the 24-Hour Samples at Station 1A

Taxa	28-29 October 1975 No.	28-29 October 1975 %	18-19 February 1976 No.	18-19 February 1976 %	28-29 April 1976 No.	28-29 April 1976 %	21-22 June 1976 No.	21-22 June 1976 %	21-22 July 1976 No.	21-22 July 1976 %	10-11 October 1976 No.	10-11 October 1976 %
Corixidae	1418	94.5	197	50.1	29	4.9					2376	96.8
Chironomidae (l)	5	0.26	26	6.6	53	9.0	46	24.5	42	21.9	4	0.16
(p)							11	5.9	30	15.6	4	0.16
(a)	2	0.13					11	5.9	30	15.6	4	0.16
Ephemeroptera (total)	37	2.5	68	17.3	40	6.8	71	37.7	55	28.1	40	1.6
Baetis sp.	17	1.13	52	13.2	18	3.0	52	27.6	22	11.4	23	0.9
Ephemerella sp.	7	0.5	10	2.5	15	2.6			3	1.5	5	0.2
Heptageniinae	1	0.07	2	0.5			2	1.1	13	6.7	2	0.8
Rhithrogena sp.	11	0.7	3	0.76	1	0.17	4	2.2	4	2.1	9	0.4
Leptophlebia sp.			1	0.25	4	0.7					1	0.04
Plecoptera (total)	16	1.1	94	23.9	53	8.8	18	9.6	16	8.3	11	0.5
Brachyptera sp.	11	0.7	42	10.7	10	1.7					4	0.16
Isogenus sp.	3	0.2	22	5.6	40	6.8	17	9.0	13	6.7	5	0.2
Capnia sp.	2	0.13	30	7.6	2	0.34			3	1.5	2	0.08
Trichoptera (total)	19	1.3	8	2.0	6	1.0	21	11.2	14	7.3	10	0.4
Brachycentrus sp.							16	8.5	6	3.1		
Chuamatopsyche sp.	14	0.93	8	2.0	3	0.5	1	0.5	8	4.2	6	0.24
Hydropsyche sp.	5	0.3					1	0.5			4	0.16
Pisces												
Catastomus sp.					1	0.17	1	0.5	7	3.6	1	0.4
Lota lota					390	66.0						
Others	3	0.13			19	3.2	8	4.25	11	5.7	4	0.16

TABLE 12

Percentage Composition of the Major Drift Taxa Occurring in the 24-Hour Samples at Station 1B

Taxa	Date									
	28-29 October 1975		18-19 February 1976		21-22 June 1976		21-22 July 1976		10-11 October 1976	
	No.	%	No.	%	No.	%	No.	%	No.	%
Corixidae	1827	95	168	64.1					4334	98.1
Chironomidae (l)	5	0.26	7	2.7	45	28.7	52	25.7	11	0.25
(p)					25	15.3	32	15.8	3	0.7
(a)	1	0.05			8	5.1	19	9.4	4	0.09
Ephemeroptera (total)	37	1.9	31	11.8	45	28.7	46	22.8	32	0.7
Baetis sp.	19	1.0	26	9.9	29	18.5	31	15.3	17	0.4
Ephemerella sp.	4	0.2	4	1.5	2	1.3	2	1.0	4	0.09
Heptageniinae					1	0.6	5	2.5		
Rhithrogena sp.	13	0.67	1	0.4	6	3.8	8	3.9	11	0.25
Plecoptera (total)	18	0.93	45	17.1	8	5.1	18	8.9	9	0.2
Brachyptera sp.	6	0.3	21	8.0					4	0.09
Capnia sp.	2	0.1	8	3.1			7	3.5		
Isogenus sp.	9	0.47	13	4.9	7	4.4	11	5.4	4	0.09
Trichoptera (total)	36	1.8	5	1.9	14	8.9	18	8.9	18	0.4
Brachycentrus sp.					8	5.1	5	2.5		
Cheumatopsyche sp.	28	1.5	5	1.9	5	3.2	13	6.4	13	0.3
Hydropsyche sp.	6	0.3							5	0.1
Pisces										
Catastomus sp.			2	0.8	3	1.9	4	2.0	1	0.02
Others			4	1.5	10	6.4	13	6.4	1	0.02

TABLE 13

Percentage Composition of the Major Drift Taxa Occurring in the 24-Hour Samples at Station 2A

Taxa	Date									
	9-10 November 1975		9-10 March 1976		27-28 May 1976		28-29 June 1976		22-23 September 1976	
	No.	%	No.	%	No.	%	No.	%	No.	%
Corixidae	1079	34.9	862	28.7			1	0.08	84	3.6
Chironomidae (l)	1476	47.7	1558	52	13	1.6	53	4.4	1677	71.9
(p)	20	0.6	34	1.1	58	7.0	52	4.4	18	0.8
(a)	282	9.1	110	3.6	29	3.5	465	39	217	9.3
Ephemeroptera (total)	12	0.4	41	1.4	2	0.24	102	8.5	18	0.8
Baetis sp.	1	0.03	26	0.9	1	0.1	81	6.8	12	0.5
Ephemerella sp.			2	0.7						
Heptageniinae	2	0.06			1	0.1	13	1.1	4	0.17
Leptophlebia sp.	9	0.3	10	0.33						
Plecoptera (total)	5	0.16	9	0.3	3	0.36	57	4.8	8	0.3
Brachyptera sp.	1	0.03							2	0.09
Capnia sp.			9	0.3						
Isogenus sp.	4	0.12			3	0.36	57	4.8	6	0.26
Trichoptera (total)	2	0.06	5	0.2	2	0.24	29	2.4	10	0.4
Cheumatopsyche sp.							5	0.17		
Hydropsyche sp.	2	0.6	3	0.1	2	0.24	24	2.0	10	0.4
Oligochaeta	215	6.9	379	12.6	595	72.4	418	35.1	297	12.7
Pisces										
Catastomus sp.					120	14.6	11	0.9	1	0.04
Others	4	0.12	1	0.03	1	0.1	4	0.3	1	0.04

TABLE 14

Percentage Composition of the Major Drift Taxa Occurring in the 24-Hour Samples at Station 2B

Taxa	9-10 November 1975		9-10 March 1976		27-28 May 1976		28-29 June 1976		22-23 September 1976	
	No.	%	No.	%	No.	%	No.	%	No.	%
Corixidae	1024	22.5	35	1.1						
Chironomidae (l)	2835	62.4	2777	88.0	3	4.6	43	5.0	2006	70.1
(p)	12	0.26	26	0.8	2	3.1	58	6.7	23	0.8
(a)	313	6.9	2	0.06			326	37.8	499	17.6
Ephemeroptera (total)	14	0.3	45	1.4	5	7.7	134	15.5	21	0.74
Baetis sp.	2	0.04	30	0.95	1	1.5	110	12.7	8	0.3
Ephemerella sp.	1	0.02	10	0.3	4	6.1	3	0.35	3	0.1
Heptageniinae	2	0.04					17	1.9	3	0.1
Leptophlebia sp.	7	0.15	3	0.09					5	0.2
Plecoptera (total)	5	0.1	7	0.2	11	16.9	49	5.7	11	0.4
Brachyptera sp.	1	0.02	2	0.06					1	0.03
Capnia sp.			1	0.03						
Isogenus sp.	4	0.08	3	0.03	11	16.9	49	5.7	10	0.35
Trichoptera (total)	10	0.02	5	0.16	1	1.5	26	3.0	7	0.25
Cheumatopsyche sp.	3	0.03					6	0.7	3	0.1
Hydropsyche sp.	6	0.13	1	0.03	1	1.5	20	2.3	4	0.14
Oligochaeta	320	7.0	255	8	23	35.3	221	25.6	205	7.2
Pisces										
Catastomus sp.			1	0.03	20	30.7	5	0.6		
Others	9	0.2	4	0.13						

TABLE 15

Percentage Composition of the Major Drift Taxa Occurring in

the 24-Hour Samples at Station 2C

Taxa	Date									
	9-10 November 1975		9-10 March 1976		27-28 May 1976		28-29 June 1976		22-23 September 1976	
	No.	%	No.	%	No.	%	No.	%	No.	%
Corixidae	216	20.7	68	4.5						
Chironomidae (l)	389	37.3	1026	68.2	11	7.1	57	21.1	343	55.5
(p)	10	0.96	14	0.9	47	30.5	11	4.1	14	2.3
(a)	147	14.1	6	0.4	4	0.26	4	1.5	27	4.4
Ephemeroptera (total)	20	1.9	191	12.7	8	5.2	145	53.7	18	2.9
Baetis sp.	5	0.48	154	10.2	2	1.3	140	51.9	9	1.5
Ephemerella sp.	2	0.19	20	1.3	6	3.9	2		1	0.16
Heptageniinae	2	0.19	9	0.6					3	0.5
Leptophlebia sp.	11	1.1	2	0.13			2	0.7	3	0.5
Plecoptera (total)	7	0.7	21	1.4	1	0.65	11	4.1	15	2.4
Brachyptera sp.	2	0.19								
Capnia sp.			2	0.13						
Isogenus sp.	5	0.48								
Trichoptera (total)	9	0.86	1	0.06	6	3.8	27	10.0	4	0.6
Cheumatopsyche sp.					3	1.9	2	0.7		
Hydropsyche sp.	9	0.86			3	1.9	25	9.3	4	0.6
Oligochaeta	243	23.3	177	11.8	21	13.6	8	3.0	134	21.7
Pisces										
Catastomus sp.					58	37.6	2	0.7	1	0.16
Others	2	0.19			1	0.65	5	1.9	1	0.16

abundant in all samples collected at station 2. At station 2A, only the Chironomidae and Oligochaeta comprised, by numbers, at least ten percent of the total drift catch on one date or one percent on two or more dates (Table 13). At station 2B, Chironomidae, Baetis sp.; Isogenus sp.; Hydropsyche sp.; and Oligochaeta met these criteria (Table 14) and at station 2C the preceding groups plus Ephemerella sp. were included (Table 15). Wastewater loadings to the North Saskatchewan River downstream from station 1 have resulted in a reduction in the diversity of the dominant drift organisms at station 2, this effect being most discernable on the south side of the river.

5.2.2 Corixidae

Adult Corixidae were extremely abundant in drift collections made at station 1 in October, 1975; February, 1976; and October, 1976 and at station 2 in November, 1975; and March, 1976. Average densities of drifting corixids at station 1 were 472/100 m^3 on October 28 - 29, 1975; 36/100 m^3 on February 18 - 19, 1976; and 1273/100 m^3 on October 28 - 29, 1976. At station 2 on November 9 - 10, 1975, average densities were 54/100 m^3 on the north side, 259/100 m^3 in midstream and 338/100 m^3 on the south side. The corresponding densities for the March 10 - 11, 1976 samples were 18/100 m^3; 11/100 m^3; and 349/100 m^3 respectively. On September 23, 1976 corixids were only collected on the south side of the river (average density 35/100 m^3).

With the exception of a single specimen collected at station 2A on June 28, 1976, Corixids were absent from all drift samples collected during the spring and summer of 1976. In addition, no nymphal instars occurred in any of the drift samples, suggesting these insects were not permanent residents of the North Saskatchewan River near Edmonton. Corixid adults are capable of flight and may have migrated to the river from nearby ponds and lakes. According to Pennak (1953), adult female corixids typically attach their eggs to the stems of aquatic plants. Aquatic vegetation was very sparse in the North Saskatchewan River near Edmonton and, therefore, suitable rearing habitat may have been lacking. This unknown aspect of corixid biology in the North Saskatchewan River warrants further study.

The roles that such large numbers of Corixids played at certain times of the year in the river ecosystem were not investigated but two were apparent. First, corixids are organic detritivores and if they were feeding, must have been responsible for processing a large quantity of organic material on the river bottom. Second, they must provide forage for predaceous organisms including fish. This was certainly the case for mature goldeye (*Hiodon alosoides*) collected near the study area in October, 1975. The stomachs of most specimens were gorged with corixids (Environmental Protection Service, Edmonton Regional Office, unpublished data, 1976).

5.2.3 Chironomidae

Chironomid larvae, pupae and adults were collected in the drift at all stations but were most abundant at station 2. At station 1, chironomids comprised only a small proportion of the 24-hour drift catches except during June and July, 1976 when they accounted for 36 to 51 percent of the total numbers of organisms collected. Average drift densities in the June 21 - 22, 1976 and July 21 - 22, 1976 samples at station 1A were 27/100 m^3 and 30/100 m^3. Chironomid densities at station 1B on the same dates were 26/100 m^3 and 34/100 m^3 respectively. These two sample dates corresponded to periods of adult emergence and the ratio of numbers of chironomid larvae to pupae and adults was near unity at each station. The Chironomidae were the only aquatic insect group which had adult individuals in the drift catches at stations 1 and 2.

At station 2, chironomids were abundant in all 24-hour drift samples and accounted for 27 to 89 percent by numbers of the total catches. Average 24-hour drift densities ranged from 250/100 m^3 to 805/100 m^3 at station 2A, 172/100 m^3 to 1096/100 m^3 at station 2B and 29/100 m^3 to 281/100 m^3 at station 2C. Densities at stations 2A and 2B were always three to five times higher than at station 2C. The density of drifting chironomids at station 2 was generally an order of magnitude higher than densities at station 1 upstream of Edmonton. In contrast to station 1, chironomid pupae and adults were common in all 24-hour samples and emergence periods were not as distinct.

The abundance of chironomids in the drift at station 2 indicated an organically enriched river environment. The growth of large numbers of chironomids is favoured in waterbodies receiving sewage-type wastes (Section 2.4.1) and are usually found in association with large numbers of tubificid worms (Hynes, 1960). The species of Chironomidae occurring in these zones of degradation are usually determined by the severity of the pollution. For example, larvae of the genus Chironomus (commonly known as blood-worms) are known to tolerate quite severe oxygen depletion (Hynes, 1960). The chironomids collected in this study were not identified beyond the family level; however, some species identifications were made of chironomids collected from the North Saskatchewan River near Edmonton in the fall of 1974 (Boerger, 1975). The most common species found in several collections near station 2A was Cricotopus tremulus, a member of the sub-family Orthocladiinae. Hynes (1960) reported this sub-family can be abundant in rivers below sewage outfalls when the water is well oxygenated. Reynoldson (1974) also reported large numbers of Orthocladiinae in the North Saskatchewan River downstream from Edmonton. Lower chironomid densities at station 2C suggested less severe organic enrichment on that side of the river.

5.2.4 Oligochaeta

Oligochaetes were extremely rare at stations 1A and 1B; only 17 individuals were collected during the entire study. At station 2, Oligochaetes comprised 3 to 35 percent by numbers of the 24-hour drift catches. Average densities in the 24-hour samples ranged from 67/100 m^3 to 183/100 m^3 at station 2A, 82/100 m^3 to 89/100 m^3 at station 2B, and 3/100 m^3 to 61/100 m^3 at station 2C.

Oligochaetes, particularly the family Tubificidae, are, like the Chironomids, an indicator of organic enrichment. They thrive in bottom habitats where organic material has accumulated and where oxygen demand may be high. Both Paterson and Nursall (1975), and Reynoldson (1974) reported large numbers of Oligochaetes in the North Saskatchewan River downstream of Edmonton. Lower Oligochaete densities at station 2C again suggested the effects of wastewater loadings were less severe on the north side of the river.

5.2.5 Ephemeroptera

Mayfly nymphs were collected in all 24-hour drift samples at stations 1 and 2 and comprised 0.3 to 53.7 percent by numbers of the total catches. At station 1, average drift densities ranged from 7/100 m^3 to 28/100 m^3, the highest occurring in the June 21 - 22, 1976 samples. *Baetis* sp. was the most common mayfly in all samples at station 1, followed by *Rhithrogena* sp. and *Ephemerella* sp. Other mayfly genera occurred only sporadically. Diel drift patterns were evident at station 1 on most occasions with peak densities occurring during the hours of darkness (Figures 13 and 14).

Average mayfly densities in the 24-hour samples at stations 2A, 2B and 2C were similar, ranging from 4/100 m^3 to 58/100 m^3. Highest densities were recorded in the June 28 - 29, 1976 samples, the only dates on which obvious diel patterns were evident at all three sampling locatio[illegible]ure 15). *Baetis* sp. was also the most common mayfly at station 2 and was most numerous in samples collected at stations 2A, 2B and 2C on June 28 - 29, 1976 and at station 2C on March 9 - 10, 1976. *Ephemerella* sp. and Heptageniinae were the only other mayflies occurring regularly in the drift samples at station 2.

Eleven Ephemeroptera genera were collected during this

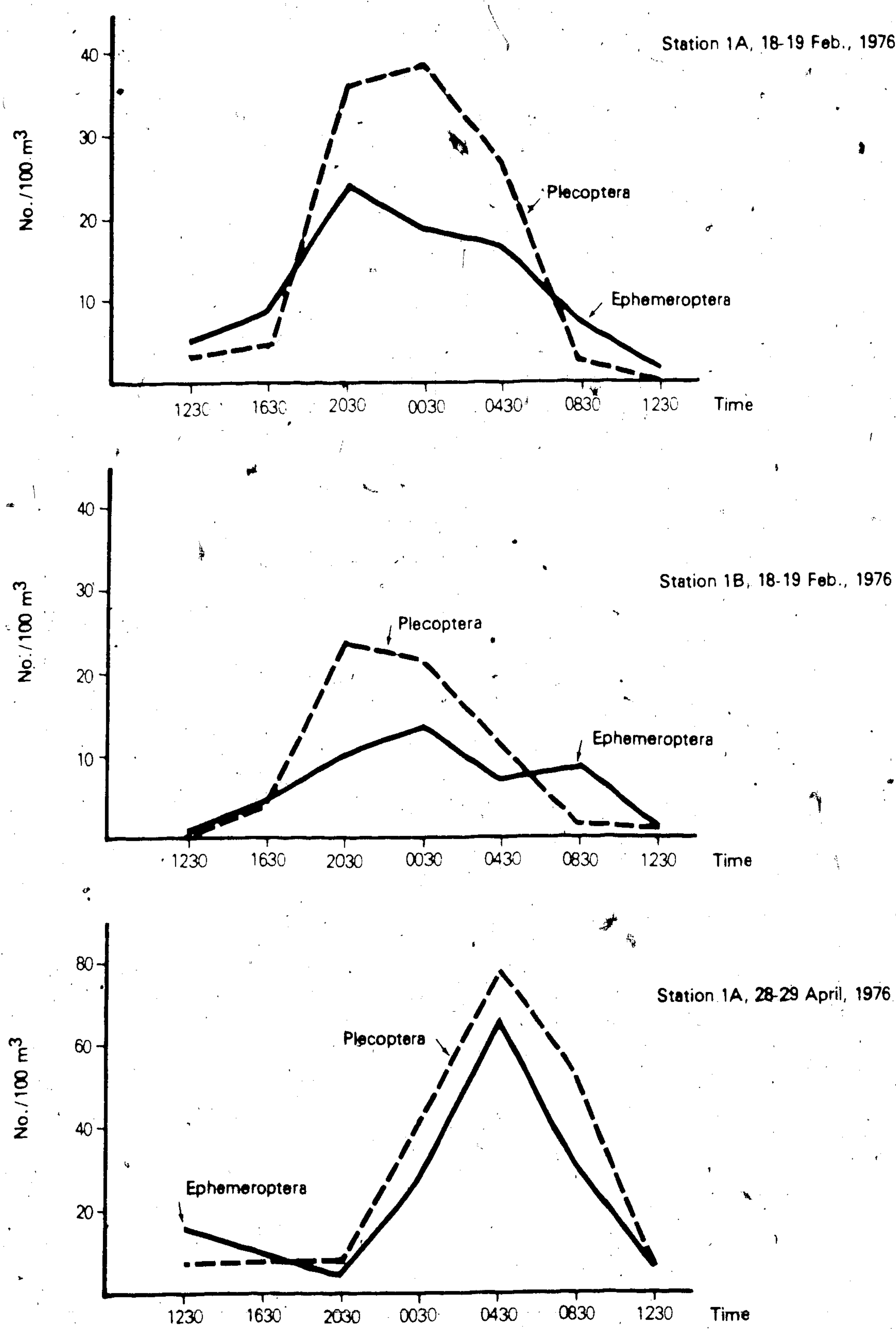
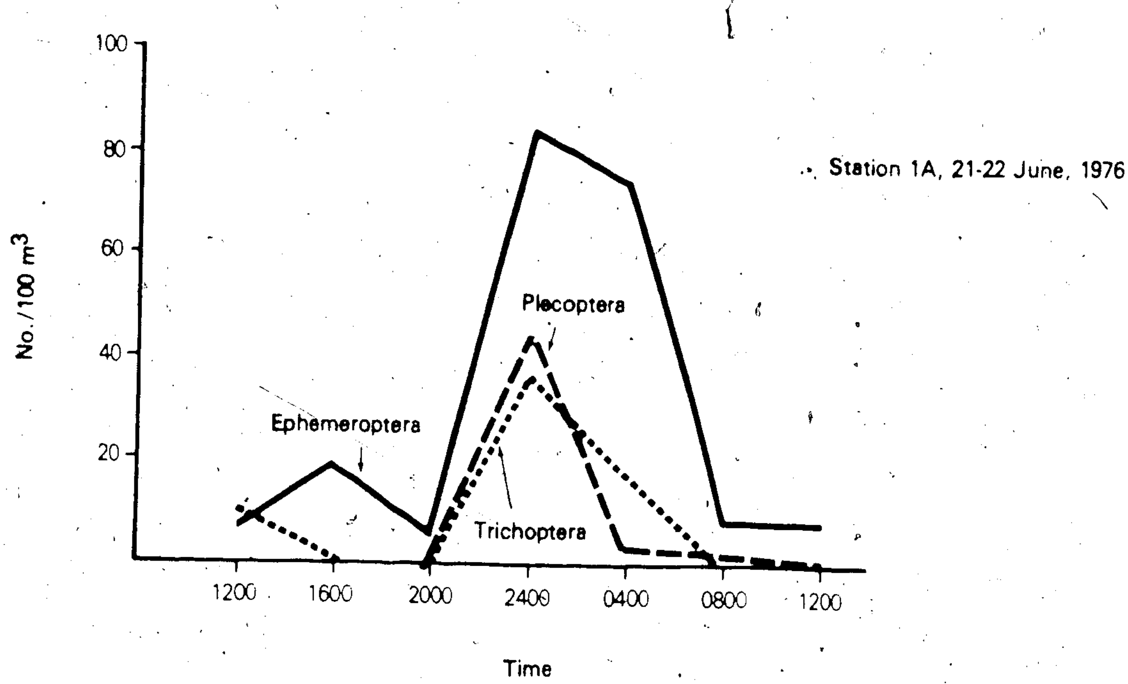


FIGURE 13
Diel Variations of Selected Taxa at Station 1,
18-19 Feb., 1976 and 28-29 April, 1976.



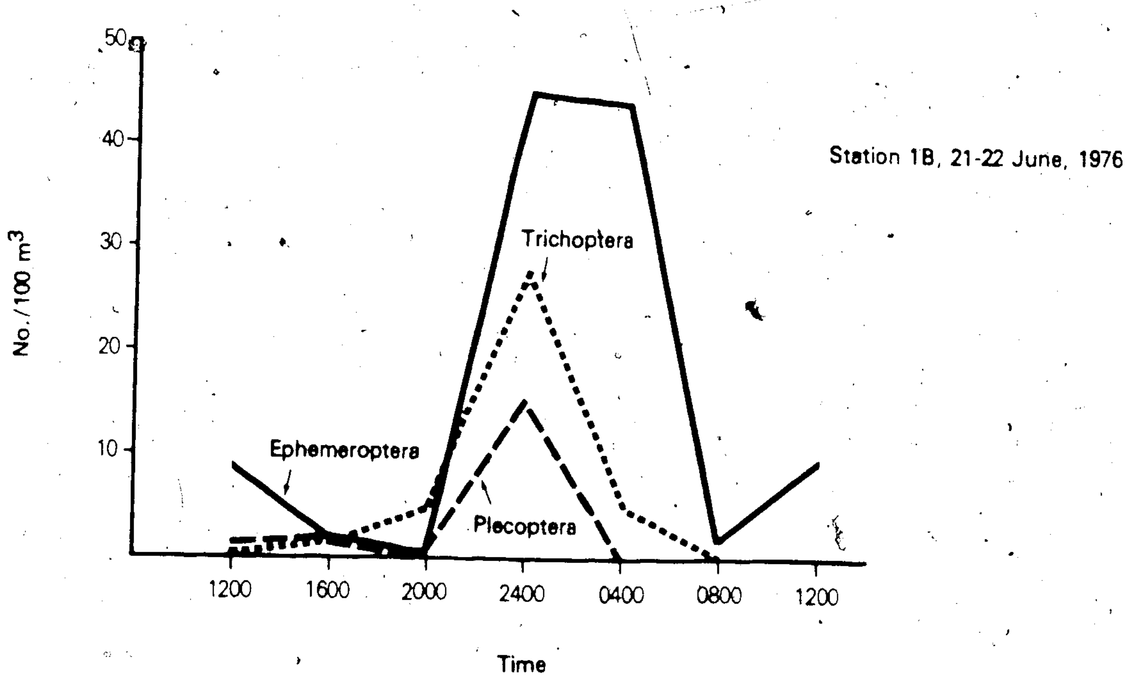


FIGURE 14

Diel Variations in Drift Densities of Selected Taxa at Station 1, 21-22 June, 1976

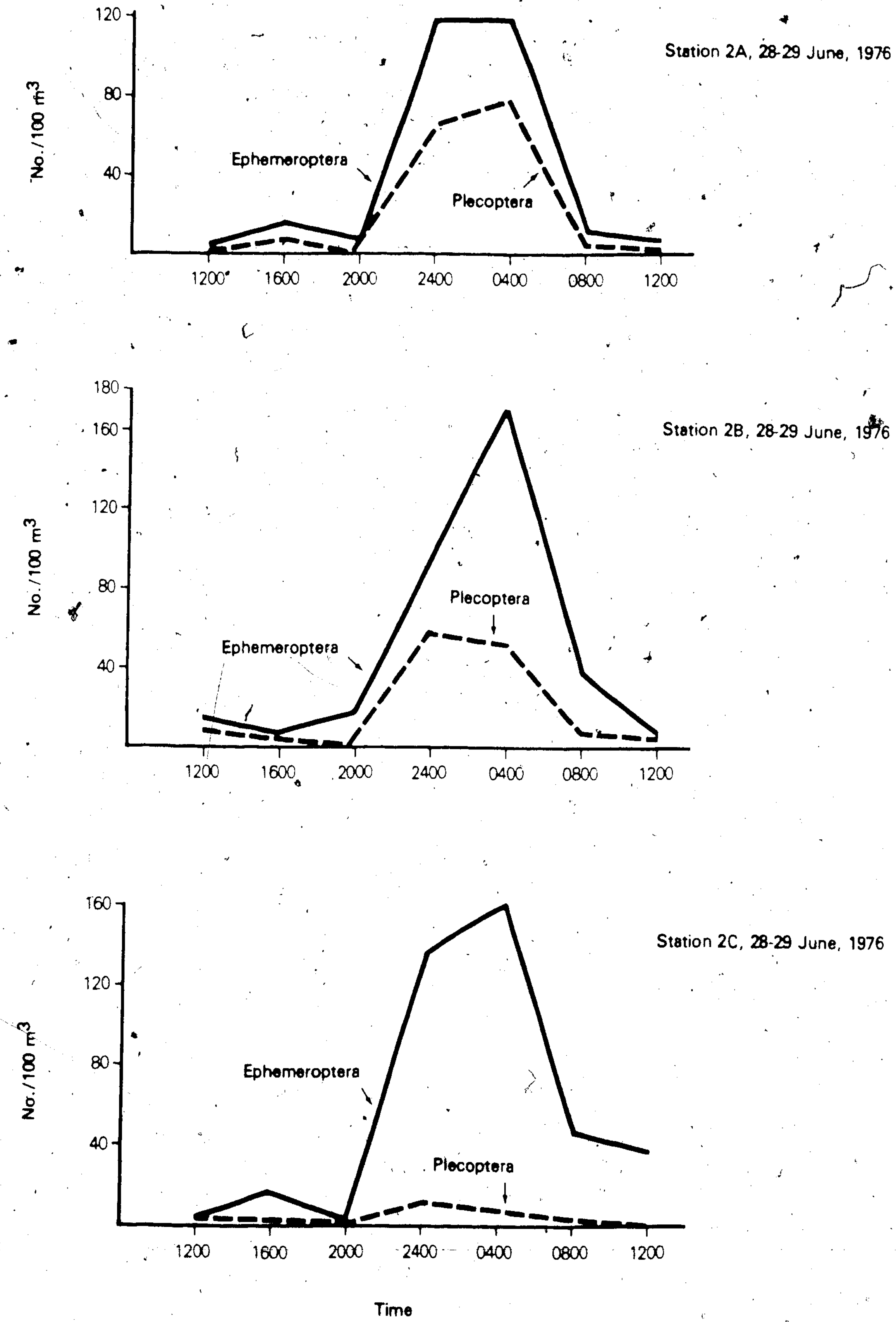


FIGURE 15

Diel Variation in Drift Densities of Selected Taxa
at Station 2, 28-29 June, 1976.

study. Paterson and Nursall (1975) reported only two and Reynoldson (1974) reported three mayfly genera in the North Saskatchewan River in the vicinity of Edmonton. Although Reynoldson's study was conducted three years prior to this study, it is doubtful that changes (improvements) in water quality over that time period were responsible for greater mayfly diversity. More likely, the ability of the drift method to collect uncommon mayfly nymphs in the North Saskatchewan River has been demonstrated.

A diverse mayfly fauna is generally considered an indicator of "clean" water conditions. The drift collections made during this study did not reveal any obvious differences in mayfly populations between stations 1 and 2. A possible exception was that the high densities of *Baetis* sp. recorded at station 2 may, in fact, have been due to higher benthic productivity, induced by organic wastewater loadings.

5.2.6 Plecoptera

Stonefly (Plecoptera) nymphs were taken in all 24-hour drift samples at stations 1 and 2. Upstream of Edmonton, average stonefly densities ranged from 3/100 m^3 to 29/100 m^3 and accounted for 0.2 to 24 percent by numbers of the total drift catch. The highest stonefly densities occurred in samples collected at stations 1A and 1B on February 18 - 19, 1976 and at station 1A on April 28 - 29, 1976. *Brachyptera* sp. and *Capnia* sp. were abundant only on these dates, suggesting these genera emerged in the spring. *Isogenus* sp. was most abundant on these dates too but was also common during the summer and fall sampling periods. Diel drift patterns with night-time maxima were exhibited by

Plecoptera nymphs on most sampling dates at station 1 (Figures 13 and 14).

At station 2, average stonefly densities ranged from $1/100\ m^3$ to $25/100\ m^3$ in the 24-hour samples and comprised 0.2 to 5.7 percent by numbers of the total drift catches. Highest average densities were recorded in samples collected at stations 2A and 2B on June 28 - 29, 1976 ($25/100\ m^3$ and $20/100\ m^3$ respectively), and included only Isogenus sp. Brachyptera sp. and Capnia sp. were rare in the drift samples at station 2. Plecopterans are also considered members of the "clean" water group of benthic organisms and are especially intolerant of organically enriched environments. The near-absence of the previously mentioned genera at station 2 may have been indicative of unsuitable bottom habitat conditions. Diel drift patterns of stoneflies were only apparent at station 2 on June 28 - 29, 1976 and are illustrated in Figure 15.

5.2.7 Trichoptera

Caddis fly larvae (Trichoptera) were not particularly abundant in any of the 24-hour drift samples. Average densities at station 1 ranged from $1/100\ m^3$ to $9/100\ m^3$ and at station 2 from $1/100\ m^3$ to $12/100\ m^3$. Brachycentrus sp. was only collected at station 1 and appeared only in the June 21 - 22, 1976 and July 21 - 22, 1976 samples. Cheumatopsyche sp. was the most abundant caddis fly at stations 1A and 1B but was rare at station 2. The opposite situation existed for Hydropsyche sp. Based on drift composition alone, differences in caddis fly distribution, upstream and downstream of Edmonton were demonstrated.

The reasons for such a difference are not obvious.

All are filter feeders, obtaining nourishment from plant and animal particles suspended in the flow and, therefore, would be expected to take advantage of the larger quantities of organic drift at station 2. However, the substrate at station 2 may not have been suitable for Brachycentrus sp. and Cheumatopsyche sp. because of accumulations of organic material.

Brachycentrus sp. was the only caddis fly to exhibit a diel drift pattern during this study (Figure 14).

5.2.8 Fish

The most abundant fish species collected during the study was the burbot (Lota lota). Burbot fry were caught only in the spring at stations 1A, 2A and 2C. At station 1A, on April 19, 1976, one drift net collected 30 fry between 0730 and 0830 (drift density 291/100 m^3, see Appendix IV, Table 5). On April 28 and 29, 1976, a total of 390 fry were collected and drift densities varied between 37 and 874/100 m^3 over the 24-hour sample period (Appendix IV, Table 6). The upper nets collected more than twice the number of fry than did the lower nets. Clifford (1972) reported a similar situation in the Bigoray River, Alberta where 90 percent of drifting white sucker fry (Catastomus commersonii) were collected in surface nets.

The densities of drifting burbot fry at station 2A were 3743/100 m^3 and 23/100 m^3 on April 19 and May 19, 1976, respectively. Densities on the same dates at station 2C were 243/100 m^3 and 6/100 m^3 (Appendix V, Tables 7 - 10).

The presence of burbot fry in the river during early spring agreed with published information on the reproductive biology of this species (e.g. Scott and Crossman, 1973). Adult burbot spawn during the winter under the ice at water temperatures of 0.6° to 1.7° C and eggs hatch in about 30 days. On April 19, 1976 water temperatures at station 1A, 2A and 2C were 1.0°, 3.5° and 2.0° C respectively. Broken ice was still abundant in the river on April 19, 1976 so no attempt was made to collect midstream or 24-hour samples.

Sucker (Catastomus sp.) fry were the second most abundant fish collected in the drift samples. Specimens were collected occasionally throughout the study at stations 1 and 2 and were only abundant in samples collected at station 2 on May 27 - 28, 1976 (Appendix V, Tables 11 - 13). Again, these dates and the water temperature of 17° C were in agreement with hatching dates and temperatures reported by Scott and Crossman (1973). Sucker fry were also very abundant on these dates in the mouths of two small tributaries of the North Saskatchewan River, approximately 1 km upstream and 0.2 km downstream of station 2A. Day-time and night-time densities at station 2A, 2B and 2C were 96 and 284/100 m^3, 28 and 25/100 m^3, and 26 and 196/100 m^3 respectively. Densities were higher in the upper nets and, in addition, densities at stations 2A and 2C were much higher in the midnight samples. Clifford (1972) found 98 percent of the sucker drift in the Bigoray River, Alberta, occurred at night.

The only other fish collected during the study were two cyprinid fry and one sculpin fry caught at station 2A on June 28, 1976.

The occurrence of large numbers of juvenile burbot and suckers in the drift collections was fortunate in that collection dates were not planned specifically to coincide with the hatching dates of these species. The results do show that drift sampling when combined with a knowledge of a particular fish species' life history can assist in providing information on the distribution and abundance of newly hatched fish in a river system. The results of the drift density analyses discussed in Section 5.1.3 considered only the 24-hour samples and, therefore, were not affected by these one-time occurrences of large numbers of juvenile fish.

5.2.9 Significance of the Faunal Composition of the Drift to Water Quality Assessment in the North Saskatchewan River

Important differences in the drifting fauna between station 1, upstream of Edmonton, and station 2, downstream of the city, have been demonstrated. Ignoring those taxa which occurred periodically in large numbers at both stations (i.e. Corixidae, Lota lota and Catastomus sp.), these differences can be summarized as follows:

Characteristic	Station 1	Station 2
Taxa representing by numbers at least 10 percent of the drift on one occasion or one percent on two or more occasions.	Chironomidae, Baetis sp., Ephemerella sp., Rhithrogena sp., Brachyptera sp., Isogenus sp., Capnia sp., Brachycentrus sp., Cheumatopsyche sp.	Chironomidae and Oligochaeta at all locations; Baetis sp.; Isogenus sp. and Hydropsyche sp. at midstream and north side; and Ephemerella sp. only at north side.
Chironomids	Uncommon except in summer emergence period.	Abundant in all samples. Densities lower at north side.

Characteristic	Station 1	Station 2
Oligochaeta	Rare	Abundant in all samples; densities lower on north side.
Ephemeroptera	Several genera collected, Baetis sp. most common. Diel drift patterns common.	Several genera collected, Baetis sp. most common. Diel patterns uncommon.
Plecoptera	Isogenus sp., Brachyptera sp. and Capnia sp. common. Diel drift patterns common.	Isogenus sp. common. Diel drift patterns uncommon.
Trichoptera	Cheumatopsyche sp. most common. Brachycentrus sp. common in summer.	Hydropsyche sp. common. Other genera rare.

In Section 5.1.4 it was stated that average total drift densities over the entire study were higher at station 2. If Corixidae, Catastomus sp. and Lota lota are omitted in the density calculations, the differences are more evident. With the above taxa excluded, average total drift densities at station 1 were much lower (n = 11, mean = 47, range 20 - 99) than at station 2 (n = 8, mean = 617, range 108 - 1208).

Wastewater discharges which entered the North Saskatchewan River in the vicinity of Edmonton had caused an order of magnitude increase in the density of drifting organisms at station 2 (excluding corixids, burbot fry and sucker fry). This increase could be attributed to chironomids and oligochaetes, organisms which characteristically occur in habitats affected by organic (nutrient) enrichment.

5.3 Suitability of Drift Sampling for Environmental Monitoring

The drift sampling method evaluated in this study was successful in describing the effects of water pollution on the benthic invertebrate fauna of the North Saskatchewan River. Statistical analyses showed significant differences in total drift densities between stations upstream and downstream of the City of Edmonton. Most groups of invertebrates associated with the bottom community in the North Saskatchewan River near Edmonton were represented in the drift samples and more taxa were collected in this study than in previous water quality surveys which included biological monitoring. Important differences in the kinds and abundance of each of these benthic invertebrate groups in the North Saskatchewan River, upstream and downstream of Edmonton, were also demonstrated using the drift sampling technique.

The drift sampler operated satisfactorily under most river conditions encountered during the study. This aspect when combined with the quantitative nature of the samples collected and relative ease of operation, showed the method to be potentially attractive as a routine biological monitoring tool in rivers similar to the North Saskatchewan. A number of modifications and additional uses of the drift sampling method for environmental monitoring are suggested here.

First, as part of a routine monitoring program involving many stations along a stream or river, sampling drift intensively over a 24-hour period would not be practical. Instead, samples could be collected once or twice during the period of highest drift densities. One rather than two nets per station would probably be adequate unless significant differences in the vertical distribution of the drift were suspected. The nets could also be made larger so that more water was filtered per sample interval. If desired, the nets could be set to sample the water surface to collect more adult specimens. This would aid in the identification of immature aquatic insect species. Sampling during each season of the year would ensure important taxa are not missed.

Second, most numerical pollution indices and diversity indices could be applied to the drift samples in the same manner they are applied to benthic samples. These indices are simple to calculate and helpful in analyzing differences between stations and differences at the same station over time.

Another possible use of the drift method is to collect samples of biomass for analysis of environmental contaminants such as chlorinated hydrocarbons. Such substances are lipophilic and tend to concentrate in living tissues rather than water and mineral sediments. Benthic invertebrates such as stoneflies, mayflies, caddis flies and amphipods, which are known to drift, have been shown to contain DDT and PCB residues in their tissues (Sodergren et al., 1972). Drift sampling could provide quantitative samples of these organisms on a routine basis for trace contaminant analysis.

Three main problems associated with sampling drift were encountered during the study. First, sampling was not possible during freeze-up and break-up periods because of floating ice. Frazil ice was also present on several occasions throughout the winter at station 2. Second, floating debris (mostly logs and twigs) was constantly a problem, especially during the summer months and periods of peak flow. Even over a 24-hour period, the amount of floating debris would vary because material deposited on shore during low discharge would be re-floated when the discharge increased. This aspect required constant attention on most sampling dates to ensure minimum interference with the drift nets. Third, many of the immature mayfly and stonefly nymphs collected were difficult to identify even to the genus level because of lost abdominal cerci and gills. These organisms are quite delicate and were subjected to considerable battering once collected in the net.

6.0 CONCLUSIONS

(a) Effluent discharges to the North Saskatchewan River in the vicinity of Edmonton had a measurable effect on invertebrate drift in the river downstream of the city. The composition of the drifting fauna downstream of Edmonton was indicative of a river environment affected by organic (nutrient) wastewater loading.

(b) Differences in invertebrate drift in the North Saskatchewan River upstream and downstream of the City of Edmonton could be described by statistical comparisons of total drift densities at different points and at different times over a 24-hour sample period on a river transect.

(c) The drift method successfully collected aquatic organisms representative of the benthic invertebrate community in the North Saskatchewan River near Edmonton.

(d) Differences in total drift densities between near-surface and near-bottom drift samples were not significant ($p < 0.01$). Total drift densities varied randomly across small (1.5 m) river sections. Therefore, the sampler probably collected a representative drift sample at each river location.

(e) Total drift densities (excluding corixids and fish) upstream of Edmonton were an order of magnitude lower than drift densities downstream of Edmonton. Diel variations in total drift densities with night-time maxima were evident upstream of Edmonton where the drift fauna was dominated by such "clean" water taxa as Plecoptera, Ephemeroptera and Trichoptera. Diel drift patterns were uncommon downstream of Edmonton where drift densities were higher and the drift fauna dominated by chironomids and oligochaetes.

(f) Lower drift densities on the north side of the river, in comparison to midstream and south side locations downstream of Edmonton, indicated incomplete lateral mixing of effluents at that station. This was in agreement with chemical, bacteriological and dye tracer studies conducted in that section of the North Saskatchewan River.

(g) The drift sampler met the design criteria for isokinetic sampling of suspended particulates thus insuring quantitative sampling of drift.

(h) The drift sampling method was suitable for most river conditions during all seasons of the year.

(i) Drift sampling should be feasible for routine environmental monitoring programs on rivers similar to the North Saskatchewan.

(j) Drift sampling offers promising potential for the quantitative collection of aquatic organism biomass for trace contaminant analysis.

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APPENDIX I

Table 1 Results of Flume Test Number 1

Test No.	V_0	V_I
1	58.7	59.0
2	60.0	58.2
3	59.0	58.2
4	59.0	58.0
5	58.5	58.1
6	58.5	58.0
7	58.0	58.0
8	59.0	58.2
9	58.8	58.1
10	58.7	58.1
Σv	588.2	581.90
$\bar{v}$	58.8	58.21

Anova Table

Source of variation	dF	SS	MS	F
Between groups	1	1.98	1.98	11
Within groups	18	3.19	0.18	
Total	19	5.17		

$F_{.01}(1, 18) = 8.28$

$F_{.001}(1, 18) = 15.4$

APPENDIX I

Table 2 Results of Flume Test Number 2
Probe Location A

Test No.	V_0	V_I
1	58.7	60.0
2	58.8	59.4
3	59.6	59.5
4	60.0	59.1
5	58.8	59.8
Σv	295.9	297.8
$\bar{v}$	59.2	59.6

Anova Table

Source of variation	dF	SS	MS	F
Between groups	1	0.36	0.36	1.57
Within groups	8	1.86	0.23	
Total	9	2.22		

$F_{.01}(1, 8) = 11.3$

APPENDIX I

Table 3 Results of Flume Test Number 2
Probe Location 3

Test No.	V_0	V_I
1	58.5	59.4
2	58.7	60.0
3	59.6	59.5
4	58.4	59.8
5	59.0	59.5
Σv	294.2	298.2
$\bar{v}$	58.8	59.6

Anova Table

Source of variation	dF	SS	MS	F
Between groups	1	1.6	1.6	10.67
Within groups	8	1.18	0.15	
Total	9	2.78		

$F_{.01}(1, 8) = 11.3$

APPENDIX I

Table 4 Results of Flume Test Number 2
Probe Location C

Test No.	V_0	V_I
1	58.8	58.1
2	59.5	58.2
3	59.0	58.1
4	59.6	58.2
5	59.0	58.1
Σv	295.9	290.7
$\bar{v}$	59.2	58.1

Anova Table

Source of variation	dF	SS	MS	F
Between groups	1	2.7	2.7	45
Within groups	8	0.5	0.06	
Total	9	3.2		

$F_{.01}(1, 8) = 11.3$

$F_{.001}(1, 8) = 25.4$

APPENDIX I

Table 5 Results of Flume Test Number 2
Probe Location D

Test No.	V_0	V_I
1	59.6	59.5
2	58.3	58.2
3	58.5	59.0
4	58.8	59.5
5	59.6	59.4
Σv	294.8	295.6
$\bar{v}$	59.0	59.1

<u>Anova Table</u>

Source of variation	dF	SS	MS	F
Between groups	1	0.06	0.06	0.18
Within groups	[illegible]	2.74	0.34	
Total	9	2.80		

$F_{.01}(1, 8) = 11.3$

APPENDIX I

Table 6 Results of Flume Test Number 2
Probe Location E

Test No.	V_0	V_I
1	58.7	59.8
2	58.7	59.5
3	59.6	59.4
4	59.6	59.4
5	60.0	59.4
Σv	296.6	297.5
$\bar{v}$	59.3	59.5

Anova Table

Source of variation	dF	SS	MS	F
Between groups	1	0.08	0.08	0.42
Within groups	8	1.51	0.19	
Total	9	1.59		

$F_{.01}(1, 8) = 11.3$

APPENDIX I

Table 7 Results of Flume Test Number 3
Plug Located 55 cm Behind Net Mouth

Test No.	V_0	V_I
1	60.1	58.0
2	60.0	58.0
3	60.1	58.5
4	58.6	58.0
5	59.5	58.2
Σv	298.3	290.7
$\bar{v}$	59.7	58.1

Anova Table

Source of variation	dF	SS	MS	F
Between groups	1	5.78	5.78	25.13
Within groups	8	1.84	0.23	
Total	9	7.62		

$F_{.01}(1, 8) = 11.3$

$F_{.001}(1, 8) = 25.4$

APPENDIX I

Table 8 Results of Flume Test Number 3
Plug Located 35 cm Behind Net Mouth

Test No.	V_0	V_I
1	59.0	60.0
2	60.1	59.2
3	59.5	59.2
4	58.5	59.8
5	59.6	59.5
Σv	296.7	297.7
$\bar{v}$	59.3	59.5

Anova Table

Source of variation	dF	SS	MS	F
Between groups	1	0.1	0.1	0.4
Within groups	8	2.0	0.25	
Total	9	2.1		

$F_{.01}(1, 8) = 11.3$

APPENDIX I

Table 9 Results of Flume Test Number 3
Plug Located 25 cm Behind Net Mouth

Test No.	V_0	V_I
1	59.6	54.5
2	59.5	55.0
3	60.0	53.5
4	58.5	54.7
5	59.5	54.3
Σv	297.1	272.0
$\bar{v}$	59.4	54.5

Anova Table

Source of variation	dF	SS	MS	F
Between groups	1	63.00	63.00	203.22
Within groups	8	2.51	0.31	
Total	9	65.51		

$F_{.01}(1, 8) = 11.3$

$F_{.001}(1, 8) = 25.4$

APPENDIX I

Table 10 Results of Flume Test Number 3
Plug Located 20 cm Behind Net Mouth

Test No.	V_O	V_I
1	60.1	43.0
2	59.5	44.0
3	59.5	43.5
4	59.8	42.5
5	59.7	43.2
Σv	298.6	216.2
$\bar{v}$	59.7	43.2

Anova Table

Source of variation	dF	SS	MS	F
Between groups	1	678.98	678.98	3573.59
Within groups	8	1.5	0.19	
Total	9	680.48		

$F_{.01}(1, 8) = 11.3$

$F_{.001}(1, 8) = 25.4$

APPENDIX II

Table 1 Number of Organisms Collected in Nine Drift Nets Set at the Same Depth in the North Saskatchewan River at Station 1A

Test Number 1 14 September /76 2030 - 2130

Net Number	1	2	3	4	5	6	7	8	9
Corixidae	983	968	937	1004	956	1070	987	934	946
Baetidae	2	2	0	1	4	4	0	0	3
Heptageniinae	0	1	0	0	1	0	1	1	0
Chironomidae	0	2	1	0	1	0	0	2	0
Hydropsyche sp.	0	2	2	1	2	1	0	0	0
Isogenus sp.	0	0	0	0	0	1	0	0	0
Leptophlebia sp.	0	0	0	0	0	1	0	0	0
Total Number of Organisms	985	975	940	1006	964	1077	988	937	949

River depth 60 cm Net depth 20 cm Velocity 0.77 m/s

Test Number 2 15 September /76 0830 - 0930

Net Number	1	2	3	4	5	6	7	8	9
Corixidae	189	226	188	219	205	187	194	164	153

River depth 50 cm Net depth 20 cm Velocity 0.66 m/s

APPENDIX II

Table 2 Number of Organisms Collected in Nine Drift Nets Set at the Same Depth in the North Saskatchewan River at Station 2A

Test Number 1 9 September /76 1130 - 1230

Net Number	1	2	3	4	5	6	7	8	9
Chironomidae	14	11	17	13	8	11	12	13	10
Oligochaeta	11	9	5	7	15	6	3	10	5

River depth 70 cm Sample depth 20 cm
Velocity 0.68 m/s

Test Number 2 9 September /76 2330 - 0030

Net Number	1	2	3	4	5	6	7	8	9
Chironomidae	5	4	1	7	5	8	6	4	3
Oligochaeta	6	9	0	4	9	2	3	11	3

River depth 60 cm Sample depth 20 cm
Velocity 0.49 m/s

APPENDIX III

Table 1 Two-Way Analysis of Variance of Drift Densities Recorded at Station 1, 28 - 29 October, 1975

	Sample Interval					
Station	1	2	3	4	5	6
1A	582	394	408	205	456	762
1B	612	408	507	304	516	827

Anova Table

Source of variation	dF	SS	MS	F
Between stations	1	6.66	6.66	12.05 n.s.
Between intervals	5	171.72	34.34	62.16 **
Error	5	2.76	0.55	
Total	11	181.14		

$F_{.01}\ (1, 5) = 16.26$

$F_{.01}\ (5, 5) = 10.97$

n.s. - not significant

* - significant at $p < 0.01$

** - significant at $p < 0.001$

APPENDIX III

Table 2 Two-Way Analysis of Variance of Drift Densities Recorded at Station 1, 18 - 19 February, 1976

	Sample Interval						
Station	1	2	3	4	5	6	7
1A	28	38	131	99	96	51	47
1B	12	30	98	86	89	64	19

Anova Table

Source of variation	dF	SS	MS	F
Between stations	1	3.25	3.25	5.35 n.s.
Between intervals	6	70.17	11.69	19.24 *
Error	6	3.65	0.61	
Total	13	77.07		

$F_{.01}$ (1, 6) = 13.75

$F_{.01}$ (6, 6) = 8.47

APPENDIX III

Table 3 Two-Way Analysis of Variance of Drift Densities Recorded at Station 1, 21 - 22 June, 1976

	Sample Interval						
Station	1	2	3	4	5	6	7
1A	30	43	19	210	143	57	19
1B	28	46	31	133	78	40	27

Anova Table

Source of variation	dF	SS	MS	F
Between stations	1	1.96	1.96	1.28 n.s.
Between intervals	6	116.06	19.34	12.6 *
Error	6	9.20	1.53	
Total	13	127.22		

$F_{.01}$ (1, 6) = 13.75

$F_{.01}$ (6, 6) = 8.47

APPENDIX III

Table 4 Two-Way Analysis of Variance of Drift Densities Recorded at Station 1, 21 - 22 July, 1976

	Sample Interval						
Station	1	2	3	4	5	6	7
1A	50	45	52	132	82	33	34
1B	56	46	56	140	86	47	39

Anova Table

Source of variation	dF	SS	MS	F
Between stations	1	0.56	0.56	9.82 n.s.
Between intervals	6	47.42	7.90	138.56 **
Error	6	0.34	0.06	
Total	13	48.32		

$F_{.01}$ (1, 6) = 13.75

$F_{.01}$ (6, 6) = 8.47

APPENDIX III

Table 5 Two-Way Analysis of Variance of Drift Densities Recorded at Station 1, 10 - 11 October, 1976

	Sample Interval						
Station	1	2	3	4	5	6	7
1A	710	629	1693	529	436	1154	1550
1B	1549	1492	2041	2533	1545	1055	1350

Anova Table

Source of variation	dF	SS	MS	F
Between stations	1	369.39	369.36	6.17 n.s.
Between intervals	6	239.25	39.88	0.67 n.s.
Error	6	358.93	59.82	
Total	13	967.54		

$F_{.01}$ (1, 6) = 13.75

$F_{.01}$ (6, 6) = 8.47

APPENDIX III

Table 6 Two-Way Analysis of Variance of Drift Densities Recorded at Station 2, 9 - 10 November, 1975

	Sample Interval					
Station	1	2	3	4	5	6
2A	1393	1061	1967	622	303	480
2B	1114	2185	857	742	275	872
2C	267	289	223	317	204	175

Anova Table

Source of variation	dF	SS	MS	F
Between stations	2	769.34	384.67	8.5*
Between intervals	5	575.27	115.05	2.54 n.s.
Error	10	452.60	45.26	
Total	17	1797.21		

$F_{.01}$ (2, 10) = 7.56

$F_{.01}$ (5, 10) = 5.64

APPENDIX III

Table 7 Two-Way Analysis of Variance of Drift Densities Recorded at Station 2, 9 - 10 March, 1976

	Sample Interval					
Station	1	2	3	4	5	6
2A	2141	2105	955	638	564	898
2B	2484	1487	331	464	711	693
2C	673	417	625	217	237	259

Anova Table

Source of variation	dF	SS	MS	F
Between stations	2	644.9	322.46	9.45 *
Between intervals	5	983.5	196.70	5.76 *
Error	10	341.1	34.11	
Total	17	1969.5		

$F_{.01}$ (2, 10) = 7.56

$F_{.01}$ (5, 10) = 5.64

APPENDIX III

Table 8 Two-Way Analysis of Variance of Drift Densities Recorded at Station 2, 28 - 29 June, 1976

	Sample Interval						
Station	1	2	3	4	5	6	7
2A	1556	193	580	532	568	102	128
2B	286	322	543	421	493	194	182
2C	36	51	42	211	240	108	69

Anova Table

Source of variation	dF	SS	MS	F
Between stations	2	471	235.5	6.03 n.s.
Between intervals	6	335.95	55.99	1.43 n.s.
Error	12	468.67	39.06	
Total	20	1275.62		

$F_{.01}$ (2, 12) = 6.93

$F_{.01}$ (6, 12) = 4.82

APPENDIX III

Table 9 Two-Way Analysis of Variance of Drift Densities Recorded at Station 2, 22 - 23 September, 1976

	Sample Interval						
Station	1	2	3	4	5	6	7
2A	820	1038	1752	1163	435	1163	496
2B	978	1650	724	1495	1500	781	1327
2C	158	354	243	252	245	251	231

Anova Table

Source of variation	dF	SS	MS	F
Between stations	2	1371.77	685.88	19.9 **
Between intervals	6	115.85	19.31	0.56 n.s.
Error	12	413.14	34.43	
Total	20	1900.76		

$F_{.01}$ (2. 12) = 6.93

$F_{.01}$ (6, 12) = 4.82

APPENDIX IV

Table 1

Catch of Drifting Organisms at Station 1A,
28-29 October, 1975

Taxa	Time 1130 to 1330 T	B	1530 to 1730 T	B	1930 to 2130 T	B	2330 to 0130 T	B	0730 to 0930 T	B	1130 to 1330 T	B
O. Diptera												
Chironomidae (l)		1						2	1			1
Chironomidae (a)					1		1					
Tabanidae		1										
O. Ephemeroptera												
Ameletus sp											1	
Baetis sp	1	8	1			2	1	1	1	1	1	
Ephemerella sp		5							1			1
Heptageniinae		1										
Rhithrogena sp		5	1	2	1	1						1
O. Hemiptera												
Corixidae	178	145	135	91	177	26	71	13	92	94	218	178
O. Plecoptera												
Brachyptera sp	1	5	1			1			2		1	
Capnia sp	1	1										
Isogenus sp			1		1	1						
O. Trichoptera												
Cheumatopsyche sp		9		1		1		1	1		1	
Hydropsyche sp			2	1			1				1	
C. Oligochaeta		1										
C. Gastropoda												
Lymnaea sp					1							
P. Bryozoa												
Plumatella sp		p′										
Total No. Organisms	181	182	140	95	181	31	75	18	98	95	223	181
River Velocity (m/s)	0.96	.94	.91	.91	.80	.75	.68	.71	.65	.64	.80	.82
Total Drift Density (no./100 m^3)	574	590	469	318	689	126	336	73	460	452	850	673

p′ - denotes part of colony was collected - not included in density calculation

T - top net

B - bottom net

l - denotes larvae
p - denotes pupae
a - denotes adults

APPENDIX IV

Table 2

Catch of Drifting Organisms at Station 1B,
28-29 October, 1975

Taxa	Time: 1130 to 1330		1530 to 1730		1930 to 2130		2330 to 0130		0730 to 0930		1130 to 1330	
	T	B	T	B	T	B	T	B	T	B	T	B
O. Diptera												
Chironomidae (l)		1			1	1		1		1		
Chironomidae (a)	1											
O. Ephemeroptera												
Ameletus sp							1					
Baetis sp	1	2	1		4	1	1	1	1	2	2	3
Ephemerella sp		2								1		1
Rhithrogena sp		3			3	3	2			1		1
O. Hemiptera												
Corixidae	247	144	191	66	222	65	130	33	125	124	261	219
O. Plecoptera												
Brachyptera sp		1	1					1			2	1
Capnia sp	1									1		
Hastaperla sp	1											
Isogenus sp	1				1		1	1	2	2		1
O. Trichoptera												
Agapetus sp		1										1
Cheumatopsyche sp	1	9		3		3			5	2		5
Hydropsyche sp		1				1	1	1			1	1
Total No. Organisms	253	164	193	69	231	74	136	38	133	134	266	233
River Velocity (m/s)	1.05	1.02	.98	.98	.92	.91	.88	.85	.80	.78	.92	.92
Total Drift Density (no./100 m^3)	734	490	600	215	766	248	471	136	507	524	882	772

APPENDIX IV

Table 3

Catch of Drifting Organisms at Station 1A,
18-19 February, 1976

Taxa	Time													
	1130 to 1330		1530 to 1730		1930 to 2130		2330 to 0130		0330 to 0530		0730 to 0930		1130 to 1330	
	T	B	T	B	T	B	T	B	T	B	T	B	T	B
O. Diptera														
Chironomidae (1)	4	1	1	1	1	2	1		2	1	1	1	6	4
O. Ephemeroptera														
<u>Baetis</u> sp	1	3	4	1	4	9	7	5	2	11	2	2		1
<u>Ephemerella</u> sp		1	1		1	1	3				1	1		1
<u>Heptageniinae</u>						2								
<u>Leptophlebia</u> sp						1								
<u>Rhithrogena</u> sp					1	1							1	
O. Hemiptera														
Corixidae	3	7	9	9	18	31	12	19	13	21	11	19	7	18
O. Plecoptera														
<u>Brachyptera</u> sp	1				6	8	5	12	5	3	1	1		
<u>Capnia</u> sp					4	5	8	4	4	5				
<u>Isogenus</u> sp	2	1	1	2	3	4	1	1	3	3		1		
O. Trichoptera														
<u>Cheumatopsyche</u> sp			1	1		1	1		1	1		1	1	
Total No. Organisms	11	13	17	14	38	65	38	41	30	45	16	26	15	24
River Velocity (m/s)	.99	.98	.92	.90	.90	.90	.90	.93	.93	.88	.97	.94	.98	.94
Total Drift Density (no/100 m^3)	25	30	40	36	96	165	96	101	74	117	38	63	35	58

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Table 4

Catch of Drifting Organisms at Station 1B, 18-19 February, 1976

Taxa	Time: 1130 to 1330 T	B	1530 to 1730 T	B	1930 to 2130 T	B	2330 to 0130 T	B	0330 to 0530 T	B	0730 to 0930 T	B	1130 to 1330 T	B
O. Coleoptera														
Dytiscus sp					1				1					
O. Diptera														
Chironomidae (1)		1	1			1		1		1		1	1	
O. Ephemeroptera														
Baetis sp		1	1	2	3	3	3	3	2	2	2	3		1
Ephemerella sp						1		1	1			1		
Rhithrogena sp								1						
O. Hemiptera														
Corixidae	1	5	4	9	17	22	11	17	15	26	15	17	4	5
O. Plecoptera														
Acroneuria sp													1	
Brachyptera sp				1	3	8	1	7	1					
Capnia sp					2		1	1		2	2			
Isogenus sp			1			3		3	1	4			1	
Isoperla sp								1						
Hastaperla sp				1										
O. Trichoptera														
Cheumatopsyche sp				1		1		2			1			
O. Hydracarina								2						
C. Pisces														
Catastomus sp									1	1				
Total No. Organisms	1	7	7	14	26	39	16	38	23	36	20	22	7	6
River Velocity (m/s)	.80	.78	.80	.80	.78	.74	.76	.71	.76	.76	.78	.74	.78	.80
Total Drift Density (no/100 m^3)	3	21	20	40	76	120	48	123	69	108	59	68	21	17

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Table 5

Catch of Drifting Organisms at Station 1A,
19 April, 1976

Taxa	Time 0730 to 0830-T
O. Coleoptera	
Hydrovatus sp	1
O. Hemiptera	
Corixidae	6
C. Pisces	
Lota lota	30
Total No. Organisms	37
River Velocity (m/s)	0.47
Total Drift Density (no/100 m^3)	359

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Table 6

Catch of Drifting Organisms at Station 1A,
28-29 April, 1976

Taxa	Time: 1130 to 1330		1530 to 1730		1930 to 2130		2330 to 0130		0330 to 0530		0730 to 0930		1130 to 1330	
	T	B	T	B	T	B	T	B	T	B	T	B	T	B
O. Coleoptera														
Elmidae			2	1	1	1								
Hydrovatas sp			4		1	1		2						
O. Diptera														
Chironomidae (1)	4	3	7	3		3	16	4	2	1	3	4	2	1
Chrysops sp	1													
O. Ephemeroptera														
Ameletus sp									1					
Baetis sp		2	1				1	3	2	4	2	2		1
Ephemerella sp	1	1	1			1	1	1	3	2	1	3		
Hexagenia sp								1						
Leptophlebia sp							2			1			1	
Rhithrogena sp									1					
O. Hemiptera														
Corixidae	4	1	1		6		3		12			1		1
O. Plecoptera														
Brachyptera sp							1		3	2	2	2		
Capnia sp	1						1							
Hastaperla sp					1									
Isogenus sp	1			2	1		8	4	5	7	6	4	1	1
O. Trichoptera														
Agapetus sp			1					1						1
Cheumatopsyche sp		2		1										
O. Hydracarina					2	2								
C. Pisces														
Catastomus sp									1					
Lota lota	111	56	69	28	27	4	28	11	8	7	9	10	14	8
Total No. Organisms	123	65	86	35	39	12	63	25	38	24	23	26	18	13
River Velocity (m/s)	0.58	0.56	0.54	0.48	0.54	0.50	0.81	0.65	0.50	0.50	0.61	0.61	0.73	0.65
Total Drift Density (no./100 m^3)	969	530	712	333	331	110	356	176	347	219	173	195	113	92

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Table 7

Catch of Drifting Organisms at Station 1A
21-22 June, 1976

Taxa	Time: 1130 to 1230 T	B	1530 to 1630 T	B	1930 to 2030 T	B	2330 to 0030 T	B	0330 to 0430 T	B	0730 to 0830 T	B	1130 to 1230 T	B
O. Diptera														
Ceratopogonidae		1							1	1		1		
Chironomidae (l)	2		3	3	2	2	5	9	2	8	4	3		3
(p)	1			1			1	1		2	2	2	1	
(a)							3	1	2	1	3	1		
Simuliidae (l)									1			1		
O. Ephemeroptera														
Baetis sp.	1		4	1		2	8	15	8	7	3		1	2
Caenis sp.								1						
Heptageniinae				1			1							
Baetidae	1									11				
Rhithrogena sp.							1	3		1				
O. Plecoptera														
Hastaperla sp.							1							
Isogenus sp.							2	13	1			1		
O. Trichoptera														
Arctopsyche sp.										1				
Brachycentrus sp.		1					4	7	2	2				
Cheumatopsyche sp.							1							
Hydropsyche sp	1													
Psychomyia sp.								1		1				
O. Hydracarina		1		1										
C. Pisces														
Catastomus sp.					1									
Total No. Organisms	6	3	7	7	3	4	27	51	17	35	12	9	2	5
River Velocity (m/s)	0.78	0.58	0.85	0.67	0.90	0.80	0.88	0.83	0.88	0.81	0.88	0.81	0.92	0.83
Total Drive Density (No./100 m^3)	35	24	38	48	15	23	140	280	88	198	62	51	10	27

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Table 8

Catch of Drifting Organisms at Station 1B
21-22 June, 1976

Taxa	Time: 1130 to 1230 T	B	1530 to 1630 T	B	1930 to 2030 T	B	2330 to 0030 T	B	0330 to 0430 T	B	0730 to 0830 T	B	1130 to 1230 T	B
O. Diptera														
Ceratopogonidae								1	1					
Chironomidae (l)	3	1	1	7	6	2	4	3	2	3	3	6	1	3
(p)		1	5	2	2		4	2	1	2	5			1
(a)		1			1		1	1	1	2	1			
Simuliidae								1						
O. Ephemeroptera														
Baetis sp.	1	3	1				6	3	4	8			3	1
Ephemerella sp.									1		1			
Heptageniinae								1						
Pseudocleon sp.							5		2					
Rhithrogena sp.		1					1	2	1	1				
O. Plecoptera														
Hastaperla sp.								1						
Isogenus sp	1		1				1	4						
O. Trichoptera														
Brachycentrus sp.				1			4	2		1				
Cheumatopsyche sp.							1	3	1					
Psychomyia sp.								1						
O. Hydracarina					1	1								
C. Oligochaeta													1	1
P. Nematomorpha														
Gordius sp.	1		1				1							
C. Pisces														
Catastomus sp.				2							1			
Total No. Organisms	6	7	9	12	10	3	28	25	14	16	10	7	5	6
River Velocity (m/s)	1.12	1.01	1.11	1.02	1.00	0.92	0.94	0.88	0.92	0.86	0.90	0.98	0.98	0.88
Total Drift Density (No./100 m^3)	24	32	37	54	46	15	136	130	70	85	51	33	23	31

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Table 9

Catch of Drifting Organisms at Station 1A
21-22 July, 1976

Taxa	Time: 1130 to 1230		1530 to 1630		1930 to 2030		2330 to 0030		0330 to 0430		0730 to 0830		1130 to 1230	
	T	B	T	B	T	B	T	B	T	B	T	B	T	B
O. Coleoptera														
Hydr[illegible]rinae (a)							1							
O. Diptera														
Chironomidae (l)	2	2	1	1	3	2	8	5	6	2	1	4	2	3
(p)	4	4	2	2			6	6	3	1			2	
(a)		1	3				3	1	2	4		1		2
Simuliidae (l)				1			2	3			1			
O. Ephemeroptera														
Baetis sp.		1	1	2	3	1	2	3	2	4		1	1	1
Ephemerella sp.	1			1								1		
Heptageniinae	1				1		5	4		1	1			
Pseudocloeon sp		1				1	5	1	3		1			
Rhithrogena sp	1		1				1			1				
O. Plecoptera														
Capnia sp.			1	1		1								
Isogenus sp.					1	3		4	2	3				
O. Trichoptera														
Brachycentrus sp.		1				2			1	2				
Cheumatopsyche sp.	3			1							1		1	2
C. Oligochaeta		2			1									
C. Pisces														
Catastomus sp.			2				3				1	1		
Total No. Organisms	12	12	11	9	9	11	36	27	19	18	6	8	6	8
River velocity (m/s)	1.14	1.05	1.1	0.96	0.94	0.85	1.17	1.0	1.12	0.96	1.07	0.92	0.96	0.94
Total Drift Density (No./100 m^3)	48	52	46	43	44	59	141	123	78	86	26	40	29	39

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Table 10

Catch of Drifting Organisms at Station 1B
21-22 July, 1976

Taxa	Time: 1130 to 1230		1530 to 1630		1930 to 2030		2330 to 0030		0330 to 0430		0730 to 0830		1130 to 1230	
	T	B	T	B	T	B	T	B	T	B	T	B	T	B
O. Diptera														
Chironomidae (l)	3	3	6	3	4	1	9	8	2	2	3	1	3	4
(p)	2	4	1		5		5	7	2	1		1	2	2
(a)			1		1	2	6	3	3	2		1		
Simuliidae (l)	1						1							
O. Ephemeroptera														
Baetis sp.	1		2	1	1	2	4	3	6	7	3			1
Ephemerella sp.							1	1						
Heptageniinae	1	1		1				1				1		
Rhithrogena sp.					3		2	1	1	1				
O. Plecoptera														
Capnia sp.	1			1				1			1	2		1
Isogenus sp				1	1		3	3	2			1		
O. Trichoptera														
Brachycentrus sp							2		1	2				
Cheumatopsyche sp	1	2			1	1				1	2	3	2	
O. Hydracarina			1										1	
C. Oligochaeta	1	2			1				2	3				
C. Pisces														
Catastomus sp.			1				1	1				1		
Total No. Organisms	11	12	12	7	17	6	34	29	19	19	9	11	8	8
River Velocity (m/s)	0.97	0.92	0.96	0.94	0.95	0.94	1.14	0.92	1.1	0.94	1.0	1.03	0.97	0.94
Total Drift Density (No./100 m3)	52	60	57	34	82	29	136	144	79	92	41	49	38	39

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Table 11

Catch of Drifting Organisms at Station 1A
10-11 October, 1976

Taxa	Time: 1130 to 1230 T	B	1530 to 1630 T	B	1930 to 2030 T	B	2330 to 0030 T	B	0330 to 0430 T	B	0730 to 0830 T	B	1130 to 1230 T	B
O. Diptera														
Chironomidae (l)		1							1		2			
(p)				1		1	1						1	
(a)			1	1	1	1								
O. Ephemeroptera														
Baetis sp.	3	1		1	2	1	4	3	2	4	1			1
Ephemerella sp.		2								1	2			
Heptageniinae	1											1		
Leptophlebia sp.					1									
Rhithrogena sp.		2	1				3	2					1	
O. Hemiptera														
Corixidae	111	132	124	98	280	317	74	108	92	61	219	194	272	294
O. Plecoptera														
Brachyptera sp.		1			1	1						1		
Capnia sp.													1	1
Isogenus sp				2			1	1		1				
O. Trichoptera														
Cheumatopsyche sp.		2	1	1			1			1				
Hydropsyche sp.		1				1		[illegible]						
O. Hydracarina				1										1
C. Oligochaeta			1						[illegible]					
C. Pisces														
Catastomus sp.													1	
Total No. Organisms	115	142	128	105	285	322	84	116	96	68	224	196	276	297
River Velocity (m/s)	0.89	0.78	0.86	0.83	0.83	0.81	0.87	0.86	0.87	0.85	0.83	0.83	0.86	0.83
Total Drift Density (No./100 m^3)	590	830	681	577	1566	1819	440	617	505	366	1231	1077	1468	1632

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Table 12

Catch of Drifting Organisms at Station 1B
10-11 October, 1976

Taxa	Time: 1130 to 1230 T	1130 to 1230 B	1530 to 1630 T	1530 to 1630 B	1930 to 2030 T	1930 to 2030 B	2330 to 0030 T	2330 to 0030 B	0330 to 0430 T	0330 to 0430 B	0730 to 0830 T	0730 to 0830 B	1130 to 1230 T	1130 to 1230 B
O. Coleoptera														
Hydrovatus sp (a)							1							
O. Diptera														
Chironomidae (l)		1	1	2					1	1	1	3		1
(p)			2					1						
(a)	1				1								1	1
O. Ephemeroptera														
Ameletus sp.				1										
Baetis sp.	1		2	1	1	4	1	1	2		1	1		1
Ephemerella sp.	2										1	1		
Hexagenia sp.														1
Rhithrogena sp.		2			3	2		1		2			1	
O. Hemiptera														
Corixidae	310	237	298	261	426	404	518	461	357	214	197	173	212	266
O. Plecoptera														
Brachyptera sp.		1			1	1							1	
Hastaperla sp.					1									
Isogenus sp.	1			1					1	1				
O. Trichoptera														
Cheumatopsyche sp.	1				2	2	1	6			1			
Hydropsyche sp.	1		1	1					1				1	
C. Pisces														
Catastomus sp.			1											
Total No. Organisms	317	241	305	267	435	413	521	470	362	218	201	178	216	270
River Velocity (m/s)	0.85	0.79	0.92	0.83	0.98	0.92	0.92	0.87	0.87	0.84	0.83	0.81	0.84	0.81
Total Drift Density (No. /100 m3)	1704	1393	1517	1467	2027	2055	2592	2474	1905	1185	1104	1006	1174	1525

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Table 1

Catch of Drifting Organisms at Station 2A
9-10 November, 1975

Taxa	Time: 1530 to 1730 T	B	1930 to 2130 T	B	2330 to 0130 T	B	0330 to 0530 T	B	0730 to 0930 T	B	1530 to 1730 T	B
O. Collembola							1					
O. Coleoptera												
Hydrovatus sp.							1					
O. Diptera												
*Chironomidae (l)	239	229	27	261	105	245	75	80	30	21	160	4
(p)	5			5		5	1	1			3	
(a)	9	8	8	42	175	23	4			3	10	
O. Ephemeroptera												
Baetis sp.					1							
Heptageniinae					1	1						
Leptophlebia sp.				5	2		2					
O. Hemiptera												
Corixidae	60	37	2	144	445	131	132	52	25	24	17	10
O. Plecoptera												
Brachyptera sp.								1				
Isogenus sp.	2			1							1	
O. Trichoptera												
Hydropsyche sp.		1								1		
C. Oligochaeta	31	10	26	37	14	1	18	11	34	4	12	17
C. Hydrozoa												
Hydra sp.									1			
C. Gastropoda												
Lymnaea sp.					1							
Total No. Organisms	346	285	63	495	746	406	232	145	90	53	203	31
River Velocity (m/s)	.69	.69	.81	.80	.90	.88	.94	.90	.74	.69	.74	.76
Total Drife Density (No./100 m^3)	1528	1258	237	1885	2529	1405	751	492	370	235	835	124

* l - denotes larvae
p - denotes pupae
a - denotes adults

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Table 2

Catch of Drifting Organisms at Station 2B
9-10 November, 1975

Taxa	Time: 1530 to 1730 T	B	1930 to 2130 T	B	2330 to 0130 T	B	0330 to 0530 T	B	0730 to 0930 T	B	1130 to 1330 T	B	1530 to 1730 T	B
O. Araneae	1												1	
O. Coleoptera														
Hydrovatus sp.			2	1				1						
O. Diptera														
Atherix sp.						1								
Chironomidae (l)	186	174	278	376	7	283	87	118	21	44	465	572	224	
(p)						5	1	1		1	2	1	1	
(a)		11	153	46	7	42	2	6	1	1	34	8	2	
O. Ephemeroptera														
Ameletus sp.			1											
Baetis sp.				1					1					
Ephemerella sp.			1											
Heptageniinae									1	1				
Leptophlebia sp.			1			2	1	3						
Tricorythodes sp.						1								
O. Hemiptera														
Corixidae	41	27	417	137	2	149	120	39	27	15	24	19	7	
O. Plecoptera														
Brachyptera sp.			1											
Isogenus sp.						1		2		1				
O. Trichoptera														
Brachycentrus sp.										1				
Cheumatopsyche sp.			1							1			1	
Hydropsyche sp.				4					1			1		
O. Hydracarina				1					1					
C. Oligochaeta	14		20		24	82		95	29	11	17	12	16	
Total No. Organisms	242	212	875	566	40	566	211	265	82	76	542	613	252	
River Velocity (m/s)	.64	.60	1.01	1.00	1.06	1.08	1.00	.96	.96	.80	.81	.92	.88	
Total Drift Density (no. /100 m^3)	1152	1076	2643	1726	115	1599	643	841	260	289	2038	2030	872	

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Table 3

Catch of Drifting Organisms at Station 2C
9-10 November, 1975

Taxa	Time: 1530 to 1730 T	1530 to 1730 B	1930 to 2130 T	1930 to 2130 B	2330 to 0130 T	2330 to 0130 B	0330 to 0530 T	0330 to 0530 B	0730 to 0930 T	0730 to 0930 B	1130 to 1330 T	1130 to 1330 B	1530 to 1730 T	1530 to 1730 B
O. Diptera														
Chironomidae (l)	25	17	38	45	26	6	29	53	22	38	36	17	10	27
(p)		1	2		1	1	3			1		1		
(a)	3		19	12	16	1	6	25	10	5	23	11	11	5
O. Ephemeroptera														
Baetis sp	2		1			1			1					
Ephemerella sp.		1									1			
Heptageniinae													1	1
Leptophlebia sp.		1			3	4	2	1						
O. Hemiptera														
Corixidae	24	12	8	15	31	17	11	10	4	13	29	27	6	9
O. Plecoptera														
Brachyptera sp.		1							1					
Isogenus sp.				1	2		1						1	
O. Trichoptera														
Hydropsyche sp.	2				2	1		3			1			
C. Oligochaeta	10	16	21	11	6	18	17	44	13	19	29	21	11	7
O. Hydracarina		1						1						
Total No. Organisms	66	49	90	84	87	49	69	137	51	76	118	78	40	49
River Velocity (m/s)	.67	.64	.91	.88	.94	.90	1.01	.98	.96	.94	.86	.81	.78	.78
Total Drift Density	302	232	301	289	281	165	209	425	163	245	417	295	158	192

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Table 4

Catch of Drifting Organisms at Station 2A
9-10 March, 1976

Taxa	Time: 1130 to 1330 T	1130 to 1330 B	1530 to 1730 T	1530 to 1730 B	1930 to 2130 T	1930 to 2130 B	0130 to 0330 T	0130 to 0330 B	0730 to 0930 T	0730 to 0930 B	1130 to 1330 T	1130 to 1330 B
O. Diptera												
Chironomidae (l)	299	394	158	220	64	65	41	56	41	21	91	108
(p)		2	15	1	7	4		1	1	1	2	
(a)	5	1	70	2	5	11	1			7	4	4
O. Ephemeroptera												
Baetis sp.	1	3	1	2		6	4	3	2	3	1	
Caenis sp										1		
Ephemerella sp.	1						1	1				
Leptophlebia sp.			1		2	4		1		1	1	
Rhithrogena sp.					1	1						
O. Hemiptera												
Corixidae	29	32	263	100	95	103	74	46	7	13	41	59
O. Plecoptera												
Capnia sp			2		2	1	1	1	1	1		
O. Trichoptera												
Agapetus sp.				1	1							
Hydropsyche sp.						1		1				1
C. Oligochaeta	61	14	12	18	46	40	19	50	68	3	19	28
C. Gastopoda												
Ferrissia sp.				1								
Total No. Organisms	396	446	522	345	223	236	141	160	120	51	159	200
River Velocity (m/s)	.46	.44	.47	.47	.56	.54	.54	.54	.34	.36	.44	.47
Total Drift Density (no./100 m^3)	1970	2311	2534	1675	910	1000	597	678	805	323	824	971

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Table 5

Catch of Drifting Organisms at Station 2B
9-10 March, 1976

Taxa	Time: 1130 to 1330		1530 to 1730		1930 to 2130		0130 to 0330		0730 to 0930		1130 to 1330	
	T	B	T	B	T	B	T	B	T	B	T	B
O. Diptera												
Chironomidae (l)	568	575	244	532	95	46	97	114	88	141	174	103
(p)	4	3	2	4	4			3	3		2	1
(a)	1											1
O. Ephemeroptera								1				
Ameletus sp.	1	4	2	4	2	1	3	5		2	3	3
Caenis sp.			1									
Ephemerella sp	1	4		2	2					1		
Leptophlebia sp.								1			1	
O. Hemiptera												
Corixidae	3	4		7	4	1	8	4	1	1	2	
O. Pleroptera												
Brachyptera sp.				1	1							
Capnia sp								1				
Isogenus sp		1			1			1				
Nemoura sp.							1					
O. Trichoptera												
Agapetus sp.		1		1						1		
Arctopsyche sp.				1								
Hydropsyche sp.								1				
O. Hydracarina	1			2		1						
C. Oligochaeta	30	20	11	28	14	18	6	12	41	38	16	21
C. Pisces												
Catastomus sp.								1				
Total No. Organisms	609	612	260	582	124	67	115	144	133	184	198	129
River Velocity (m/s)	.71	.47	.75	.61	.73	.56	.67	.61	.51	.51	.56	.51
Total Drift Density (no. /100 m^3)	1996	2971	793	2180	388	273	392	539	596	825	808	578

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Table 6

Catch of Drifting Organisms at Station 2C
9-10 March, 1976

Taxa	Time: 1130 to 1330 T	B	1530 to 1730 T	B	1930 to 2130 T	B	0130 to 0330 T	B	0730 to 0930 T	B	1130 to 1330 T	B
O. Diptera												
Chironomidae (l)	122	231	163	39	94	129	30	45	41	21	60	51
(p)				1		1			1	7	4	
(a)		1			1	1		1		1		1
O. Ephemeroptera												
Baetis sp.	17	8	19	3	37	23	19	17	2	3	1	5
Caenis sp.		1	1			1				1		
Ephemerella sp.	1	4	5	2	3	3	2					
Heptageniinae	2	1		1	1	1	2				1	
Leptophlebia sp.					1					1		
Rhithrogena sp		1				1						
O. Hemiptera												
Corixidae	3	3	1		8	7	8	4	7	13	8	6
O. Plecoptera												
Capnia sp.									1	1		
Isogenus sp		1			3	11	1	2				1
O. Trichoptera												
Agapetus sp.					1							
C. Oligochaeta	15	12	21	11	4	14	7	9	36	11	24	13
Total No. Organisms	160	263	210	57	153	192	69	78	88	59	98	77
River Velocity (m/s)	0.90	0.64	0.73	0.73	0.63	0.63	0.90	0.69	0.71	0.71	0.81	0.73
Total Drift Density (No/100 m^3)	406	939	656	178	554	696	175	258	283	190	276	241

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Table 7

Catch of Drifting Organisms at Station 2A
19 April, 1976

Taxa	Time 1030 to 1130 T
O. Diptera	
Chironomidae (l)	18
(a)	2
O. Hemiptera	
Corixidae	292
C. Oligochaeta	174
C. Pisces	
Lota lota	393
Total No. Organisms	879
River Velocity (m/s)	0.48
Total Drift Density (No./100 m^3)	8371

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Table 8

Catch of Drifting Organisms at Station 2C
19 April, 1976

Taxa	Time 1230 to 1330 T
O. Diptera	
Chironomidae (l)	30
(p)	7
O. Ephemeroptera	
Baetis sp.	1
O. Hemiptera	
Corixidae	31
O. Plecoptera	
Capnia sp.	1
O. Trichoptera	
Arctopsyche sp.	1
Hydropsyche sp.	1
C. Oligochaeta	2
C. Pisces	
Lota lota	25
Total No. Organisms	99
River velocity m/s	0.47
Total Drift Density (No. /100 m^3)	961

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Table 9

Catch of Drifting Organisms at Station 2A
19 May, 1976

Taxa	Time 1200 to 1300 T
O. Diptera	
Chironomidae (l)	7
(p)	18
(a)	13
O. Ephemeroptera	
Heptageniinae	1
O. Trichoptera	
Hydropsyche sp.	1
O. Hydracarina	2
C. Pisces	
Lota lota	4
Total No. Organisms	46
River velocity (m/s)	0.81
Total Drift Density (No. /100 m^3)	260

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Table 10

Catch of Drifting Organisms at Station 2C
19 May, 1976

Taxa	Time 1400 to 1500 T
O. Diptera	
Chironomidae (l)	7
(p)	2
O. Trichoptera	
Hydropsyche sp.	1
C. Pisces	
Lota lota	1
Total No. Organisms	11
River velocity (m/s)	0.71
Total Drift Density (No./100 m^3)	71

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Table 11

Catch of Drifting Organisms at Station 2A
27-28 May, 1976

Taxa	Time 1130 to 1230 T	B	2330 to 0030 T	B
O. Collembola				
Isotoma sp.		1		
O. Diptera				
Chironomidae (l)	5	4	2	2
(p)	5	10	14	29
(a)	6	5	10	8
O. Ephemeroptera				
Baetis sp.		1		
Ephemerella sp.	1			
O. Plecoptera				
Isogenus sp.		2	1	
O. Trichoptera				
Hydropsyche sp.		1		1
C. Oligochaeta	80	132	180	203
C. Pisces				
Catastomus sp.	26	5	49	40
Total No. Organisms	123	159	247	284
River Velocity (m/s)	.85	.67	.74	.72
Total Drift Density (No./100 m^3)	661	1084	1586	1802

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Table 12

Catch of Drifting Organisms at Station 2B
27-28 May, 1976

Taxa	Time 1130 to 1230 T	B	2330 to 0030 T	B
O. Diptera				
Chironomidae (l)		2		1
(p)	2			
O. Ephemeroptera				
Baetis sp.				1
Ephemerella sp.			2	2
O. Plecoptera				
Isogenus sp			5	6
O. Trichoptera				
Hydropsyche sp.				1
C. Oligochaeta		2	20	1
C. Pisces				
Catastomus sp	7	4	8	1
Total No. Organisms	7	10	35	13
River velocity (m/s)	0.92	0.92	0.87	0.72
Total Drift Density (No. /100 m^3)	35	50	184	82

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Table 13

Catch of Drifting Organisms at Station 2C
27-28 May, 1976

Taxa	Time 1130 to 1230 T	B	2330 to 0030 T	B
O. Diptera				
Chironomidae (l)	4	2	2	3
(p)			12	35
(a)			2	2
O. Ephemeroptera				
Baetis sp.			1	1
Ephemerella sp.				6
O. Plecoptera				
Isogenus sp.	2	1		
O. Hydracarina				1
C. Oligochaeta	1			20
C. Pisces				
Catastomus sp.	5	3	47	3
Total No. Organisms	12	7	64	71
River Velocity (m/s)	0.75	0.64	0.60	0.60
Total Drift Density (No./100 m^3)	73	50	489	542

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Table 14

Catch of Drifting Organisms at Station 2A
28-29 June, 1976

Taxa	Time: 1130 to 1230		1530 to 1630		1930 to 2030		2330 to 0030		0330 to 0430		0730 to 0830		1130 to 1230	
	T	B	T	B	T	B	T	B	T	B	T	B	T	B
O. Diptera														
Chironomidae (l)	7	10	2	4	1	4	7	2	3	3	2	4	2	2
(p)	8	6	4	5	3	3	5	1	6	2	5		2	2
(a)	5	6	12	16	104	65	56	45	71	49	13	2	15	6
Tabanus sp.											1			
O Ephemeroptera														
Baetis sp.	1		1	3		2	19	15	14	23	1	1		1
Caenis sp.										1		1	1	
Heptageniinae							4	4	2	3				
Stenonema sp.			1								1			
Tricorythodes sp.	1						1		1					
O. Hemiptera														
Corixidae							1							
O. Plecoptera														
Isogenus sp.	1		2	1			22	2	11	15	1	1	1	
O. Trichoptera														
Cheumatopsyche sp.					1					1		1		2
Hydropsyche sp.		3	2	1		3	1	4	2	2	1	2		3
C. Oligochaeta	1	400	3	4			1	1					8	
C. Pisces														
Catastomus sp.	1	1					5		3	1				
Cottidae		1												
Cyprinidae	1				1									
Total No. Organisms	26	427	27	34	110	77	122	74	113	100	25	12	29	16
River Velocity (m/s)	0.76	0.66	0.74	0.71	0.78	0.68	0.90	0.76	0.88	0.83	0.83	0.83	0.82	0.78
Total Drift Density (No./100 m^3)	156	2955	167	219	643	517	619	445	587	549	137	66	161	94

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Table 15

Catch of Drifting Organisms at Station 2B
28-29 June, 1976

Taxa	Time: 1130 to 1230		1530 to 1630		1930 to 2030		2330 to 0030		0330 to 0430		0730 to 0830		1130 to 1230	
	T	B	T	B	T	B	T	B	T	B	T	B	T	B
O. Diptera														
Chironomidae (l)	6	9	3	3	1	4	2	4	3		1	2	2	3
(p)	9	7	8	4		6	3	6	2		5	1	4	3
(a)	4	9	21	34	78	51	44	18	9	12	16	2	11	17
O. Ephemeroptera														
Baetis sp.	2	1		1	3	2	19	18	29	24	6	4		1
Caenis sp.		1	1								1		1	
Ephemerella sp.	1				1			1						
Heptageniinae							2	4	5	3	2			1
O. Plecoptera														
Isogenus sp.	2	1		1			14	8	9	10		3	1	
O. Trichoptera														
Cheumatopsyche sp.			1	2					1					2
Hydropsyche sp.	1	2	3	1	1	1	2		1	1	2	1	2	2
C. Oligochaeta	21	24	18	11	10	19	4	9	26	42	11	13	1	12
C. Pisces														
Catastomus sp.			1	1			2		1					
Total No. Organisms	46	54	56	58	94	83	92	68	86	92	44	26	22	41
River Velocity (m/s)	0.80	0.80	0.82	0.80	0.78	0.71	0.90	0.83	0.88	0.78	0.83	0.82	0.82	0.78
Total Drift Density (No. /100 m^3)	263	309	312	331	550	535	467	374	447	538	242	145	123	240

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Table 16

Catch of Drifting Organisms at Station 2C
28-29 June,1976

Taxa	Time: 1130 to 1230 T	B	1530 to 1630 T	B	1930 to 2030 T	B	2330 to 0030 T	B	0330 to 0430 T	B	0730 to 0830 T	B	1130 to 1230 T	B
O. Diptera														
Ceratopogonidae								1					1	
Chironomidae (l)	3	4	1	6	4	5	6	5	6	6	2	6	1	2
(p)			1			1	2	1		2		2	2	
(a)				1				1			2			
O. Ephemeroptera														
Baetis sp.		1	2	3		1	27	21	32	24	9	8	5	7
Ephemerella sp.			1										1	
Leptophlebia sp.								1	1					
Rhithrogena sp.							1							
O. Plecoptera														
Isogenus sp.		1		1			3	2	2	1		1		
O. Trichoptera														
Archtopsyche sp.						1	1							
Hydropsyche sp.	2	1	1	1		1	4	1	5	5		2	1	1
C. Oligochaeta											1	5		2
C. Gastropoda														
Ferrissia sp.														1
P. Nematomorpha														
Gordius sp.						1								
C. Pisces														
Catastomus sp.							1				1			
Total No. Organisms	6	7	6	12	4	10	45	33	46	38	15	24	11	13
River Velocity (m/s)	0.85	0.80	.82	.80	0.81	0.75	0.82	0.88	0.78	0.82	0.92	0.78	0.86	0.76
Total Drift Density (No./100 m^3)	32	40	33	69	23	61	250	171	269	211	75	140	59	78

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Table 17

Catch of Drifting Organisms at Station 2A
22-23 September, 1976

Taxa	Time: 1130 to 1230 T	B	1530 to 1630 T	B	1930 to 2030 T	B	2330 to 0030 T	B	0330 to 0430 T	B	0730 to 0830 T	B	1130 to 1230 T	B
O. Diptera														
Chironomidae (l)	161	110	94	126	221	185	62	153	36	17	158	247	21	86
(p)	2			4	1	1	2	5			1			3
(a)	11	8	7	14	37	49	9	56	6		1	4	15	
O. Ephemerogtera														
Ameletus sp.										1				
Baetis sp.			1	1	2	3	1	1	2				1	
Heptageniinae	1					1	1	1				1		
Tricorythodes sp.				1										
O. Hemiptera														
Corixidae	6	4	5	9	10	2	5	6	4	3	8	11	5	6
O. Plecoptera														
Brachyptera sp.							1	1						
Isogenus sp.			1			1	2		1	1				
O. Trichoptera														
Hydropsyche sp.		1	1	2			1	3					1	1
O. Hydracarina													1	
C. Oligochaeta	11	4	28	31	19	24	40	12	29	39	1	10	17	32
C. Pisces														
Catastomus sp.			1											
Total No. Organisms	192	127	138	188	290	266	123	238	78	61	169	273	61	128
River Velocity (m/s)	0.94	0.82	0.73	0.71	0.72	0.73	0.75	0.69	0.71	0.76	0.90	0.85	0.92	0.85
Total Drift Density (No./100 m^3)	932	708	863	1213	1840	1663	749	1576	503	367	858	1468	303	688

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Table 18

Catch of Drifting Organisms at Station 2B
22-23 September, 1976

Taxa	Time: 1130 to 1230 T	B	1530 to 1630 T	B	1930 to 2030 T	B	2330 to 0030 T	B	0330 to 0430 T	B	0730 to 0830 T	B	1130 to 1230 T	B
O. Diptera														
Chironomidae (l)	142	151	67	253	112	98	94	212	179	191	21	38	159	289
(p)	3		1	2	6			4	2	1			4	
(a)	21	47	106	14	3		78	16	7	18	57	104	23	5
O. Ephemeroptera														
Baetis sp.	2				1		3	1					1	
Caenis sp.				2										
Ephemerella				1							1	1		
Heptageniinae		1					1		1					
Leptophlebia sp.			1				1	3						
O. Hemiptera														
Corixidae	4	1		2	1	5	7	3		1	15	17	4	3
O. Plecoptera														
Brachyptera sp.			1											
Isogenus sp.			1		1		2	5		1				
O. Trichoptera														
Cheumatopsyche sp.				1		1					1			
Hydropsyche sp.		1				1							2	
C. Oligochaeta	7	1	16	22	4	3	9	11	34	6	2	41	37	12
Total No. Organisms	179	202	193	297	128	108	195	255	223	218	97	201	230	309
River Velocity (m/s)	0.94	0.85	0.71	0.66	0.71	0.79	0.71	0.67	0.67	0.67	0.90	0.86	0.94	0.92
Total Drift Density (No./100 m^3)	869	1086	1245	2055	823	624	1254	1735	1517	1483	492	1069	1117	1537

APPENDIX V

Table 19

Catch of Drifting Organisms at Station 2C 22-23 September,1976

Taxa	Time: 1130 to 1230		1530 to 1630		1930 to 2030		2330 to 0030		0330 to 0430		0730 to 0830		1130 to 1230	
	T	B	T	B	T	B	T	B	T	B	T	B	T	B
O. Coleoptera														
Hydrovatus sp.													1	
O. Diptera														
Chironomidae (l)	14	17	29	44	36	18	2	23	16	25	51	11	38	19
(p)		1	1				1		1	2	4	3	1	
(a)	1	2	1	3	3	4	1		2	1	6		1	2
O. Ephemeroptera														
Baetis sp.	1	1		1			2	1	1	1			1	
Caenis sp.											1			
Ephemerella sp.			1											
Heptageniinae					1	1		1						
Leptophlebia sp.								3						
Tricorythodes sp.				1										
O. Hemiptera														
Corixidae	2	3	17	6	1		4	2	9	1		4	7	5
O. Plecoptera														
Isogenus sp.				1			2	7	4	1				
O. Trichoptera														
Hydropsyche sp.		2				1				1				
C. Oligochaeta	11	6	4	9	14	15	23	16	3	10	7	2	8	6
C. Pisces														
Catastomus sp.			1											
Total No. Organisms	29	32	54	65	55	39	35	53	36	42	69	20	57	32
River Velocity (m/s)	0.95	0.83	0.79	0.75	0.92	0.84	0.81	0.79	0.81	0.67	0.83	0.75	0.90	0.85
Total Drift Density (No./100 m^3)	139	176	312	396	274	212	198	306	203	286	379	122	289	172

END

1 | 2 | 1 | 1 | 8 | 1

FIN