FORT ST. VRAIN NUCLEAR GENERATING STATION

ECOLOGICAL MONITORING PROGRAM

Final Report

covering the period

1972 - 1979

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FORT ST. VRAIN NUCLEAR GENERATING STATION

for

Public Service Company

of

Colorado

by

Thorne Ecological Institute

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Boulder, Colorado

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Project Director

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SUMMARY

General Summary

This final report presents non-radiation, environmental data covering the general period 1972-1979. For the most part, the Fort St. Vrain environs have maintained comparable quality over the years monitored, with local area and environmental component independent, natural variations. All environmental components have experienced difficulty in determining cause and effect relationships because of the intermittent, irregular, and limited operation of the Nuclear Generating Station. Based on the information available, no discernible, harmful effects on the biological environment are evident.

Aquatic Section

Invertebrates

The macroinvertebrate community is composed of taxa tolerant of moderate pollution. The various collection stations had similar faunas each season each year. Eight orders of insects and six non-insect invertebrate groups were collected with Diptera and Oligochaeta dominating. Chironomidae were the most abundant in numbers and taxa. Analysis of the chemical parameters of the aquatic environments did not reveal any abnormal or unexpected conditions. Because of data vagaries, analysis of water temperature regimes possibly created by Generating Station operation and the effects on the macroinvertebrate aquatic community was inconclusive.

Fish

Collections have been made in both the St. Vrain and South Platte Rivers over the years. Species composition has remained about the same.

Most of the species are regarded as being pollution tolerant. Fish foods have varied but in the main the items taken (numbers, kinds, and volume) have reflected relative availability of the organisms.

Algae

There has been a general similarity in species composition and numbers with variations seasonally and by sites, while species diversity has remained consistently low in all aquatic habitats. The algae present indicate polluted conditions and apparently no direct effects from the Generating Station.

Avian Section

Regular censuses were conducted from 1972-1979 of the birds utilizing the Generating Station area. During this census period avian populations fluctuated widely and no specific trend was apparent. A seasonal pattern was evident with species present usually highest in May. Avian diversity has remained rather constant. Environmental impacts other than the Nuclear Generating Station have had the greatest effects upon the birds.

Terrestrial Section

Vegetation

Data obtained from permanent exclosures have indicated an increase in production values as a result of release from grazing pressure. However, the native perennial grasses apparently have not had sufficient time to increase. To date, the Nuclear Generating Station has had little or no apparent influence on the vegetation communities of the area. It is believed that Station operational consistency over a longer period of time will b. needed to evaluate probable effects on vegetation.

Ecophysiological Characteristics

In general, leaf area injured decreased with time during the growing seasons for most years of study. Elemental concentrations in samples of kochia and cottonwood were influenced little by distance or direction from the Generating Station. Five chemical constituents (P, Ca, Zn, Fe, and SO_4-S) in pinto bean plants from the controlled experiment increased in concentration after Station startup. Heavy metals (Hg, Pg, and Cd) did not change with Station startup.

Mammals, Amphibians and Reptiles

Mammalian species composition has been similar over the survey years, except that the thirteen-lined and spotted ground squirrels have not been observed recently. Deer mice and house mice are the most common species and their numbers appear to have stabilized. The other mammals have shown greater fluctuation. Amphibians and reptiles have remained about the same in response to temperature and moisture conditions. Few seasonal or yearly differences occurred in heavy metal (Pb, Zn, and Cu) concentrations in *Microtus* tissues. In amphibians the heavy metal situation was affected by local water conditions. Changes in numbers and species of mammals, amphibians and reptiles cannot be related to Station operation, but rather, seem to be influenced by agricultural activities.

Terrestrial Invertebrates

Collembola, Formicidae, *Silpha ramosa*, and Araneida were used as biological indicators of stress conditions from operation of the Nuclear Generating Station. Collembola distribution was generally uniform but population levels varied considerably. Formicidae populations were similar from three sample areas. Both Collembola and Formicidae experienced variations, which were regarded as natural fluctuations. Silpha ramosa populations are related to the availability of small mammal carcasses. Over the survey period there were population decreases and recoveries; all regarded as typical, natural variations. The general populations of Araneida are declining in the vicinity of the Station but the cause is not known.

Fort St. Vrain

Generation Summary

Year and Month	Dates with Electric Generation	Number of Days Without Generation	Gross Generation MWH
1976			
December	11-31	10	23,842
1977			
January	1-30	1	49,580
February	0	28	0
March	31	30	587
April	2-8	23	8,333
May	8-12, 14, 16-22	18	13,743
June	0	30	0
July	22, 23	29	1,150
August	6, 8-13, 17-18, 20-24	17	15,468
September	4-8, 12-30	6	46,519
October	1-25, 27-31	1	79,146
November	13-17, 20-30	14	46,509
December	0	31	0
1978			
January	13-23	20	34,290
February	0	28	0
March	0	31	0
April	4-19, 21-30	4	65,850
May	1-8, 10-26, 28-31	2	99,073
June	1-6, 12-29	6	98,459
July	3-14, 17-31	5	85,839
August	18, 19, 21-31	18	14,496
September	1-8	23	25,147
October	5-12, 14-17, 31	18	24,880
November	1-29	1	110,594
December	9-31	8	92,583
1979			
January	1-19, 23-31	3	109,306
February*	1	27	546
March*	0	31	0
April*	0	30	0
May*	0	31	0
June*	0	30	0
July*	23, 26-28, 30, 31	25	4,522
August	3-17, 20-24, 26-31	5	88,079
September	1	29	1,828
October	2-14, 24-26	15	46,367
November	0	30	0
December	0	31	0

*Refueling outage February 1 - July 22, 1979.

INTRODUCTION

Introduction

This final report presents summarized, non-radiological, environmental monitoring information concerned with the period 1972-1979. Baseline environmental studies were conducted at the Fort St. Vrain site in 1971 and a pre-NEPA environmental report was prepared. Additional background information on soils, vegetation taxonomy, water chemistry, and hydrology was obtained about the environs of the Nuclear Generating Station and reported upon (Glover, 1976), which provided a biological benchmark for the initiation of the Station monitoring program.

Throughout the period covered by this report there have been only minor changes in personnel. The Thorne Ecological Institute has been the sole contractor involved. Each investigator has operated on an individual field schedule and program. However, there are many instances of interdisciplinary, coordinated, cooperative efforts. The Thorne team has met with Public Service Company representatives as needed for reporting, interaction, coordination, discussions about progress, and the resolving of operational problems.

The intermittent, irregular, and limited operation of the Nuclear Generating Station has made it difficult or impossible to develop usable cause and effect data. Based on the information available, no discernible, harmful effects on the biological environment are evident to date.

INVESTIGATOR REPORTS

AQUATIC SECTION

AQUATIC INVERTEBRATE MONITORING

by

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and

David L. Propst

INTRODUCTION

Routine monitoring of the aquatic fauna of the South Platte and St. Vrain Rivers in the vicinity of the Fort St. Vrain Nuclear Generating Station, Colorado, began on a regular basis in May 1974. Baseline studies on the aquatic fauna were initiated in 1971 and continued intermittently through 1973. The baseline data were presented in several reports, theses and publications (Galat and McConnell 1974; Eder, Carlson and Fronk 1974; Carlson 1976a, Carlson 1976b; Johnson 1972; Eder 1974; and Eder and Carlson 1977). An environmental impact analysis was completed for the Public Service Company of Colorado in 1971.

Biweekly macroinvertebrate and annual fish collections were made to determine if the effluent discharged into the South Platte River by the Fort St. Vrain Nuclear Generating Station would have a discernible effect upon the resident macroinvertebrate and/or fish communities. Detection of changes depended upon the resolution ability of the techniques employed. Confounding analysis of possible effects of Station effluent was the import of various organic and inorganic pollutants from upstream.

Near the Station, the South Platte River (and the St. Vrain River to a lesser extent) is tremendously modified from its natural, historical condition. Industrial and municipal wastes are discharged into the river at a number of points. Runoff from agricultural lands exacerbates the enrichment of the system. Dams and irrigation withdrawal and return reduce the amplitude of natural seasonal and diurnal flow fluctuations. Diminution of spring runoff reduces the flushing capability of the stream. Higher than natural summer flows expand available habitat for aquatic fauna.

Near the Station, both streams have been characterized as being in a recovery phase (Stacey 1977). The natural restorative ability of the South Platte enables it to process a portion of the pollutants introduced upstream, particularly those introduced in the vicinity of Denver. However, this characterization is relative. Runoff from agricultural lands and municipal wastes from several communities along the river introduces additional pollutants that retard the natural processirg ability of the stream.

Water for power generation is drawn primarily from the South Platte River. After its utilization in the Station, it is directed to Goosequill Pond via Goosequill Ditch. From Goosequill Pond, it enters the South Platte River approximately 120 m upstream from the confluence of the South Platte and St. Vrain Rivers (Figure 1). Utilization of St. Vrain River water and contingency discharge into it are permitted by the Station's license but have not normally occurred. Thus, the primary monitoring emphasis has been on the South Platte River.

The heated and nutrient-enriched character of the effluent was considered most likely to cause changes in the macroinvertebrate and/or fish communities. Although algicide was used to control algal growth in the cooling towers, no specific effort was made to determine its relative effects on aquatic invertebrates.

Addition of heated effluent tends to dampen natural thermal cycles or may increase normal summer highs. The particular effect of the heated effluent depends upon the degree of change, the season, and the rate of discharge. Altered temperature may manifest itself in several ways depending upon the magnitude and duration of the change. Ward (1976)

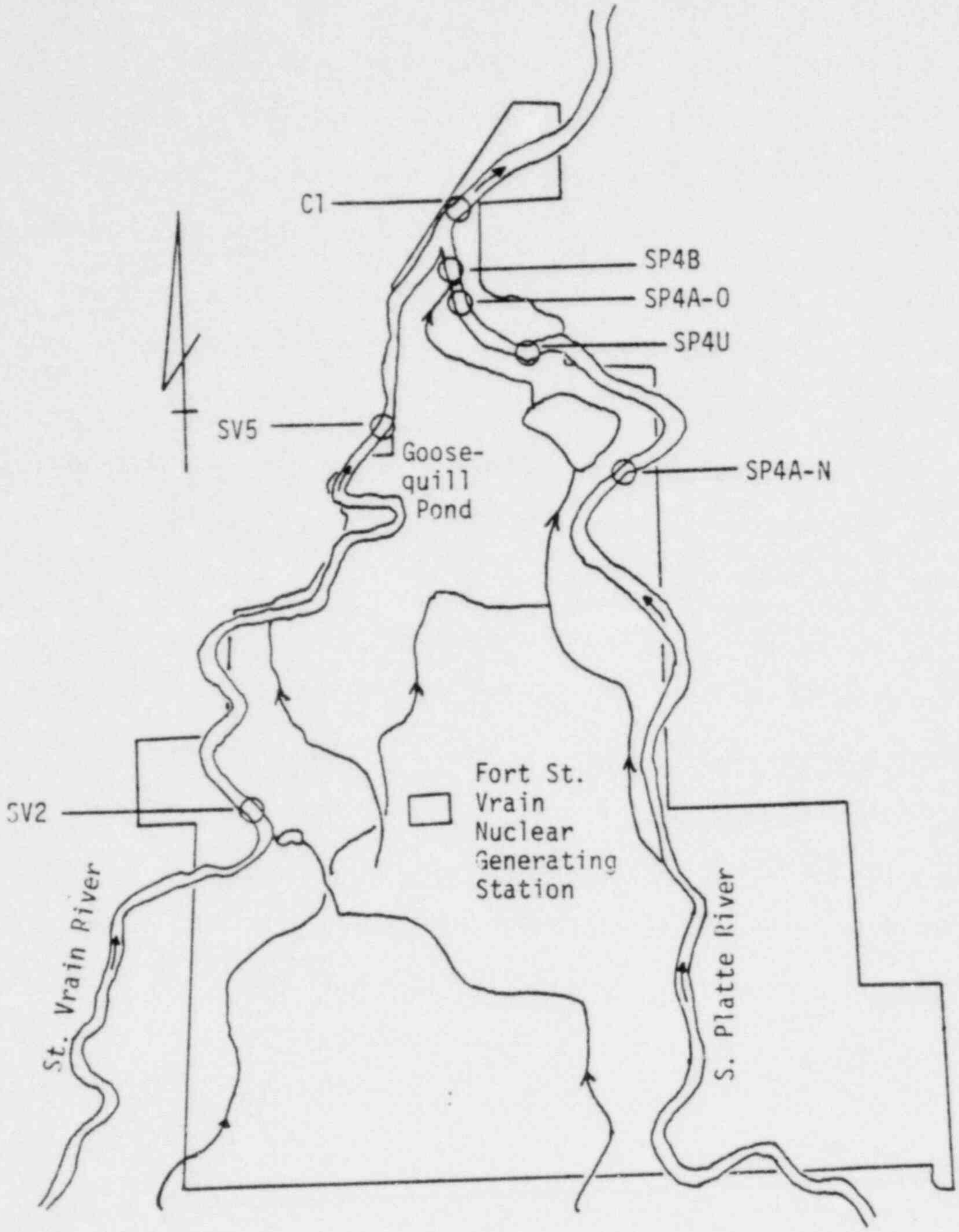

Figure 1. Location of sampling sites on the South Platte and St. Vrain Rivers in the vicinity of the Fort St. Vrain Nuclear Generating Station near Platteville, Colorado, May 1974 - December 1979.

reported reduced diversity but greater biomass of the macroinvertebrate community in a thermally-constant environment below a reservoir. Many forms are keyed to a particular temperature for initiation of different phases of their life cycles (Khoo 1968). Other forms are synchronized with rather specific numbers of degree days for initiation of different developmental stages (Hynes 1970a). Many invertebrates are adversely affected by very slight changes in temperature (Knight and Gauflin 1963, Lehmkuhl 1972, Brittain 1977, Corlcum 1978 and Elliott 1978). Sweeney and Vannote (1978) found that warmer-than-normal temperatures accelerated nymphal development; this resulted in more rapid maturation but smaller adults that were less fecund than their relatives in more "natural" environments. The manifestation of varied temperature requirements is continuous replacement of one species by another throughout the year. Such a replacement series results in a more diverse invertebrate community as interspecific (and intraspecific) competition is reduced.

Goosequill Pond serves as a cooling sump for the heated effluent from the Station. The constant (or relatively constant) pulse of water through the pond creates a polymictic lentic ecosystem in which nutrients are continuously cycled. Agricultural runoff augments the enrichment of the system. Such a situation in association with the introduction of heated water from the Generating Station prolongs the growing season of the phytoplankton. Thus, the discharge from Goosequill Pond is enriched by the nutrients circulated from the bottom of the pond and by phyto- and zooplankton nurtured in the pond. The impact of the heated and nutrient-enriched discharge upon the fauna of the South Platte River depends upon the extent of the dilution of the effluent. Enrichment may enhance a normally comparatively-sterile environment or may "overload" it to the detriment of all but the more tolerant forms.

Distinguishing the relative effects of altered thermal regimes from those of increased nutrient load is probably impossible in the present study. Indeed, the effort may be specious as the two are intimately related in the studied system. The effect of the effluent is obviously dependent upon the extent of dilution; the periodicity, timing, and duration of the discharge; and the characteristics of the effluent as compared to those of the South Platte River.

Station operation began in December 1976 and has continued intermittently since then (Table 1). Level of operation per month has varied greatly. Such irregular operation makes correlations between Station operation and changes in aquatic faunal communities rather difficult. Changes noted may be an artifact of normal, "natural" cycles, or they may be the result of the effects of the effluent.

Table 1. Number of days of power generation per month of the Fort St. Vrain Nuclear Generating Station.

	1976		1977		1978		1979	
	# days w/ generation	# days w/o generation	# days w/ generation	# days w/o generation	# days w/ generation	# days w/o generation	# days w/ generation	# days w/o generation
January	--	31	30	1	11	20	28	3
February	--	29	--	28	--	28	1	27
March	--	31	1	30	--	31	--	31
April	--	30	7	23	26	4	--	30
May	--	31	13	18	29	2	--	31
June	--	30	--	30	24	6	--	30
July	--	31	2	29	26	5	6	25
August	--	31	14	17	13	18	26	5
September	--	30	24	6	7	23	1	29
October	--	31	30	1	13	18	16	15
November	--	30	16	14	29	1	--	30
December	21	10	--	31	23	8	--	31

METHODS

Aquatic macroinvertebrates were collected by two methods and combined for analysis. A triangular aquatic insect net was suspended in the water column below the worker as he traversed the stream for 10 min. A "kick sample" consisted of those invertebrates disturbed from the substrate which were washed into the net. Organic debris was "picked" for 5 min. The kick sample was typically subsampled with a rotating carousel. However, occasional lack of availability of the subsampler required placing the sample in an enamel pan divided into eight equal sections, spreading invertebrates uniformly throughout the pan, and picking one randomly-chosen section. Kick-sample invertebrates were stained with Rose Bengal to facilitate enumeration. The invertebrates from the kick subsample and pick sample were identified to lowest feasible taxonomic level (usually genus or family). Carlson et al. (1974) established permanent collection sites at SP4A-0, SP4B and C1 in May 1974. Samples were taken at these stations (except SP4A-0) for the remainder of the study. Station SP4U was established as a permanent site by Carlson, et al. (1975) in April 1975. In July 1977, SP4A-0 was discontinued and SP4A-N was added as a permanent site (Carlson et al. 1977). Sites were selected to enable assessment and evaluation of possible effects of Station effluent upon the aquatic macroinvertebrate fauna in the South Platte River. Thus, one control site was located above the discharge points of Goosequill Pond, and several experimental sites were below. Beaver activity below Goosequill Pond and abnormally-high discharges occasionally caused Goosequill Ditch to empty into the South Platte River at points other than its normal discharge point. Such exigencies required site movement, discontinuation, and/or addition to ensure the integrity of the control site.

Annual fish collections commenced at two permanent stations each on the South Platte and St. Vrain Rivers in 1975 and continued until the termination of the project. Fish were collected with electro-fishing gear of various models. All fish collected at each site were identified and enumerated. On several occasions, weights and lengths of some or all fish were taken. Fish sampling was normally done in the autumn of each year.

Chemical and physical data were collected at each permanent station on each macroinvertebrate sampling date. Dissolved oxygen and alkalinity were measured according to Standard Methods (APHA et al. 1973). Turbidity and pH were measured with a Hach Turbidimeter and a Corning pH meter, respectively. Hardness as measured with a Hach Field Ecology kit. In 1975, filtrable solids, conductivity and dissolved carbon dioxide were added to the parameters measured. Filtrable solids were calculated according to Standard Methods (APHA et al. 1978), conductivity was determined with a Bechman Conductivity Bridge, and dissolved carbon dioxide was estimated with a nomograph. In July 1978, dissolved solids determination was added and was measured according to Standard Methods (APHA et al. 1973). Air and water temperature were measured with a mercury thermometer.

From 1975 until project termination, the Shannon-Weaver Index of General Diversity (Wilhm and Dorris 1968), MacArthur's Index of Equitibility (MacArthur 1957 and Lloyd and Ghelardi 1964), and Brinkhurst's (1968) Trophic Condition Index values were calculated quarterly for macroinvertebrates using a Fortran IV program, ECODIV, developed by Galat, Keefe, and Bergersen (1974).

Analysis of variance tests (AOV) were performed to determine if there were significant differences in selected macroinvertebrate numbers per month for each station for different years and among stations for the same year. The same test was applied to ECODIV values on the same basis.

Water temperatures of the South Platte River were recorded every 8 hours by Public Service Company personnel. These data were made available to the authors for assessment of the effect of possible temperature regime alteration upon the structure of the macroinvertebrate community of the South Platte River. Temperatures were averaged for am and pm readings for each day. Monthly means were calculated for above and below effluent discharge readings. Analysis of variance tests were performed to determine if there were significant differences in water temperatures for each month, 1974-1979 (am and pm; above and below effluent discharge), between stations above and below effluent discharge (am and pm) for each month (1975-1979), and for each month (am and pm; above and below effluent discharge) before (June 1974-November 1976) and after (December 1976-December 1979) initiation of Generating Station operation.

The data presented herein are a synthesis of work done by five researchers from 1974 through 1979. Whenever one worker replaced another, the two worked together for at least 1 month to ensure continuity of methods. However, some difference in techniques and skills were unavoidable. Standardization was enhance by one person (C. A. Carlson) reviewing all work and constantly assessing the methods and techniques of each worker. W. Don Fronk served as a special consultant to confirm identification of unusual or difficult-to-identify macroinvertebrates.

RESULTS

Macroinvertebrates

The macroinvertebrate community of the South Platte River near the Fort St. Vrain Nuclear Generating Station is composed primarily of taxa tolerant of at least moderate pollution levels. The series of collection stations had similar faunas each season and each year. Differences resulted primarily from rarely collected unusual forms and changes in the relative abundance of some more-common forms. Similarities were more marked prior to power plant operation than after. Within the sampling area, the habitat was rather uniform among stations; thus, differences would normally be minimal. With the initiation of effluent discharge into the South Platte River from Goosequill Pond, changes were apparent in the macroinvertebrate community below the discharge point.

An annual periodicity of abundance of individuals and taxa was observed (Table 2). Fewest taxa were collected at all stations in 1975 and 1976. Relatively-low numbers were collected at SP4B and C1 in 1977. In 1978, there was a marked increase in taxon numbers at all stations. In 1979, fewer taxa were collected at all stations, except SP4B, but numbers were not as low as in 1975 or 1976.

Seasonal cycles in taxon numbers were observed. In sites unaffected by Station effluent and affected sites prior to Station operation, an early peak in numbers occurred in February with a subsequent diminution in March and a gradual increase through June. In July, taxon numbers reached rather high levels and generally remained high through October. By November, taxon numbers began to decrease and reached low levels in December comparable to those collected in January (Figure 2).

Table 2. Number of taxa collected each month for each station during the study, 1974-1979.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SP4A-O												
1975	14	12	10	11	10	12	4	16	14	14	11	10
1976	8	8	3	9	5	9	15	19	13	12	12	9
1977	2	8	9	7	11	12						
SP4A-N												
1977							18	14	17	18	13	12
1978	9	9	12	10	14	18	17	21	21	18	18	7
1979	10	11	14	11	14	--	16	16	14	14	10	5
SP4U												
1975				6	9	2	7	12	16	10	15	10
1976	8	8	3	9	5	8	20	21	10	13	13	5
1977	6	10	6	8	11	15	16	14	14	16	14	9
1978	10	11	12	13	9	13	16	19	18	22	12	8
1979	11	12	15	12	13	--	15	15	13	14	12	11
SP4B												
1974					10	17	18	23	20	18	14	16
1975	12	17	14	10	11	4	9	13	13	13	13	10
1976	7	12	9	8	8	9	13	16	15	9	9	10
1977	5	11	8	8	8	15	17	10	15	16	15	12
1978	8	11	7	10	12	14	17	16	17	20	17	7
1979	12	16	11	16	17	--	17	16	18	19	12	10
C1												
1974					11	15	19	19	16	19	11	13
1975	19	15	12	16	11	3	6	17	15	15	19	10
1976	9	13	7	5	9	11	13	13	9	11	11	8
1977	6	10	5	7	10	10	13	11	10	14	11	12
1978	10	9	10	7	11	16	15	20	21	17	16	4
1979	12	14	11	12	11	--	17	15	14	13	16	10

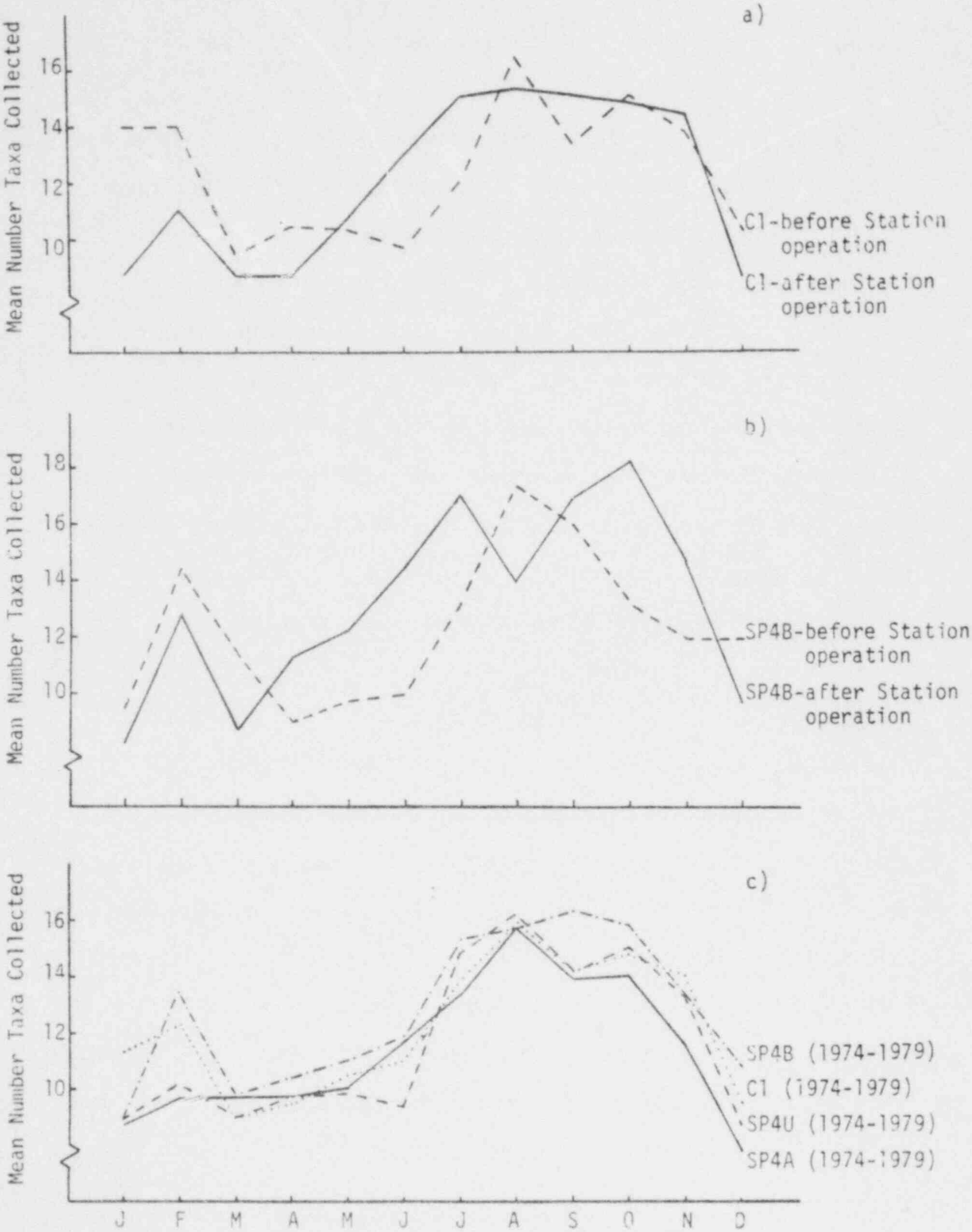

Figure 2. Mean number of taxa collected each month at each station during the study, 1974-1979.

The normal cycle of taxon numbers changed at SP4B and C1 after Generating Station operation began, although the pattern persisted. Taxon number increase occurred earlier, and the high number lasted longer.

Normally, the macroinvertebrate community of a site was composed of a few rather-abundant organisms and a number of rarer, less-common forms. Since 1974, 133 macroinvertebrate taxa have been collected in the South Platte River (Table 3). Of these, 83 (62%) were very rare, 28 (21%) were rare, 12 (9%) uncommon, 7 (5%) common, and 3 (2%) abundant.

Although eight orders of insects and six non-insect invertebrate groups were collected in the study area, two groups, Diptera and Oligochaeta, dominated the collection. Dipterans were the most speciose group, and Chironomidae were the most abundant in numbers and taxa. Simuliidae were generally common. Of the remaining insect taxa collected, only Baetis sp. (Ephemeroptera: Baetidae) and Hydropsyche sp. (Trichoptera: Hydropsychidae) were common. Hyalella azteca (Amphipoda: Talitridae) was the only common non-insect besides the Oligochaeta. Cladocerans were extremely abundant in the autumn of 1979 but were quite uncommon or absent in all other years.

Differences in diversity and biotic index values were often significant for the same quarter among years (Figure 3), but similar trends in values were observed through the year for each site (Figure 3a). Thus, the second quarter (April - June) normally had the lowest values and the third quarter (July - September) had the highest. Analysis-of-variance tests did not demonstrate significant differences in index values for a particular site for each year (except EQUIT in 1979) (Table 4). However, significant F statistics were frequently obtained when AOV was

Table 3. Aquatic macroinvertebrates collected in the South Platte River in the vicinity of the Fort St. Vrain Nuclear Generating Station, sites collected, years collected and relative abundance.

Taxa	Sites collected	Years collected	Relative abundance
Collembola			
Isotomidae			
Isotomurus palustris	SP4A,SP4U,SP4B,C1	74,77,78,79	VR
Plecoptera			
Perlodidae	SP4A(N),SP4U	78	VR
Ephemeroptera			
Siphlonuridae			
Siphlonurus sp.	SP4A,SP4U,SP4B,C1	74,76,77,78	R
Ameletus sp.	SP4B	75	VR
Baetidae			
Baetis sp.	SP4A,SP4U,SP4B,C1	74,75,76,77,78,79	C
Callibaetis sp.	CP4A(N),SP4B,C1	74	VR
Centroptilum sp.	SP4A,SP4B,C1	74,75	VR
Paracloeodes sp.	SP4A,SP4U,SP4B,C1	74	R
Pseudocloeon sp.	SP4A(O),SP4U,SP4B	75	VR
Heptageniidae			
Heptagenia sp.	SP4A,SP4U,SP4B,C1	74,75,76,77,78,79	UC
Leptophlebiidae			
Paraleptophlebia sp.	C1	76	VR
Traverella sp.	SP4U,C1	77	VR
Tricorythidae			
Tricorythodes sp.	SP4A,SP4U,SP4B,C1	74,75,76,77,78,79	UC
Caenidae			
Caenis sp.	SP4A(N),C1	77	VR
Odonata			
Gomphidae			
Ophiogomphus sp.	SP4A,SP4B,C1	74,75,77	R
Coenagrionidae	SP4U,C1	76,77,79	VR
Argia sp.	SP4A(N),SP4U,SP4B,C1	74,75,77,78,79	R
Hyponeura sp.	SP4B	74,75	VR
Amphiagrion sp.	SP4A(N),C1	78,79	VR
Ischnura sp.	SP4A,SP4U,SP4B,C1	74,76,77,78,79	R
Enallagma sp.	SP4A(O),SP4U,SP4B,C1	74,75,76,77,78	R
Anomalagrion sp.	SP4B,C1	74,77	VR
Hemiptera			
Gerridae			
Gerris sp.	SP4A(O),SP4U,SP4B,C1	74,77	R
Veliidae			
Microvelia sp.	SP4A(O),SP4U,SP4B	76	VR
Notonectidae			
Notonecta sp.	SP4B,C1	74,75	VR

Table 3. Continued.

Taxa	Sites collected	Years collected	Relative abundance
Corixidae	SP4A,SP4U,C1	75,77,78,79	R
Trichocorixa sp.	SP4A,SP4U,SP4B,C1	74,77,78	R
Corisella sp.	SP4B,C1	74	VR
Cenocorixa sp.	SP4A(O),SP4U,SP4B,C1	74,76,77,78	R
Trichoptera			
Trichoptera pupae	SP4U	78	VR
Hydropsychidae			
Hydrophyche sp.	SP4A,SP4U,SP4B,C1	74,75,76,77,78,79	C
Hydroptilidae			
Mayatrichia sp.	SP4A(N),SP4B	77	VR
Agraylea sp.	SP4U,C1	78	VR
Ochrotrichia sp.	SP4A(N),SP4U,SP4B,C1	78,79	UC
Coleoptera			
Haliplidae	SP4U	77	VR
Peltodytes sp.	SP4A(O)	75	VR
Dytiscidae	SP4U,SP4B,C1	78,79	VR
Dytiscus sp.	SP4A(O),SP4B	74,79	VR
Laccophilus sp.	SP4A(N),SP4B	74,75,79	R
Agabinus sp.	SP4U	79	VR
Agabetes sp.	SP4B,C1	78	VR
Matus sp.	SP4A(O)	74	VR
Noteridae	SP4B	79	VR
Corrhydrus sp.	SP4A(O),SP4B,C1	74	VR
Coptotomus sp.	C1	74	VR
Rhantus sp.	SP4A,SP4U,SP4B,C1	77,78	R
Hydrophilidae			
Helophorus sp.	SP4A(N),SP4U,SP4B,C1	78,79	R
Tropisternus sp.	SP4A(O),SP4U,SP4B,C1	74,75,76	R
Hydrophilus sp.	SP4A(O)	76	VR
Enochrus sp.	C1,SP4B	75,76	VR
Laccohius sp.	SP4B,C1,SP4A(O)	75	R
Hydrobius sp.	C1	74	VR
Diptera			
Tipulidae	SP4A,SP4U,SP4B,C1	75,76,77,78,79	R
Tipula sp.	SP4A(N),SP4U,SP4B	77,78	VR
Pedicia sp.	C1	79	VR
Hexatoma sp.	SP4A(N),SP4B,C1	78,79	VR
Psychodidae	SP4A(N),SP4U,SP4B,C1	75,76,77	R
Psychoda sp.	SP4A(N),SP4U,SP4B	79	VR
Simuliidae			
Simuliidae pupae	SP4U	78,79	R
Simulium sp.	SP4A,SP4U,SP4B,C1	74,76,76,88,78,79	C
Chironomidae	SP4A,SP4U,SP4B,C1	78,79	UC
Chironomidae pupae	SP4A,SP4U,SP4B,C1	77,78,79	UC
Tanypodinae			
Tanypus sp.	SP4A	77,78	VR
Procladius sp.	SP4A(O),C1	75,76	VR

Table 3. Continued.

Taxa	Sites collected	Years collected	Relative abundance
Clinotanypus sp.	SP4A(O)	75	VR
Conchapelopia sp.	SP4A,SP4U,SP4B,C1	74,76,76,77,78,79	UC
Diamesinae			
Diamesa sp.	SP4A,SP4U,SP4B	75,76,77,78,79	R
Pseudodiamesa sp.	SP4B	76,78,79	VR
Potthastia sp.	SP4B	77	VR
Monodiamesa sp.	SP4B	78	VR
Orthocladinae			
Brillia sp.	SP4A(O),SP4B,C1	74,75	VR
Thienemanniella sp.	SP4A(N),C1	78,79	VR
Smittia sp.	SP4U	79	VR
Eukiefferiella sp.	SP4A(O),SP4U,SP4B,C1	75,76	VR
Psectrocladius sp.	SP4A,SP4U,SP4B,C1	74,76,77,78,79	R
Cricotopus sp.	SP4A,SP4U,SP4B,C1	74,75,76,78,79	A
Orthocladius sp.	SP4A,SP4B,C1	74,75,76,77	R
Nanocladius sp.	St. Vrain		
Heterotrissocladius sp.	SP4A(O),C1	74,75,76	VR
Trichocladius sp.	C1	79	VR
Diplocladius sp.	SP4U	78	VR
Chironominae			
Chironomus sp.	SP4A,SP4U,SP4B,C1	74,75,76,77,78,79	C
Cryptochironomus sp.	SP4A,SP4U,SP4B,C1	74,75,76,77,78,79	UC
Glyptotendipes sp.	SP4A,SP4U,SP4B,C1	74,75,76,77,78,79	UC
Dicrotendipes sp.	SP4A,SP4U,SP4B	74,75,76,77,78,79	C
Polypedilum sp.	SP4A,SP4U,SP4B,C1	74,75,76,77,78,79	C
Stictochironomus sp.	SP4A(O),SP4U,SP4B,C1	74,75,77,78	VR
Kiefferulus sp.	SP4A(N)	77	VR
Phaenopsectra sp.	SP4A(O),SP4U,SP4B,C1	75,76,77,79	VR
Parachironomus sp.	SP4A(O),SP4U,SP4B,C1	74,76,78,79	VR
Paracladopelma sp.	SP4A(O),SP4B,C1	74	VR
Micropsectra sp.	SP4A,SP4U,SP4B,C1	74,75,76,79	R
Paralauterborniella sp.	SP4A,SP4U,SP4B,C1	75,76,77,78,79	UC
Tanytarsus sp.	SP4A,SP4U,SP4B,C1	75,76,77,78	UC
Rheotanytarsus sp.	SP4A(N),SP4U,SP4B,C1	77,78,79	R
Pseudochironomus sp.	SP4A(N),SP4U,SP4B,C1	77,78	R
Endochironomus sp.	SP4A(N),C1	75,76,77	VR
Goeldichironomus sp.	SP4U	79	VR
Ceratopogonidae	SP4A(N),SP4U	76,79	VR
Palpomiyia sp.	SP4A(O),C1	78	VR
Stratiomyidae	SP4A(N),SP4U,SP4B,C1	74,79	VR
Tabanidae	SP4A(O),SP4U,SP4B	74,75,76,78	VR
Tabanus sp.	C1	75	VR
Athericidae			
Atherix sp.	SP4A(O),SP4B,C1	74	VR
Dolichopodidae	SP4A(O),SP4U,C1	75,76	VR
Empididae	SP4B	76	VR
Syrphidae	SP4B	74	VR

Table 3. Continued.

Taxa	Sites collected	Years collected	Relative abundance
Ephydridae	SP4A,SP4U,SP4B,C1	76,77,78	R
Brachydentera sp.	SP4U	78	VR
Muscidae	SP4A,SP4U,SP4B,C1	74,75,76,78	VR
Limnophora sp.	SP4A(N),SP4U,SP4B	77	VR
Scatophagidae (=Anthomyiidae)	SP4A(O),SP4B,C1	74	VR
Coelenterata			
Hydroida	SP4B,C1	78	VR
Turbellaria			
Tricladida			
Planariidae	SP4A(N),SP4U,SP4B,C1	77,78,79	VR
Dugesia sp.	SP4A(O),SP4U	76	VR
Nematoda	SP4A(N),SP4U,SP4B,C1	79	VR
Nematomorpha	SP4A(N)	79	VR
Annelida			
Oligochaeta	SP4A,SP4U,SP4B,C1	74,75,76,77,78,79	A
Hirudinea	SP4A,SP4B,C1	78,79	VR
Pharyngobdellida			
Erophdellidae	SP4A(O),SP4U	74,78	VR
Eropbdella sp	SP4B,C1	74	VR
Crustacea			
Cladocera	SP4A(N),SP4U,SP4B,C1	79	A*
Daphnidae	SP4A(N),SP4U,SP4B,C1	78,79	R
Daphnia sp.	SP4A(N),SP4B	79	R
Copepoda	SP4A(N),SP4U,CP4B,C1	78,79	VR
Cyclopoida	SP4B	79	VR
Ostracoda	SP4B	78	VR
Isopoda			
Asellidae			
Asellus sp.	SP4A(N),SP4U,SP4B,C1	77,78,79	VR
Amphipoda			
Talitridae			
Hyalella azteca	SP4A,SP4U,SP4B,C1	74,75,76,77,78,79	C
Gammaridae			
Gammarus sp.	SP4U	79	VR
Crangonyx sp.	SP4A,SP4U,SP4B,C1	74,75,76,77,78,79	UC
Decapoda			
Astacidae			
Camborus sp.	SP4A(O),SP4U,SP4B,C1	74,75,76,77,78	R

*Cladocera extremely abundant on dates collected.

Table 3. Continued.

Taxa	Sites collected	Years collected	Relative abundance
Gastropoda			
Physidae			
Physa sp.	SP4A,SP4U,SP4B,C1	74,75,76,77,78,79	UC
Lymnaeidae			
Lymnaea sp.	SP4A(O),SP4B,C1	74,77,78	UR

133 taxa total
83 taxa VR = 62%
28 taxa R = 21%
12 taxa UC = 9%
7 taxa C = 5%
3 taxa A = 2%

Very Rare (VR): collected in only one year in very low numbers (<10) on one or more sampling dates at one station and/or collected in several years on one or more sampling dates at one or more stations in extremely low numbers (<5).

Rare (R): collected at one or more sampling sites on one or more sampling dates in several years in low numbers (<25).

Uncommon (UC): collected at several sampling sites on several sampling dates in most to all years in generally low to moderate numbers (10-100).

Common (C): collected at most sites on most sampling dates in most years in moderate to high numbers (25-250).

Abundant (A): always (or almost always) collected on all sampling dates at all sampling sites in all years in moderate to extremely high numbers (25).

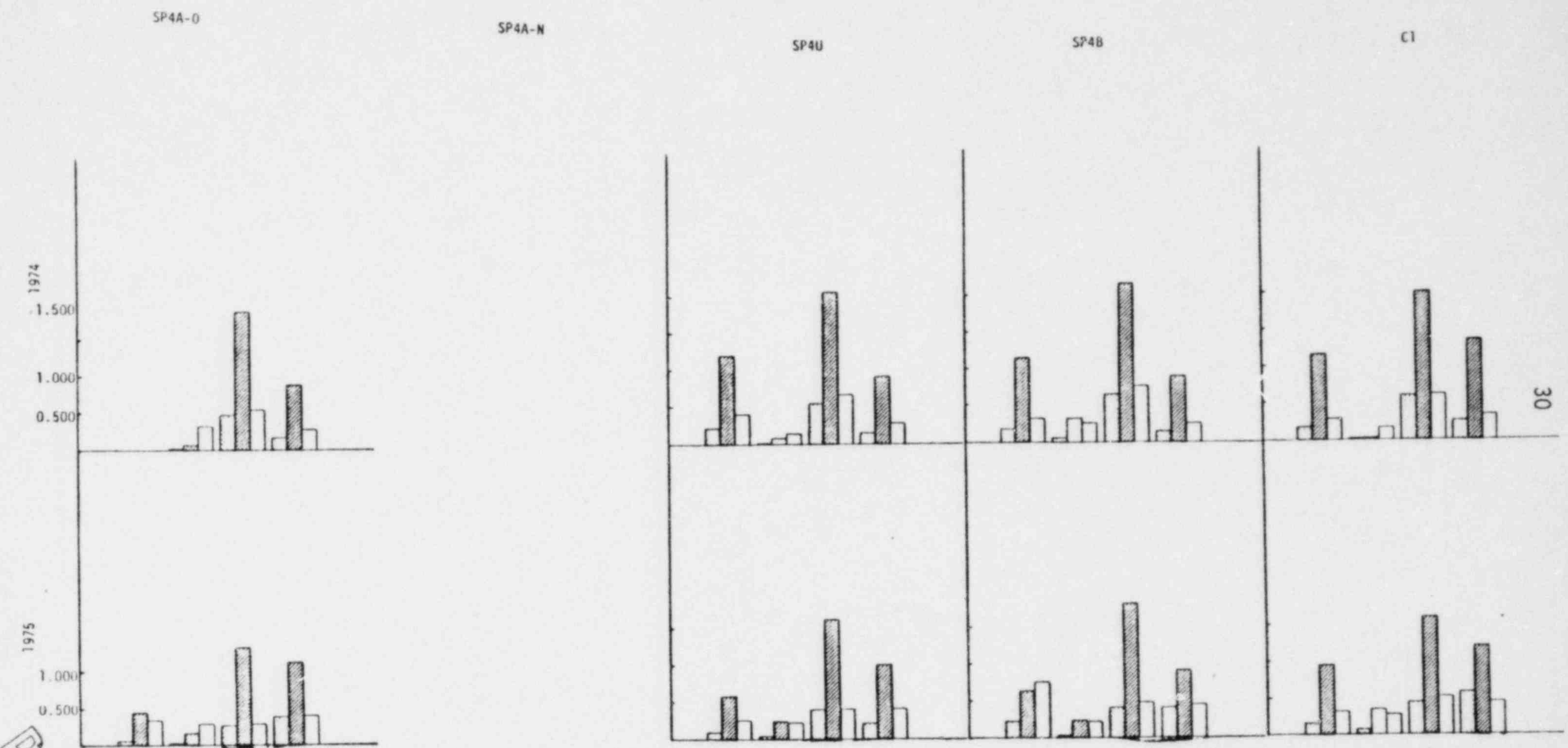

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Figure 3. ['versity and Biotic Index values for each quarter at four sampling stations on the S ,th Platte River, Colorado.

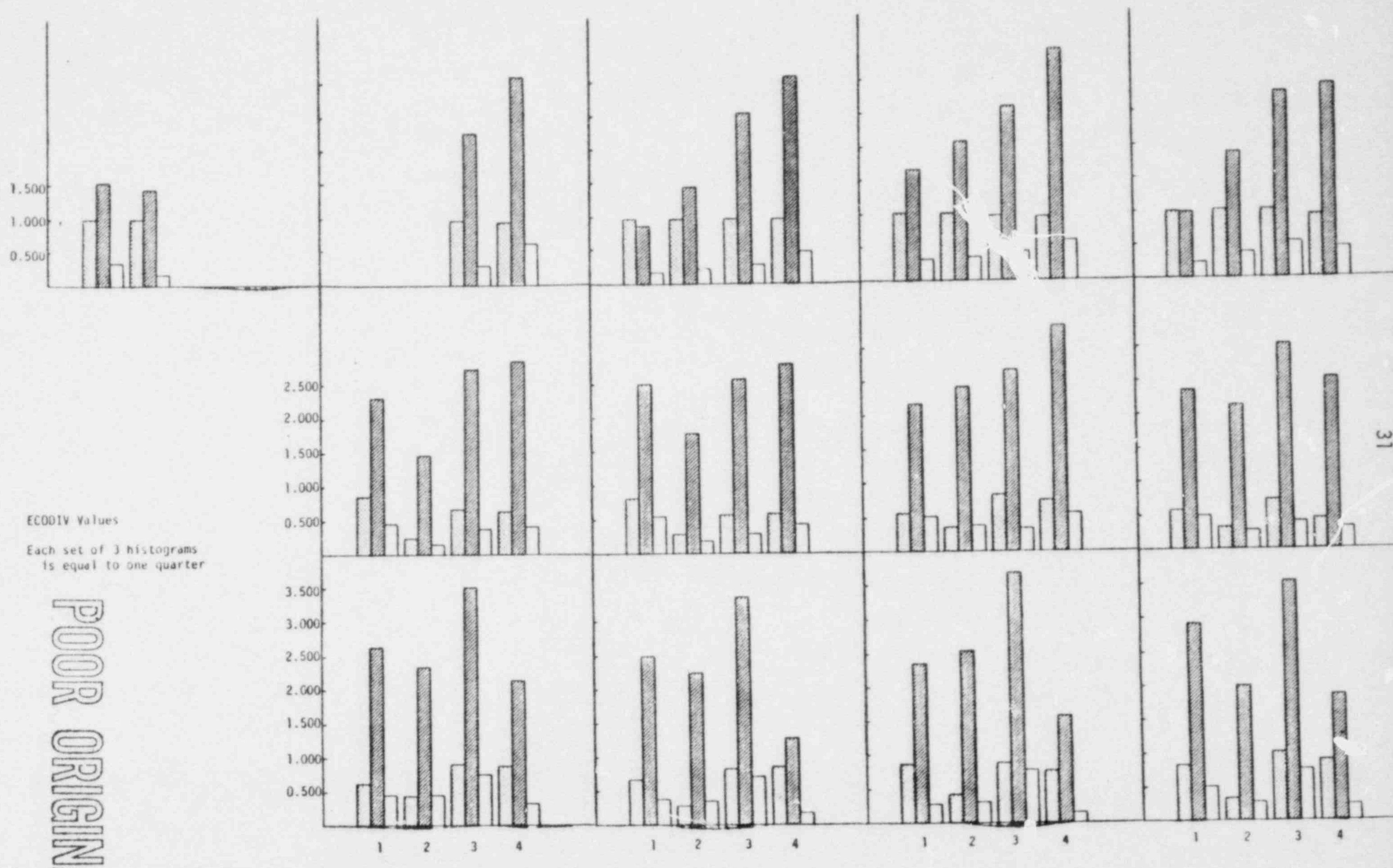

Figure 3. (Continued)

Table 4. AOV comparison of ECODIV values by year in a downstream direction. ECODIV values are for all sites and all quarters.

	H_o [1]	F_s [2]	F_t [3]	Reject?
TCI				
1975	No difference in ECODIV value for year among sites	0.0469	3.59	No
1976	"	0.5339	3.49	No
1977	"	0.0933	3.36	No
1978	"	0.1676	3.49	No
1979	"	0.0779	3.49	No
DBAR				
1975	"	0.1193	3.59	No
1976	"	0.1367	3.49	No
1977	"	1.4298	3.36	No
1978	"	0.2534	3.49	No
1979	"	0.[illegible]154	3.49	
EQUIT				
1975	"	0.0212	3.59	No
1976	"	1.1985	3.49	No
1977	"	0.8634	3.36	No
1978	"	0.3871	3.49	No
1979	"	4.2415	3.49	Yes

[1] H_o = null hypothesis.
[2] F_s = calculated F statistic.
[3] F_t = table F statistic.

performed to analyze differences for the same quarter among stations (Table 5).

Statistical analysis of other aspects of invertebrate numbers, relative abundance, and taxon numbers by several approaches failed to demonstrate significant changes among stations or through the years at a particular station.

Fishes

Annual fish collections at two sites each on the South Platte and St. Vrain Rivers showed no significant changes in the fish community of either stream in this study. Twenty-five species representing eight families were collected (Tables 6 and 7). Four species (Salmo gairdneri, Hybognathus hankinsoni, Fundulus sciadicus and Micropterus dolomieui) were found only in the St. Vrain River. None was common. Minnows (Cyprinidae) were the most speciose family and most numerous fish in both streams in all collections. The number of species collected bore a strong relation to the intensity of sampling effort. Never were all species collected during the study present in one sample. Notropis stramineus was normally the most abundant species. Game fish were never abundant, and the few captured were always rather small.

Sampling Stations

SP4A-N and O

The location of SP4A was moved in 1977 because of effluent discharge near SP4U. From 1974 through June 1977, SP4A was immediately above the primary effluent discharge point. In July 1977, SP4A was relocated opposite Goosequill Pond (SP4A-O designates the pre-July 1977 and SP4A-N the post-July 1977 location of SP4A). Although major differences in the macroinvertebrate communities of the two sites were

Table 5. AOV comparison of ECODIV values of four sites on the South Platte River. ECODIV values are based upon quarters, and F Statistics are calculated for comparison of sites in a downstream direction for each quarter.

	H_o[1]	F_s[2]	F_t[3]	Reject?
TCI				
J - M	Each site is not significantly different	59.7157	3.11	Yes
A - J	"	454.3557	3.06	Yes
J - S	"	45.4451	3.06	Yes
O - D	"	45.5131	3.06	Yes
DBAR				
J - M	"	47.8563	3.11	Yes
A - J	"	36.1712	3.06	Yes
J - S	"	66.0255	3.06	Yes
O - D	"	58.2430	3.06	Yes
EQUIT				
J - M	"	2.3120	3.11	No
A - J	"	1.3645	3.06	No
J - S	"	17.3845	3.06	Yes
O - D	"	11.8146	3.06	Yes

[1] H_o = null hypothesis.
[2] F_s = calculated F statistic.
[3] F_t = table F statistic.

Table 6. Ichthyofauna of St. Vrain Creek in the vicinity of the Fort St. Vrain Nuclear Generation Station, 1975 to 1979.

	1975 #/%	1976 #/%	1977 #/%	1978 #/%	1979 #/%
Dorosoma cepedianum		1/0.3	3/0.3		
Cyprinus carpio	6/1.3	64/18.9	496/44.6	26/1.9	62/1.4
Pimephales promelas	39/8.7	12/3.5	43/3.9	250/18.3	106/2.4
Notropis lutrensis	66/14.7	11/3.2	6/0.5	14/1.0	595/13.6
N. dorsalis				15/1.1	73/1.7
N. stramineus	270/60.3	88/26.0	164/14.8	939/68.6	3288/75.4
Hybognathus hankinsoni				9/0.7	12/0.3
N. stramineus x H. hankinsoni					
Semotilus atromaculatus	1/0.2	4/1.2			3/0.1
Rhinichthys cataractae		6/1.8	2/0.2	18/1.3	62/1.4
Campostoma anomalum				4/0.3	4/0.1
Cyprinidae hybrids		37/10.9			
Catostomus catostomus		4/1.2	75/6.8	2/0.1	8/0.2
C. commersoni	41/9.2	59/17.4	172/15.5	53/3.9	88/2.0
Ictalurus melas		1/0.3			5/0.1
Fundulus kansae		1.0.3	10/0.9	23/1.7	11/0.3
F. sciadicus					
Culaea inconstans	3/0.7			2/0.1	1/>0.1
Lepomis cyanellus	22/4.9	39/11.5	117/10.5	13/1.0	34/0.8
L. humilus		1/0.3			2/>0.1
L. macrochirus			1/0.1		
Pomoxis annularis		3/09			4/0.1
P. nigromaculatus			2/0.2		
Perca flavescens		.5	13/1.2		
Micropterus salmoides		,/0.3			1/>0.1
M. dolomieui		2/0.6	7/0.6		
Total # specimens	448	339	1111	1368	4359
Total # species	8	18	14	13	18

Table 7. Ichthyofauna of the South Platte River in the vicinity of the Fort St. Vrain Nuclear Generating Station, 1975 to 1979.

	1975 #/%	1976 #/%	1977 #/%	1978 #/%	1979 #/%
Dorosoma cepedianum		1/0.5			
Salmo gairdneri					
Cyprinus carpio	18/5.2	54/29.0	75/17.4	23/3.2	133/5.1
Pimephales promelas	52/15.0	20/10.8	35/8.1	217/29.8	123/4.8
Notropis lutrensis	38/11.0	2/1.1		6/0.8	290/11.2
N. dorsalis				32/4.4	147/5.7
N. stramineus	172/49.7	31/16.7	197/45.6	388/53.2	1759/68.6
Semotilus atromaculatus	2/0.6	1/0.5	1/0.2		2/0.1
Rhinichthys cataractae	10/2.9	2/1.1	16/3.7	1/0.1	5/0.2
Campostoma anomalum				5/0.7	
Cyprinidae hybrids	45/13.0				
Catostomus catostomus		7/3.8	12/2.8	3/0.4	2/0.1
C. commersoni	5/1.4	57/30.6	72/16.7	4/0.5	54/2.1
C. catostomus x C. commersoni					2/0.1
Ictalurus melas	1/0.3		6/1.4		2/0.1
Fundulus kansae			6/1.4	53/7.3	28/1.1
Culaea inconstans					2/0.1
Lepomis cyanellus	3/0.9	9/4.8	12/2.8	1/0.1	29/1.1
L. humilus					
L. macrochirus					8/0.3
L. cyanellus x L. gibbosus				1/0.1	
Pomoxis annularis					
P. nigromaculatus		1/0.5			
Perca flavescens		1.0.5			
Micropterus salmoides					1/>0.1
Total # specimens	3461	186	432	729	2587
Total # species	10	12	10	12	16

not observed, some differences were detected and are at least partially explained by the relocation of collection points.

Dipterans and oligochaetes were the preponderant groups found at both SP4A sites. Chironomidae was the most speciose dipteran family. More genera of Chironomidae were found at SP4A-N than at SP4A-O. However, none of the genera unique to SP4A-N was very abundant or found throughout the year. In 1975 and 1976, *Cricotopus* sp. had two periods of maximum abundance, but the 1975 peaks were more equal in numbers and duration (Figure 4). In 1978, they were extremely abundant from June through November, but in 1979 peak abundance occurred early in the year followed by a lower peak in late summer. *Polypedilum* sp. and *Paralauterborniella* sp. had abbreviated periods of peak abundance in the summer at both SP4A sites (Figures 5 and 6). *Chironomus* sp. normally had a summer high but were found in other months in varying numbers (Figure 7). *Dicrotendipes* sp. was usually more abundant earlier in the year than at any other time, but the pattern was not absolute (Figure 8). *Conchapelopia* sp. had no obvious pattern of appearance or abundance (Figure 9). At SP4A-O, *Simulium* sp. were never particularly common; they were frequently abundant at SP4A-N and evidenced two periods of high numbers (Figure 10). No other dipterans were commonly collected at either SP4A-O or SP4A-N.

Hydropsyche sp. and *Baetis* sp. were the only non-dipteran insects commonly collected at both SP4A sites. *Baetis* sp. were normally collected in a rather restricted period in moderate to high numbers at both sites (Figure 11). *Hydropsyche* sp. were found in most months but were typically most abundant in the first and last quarters of the year (Figure 12).

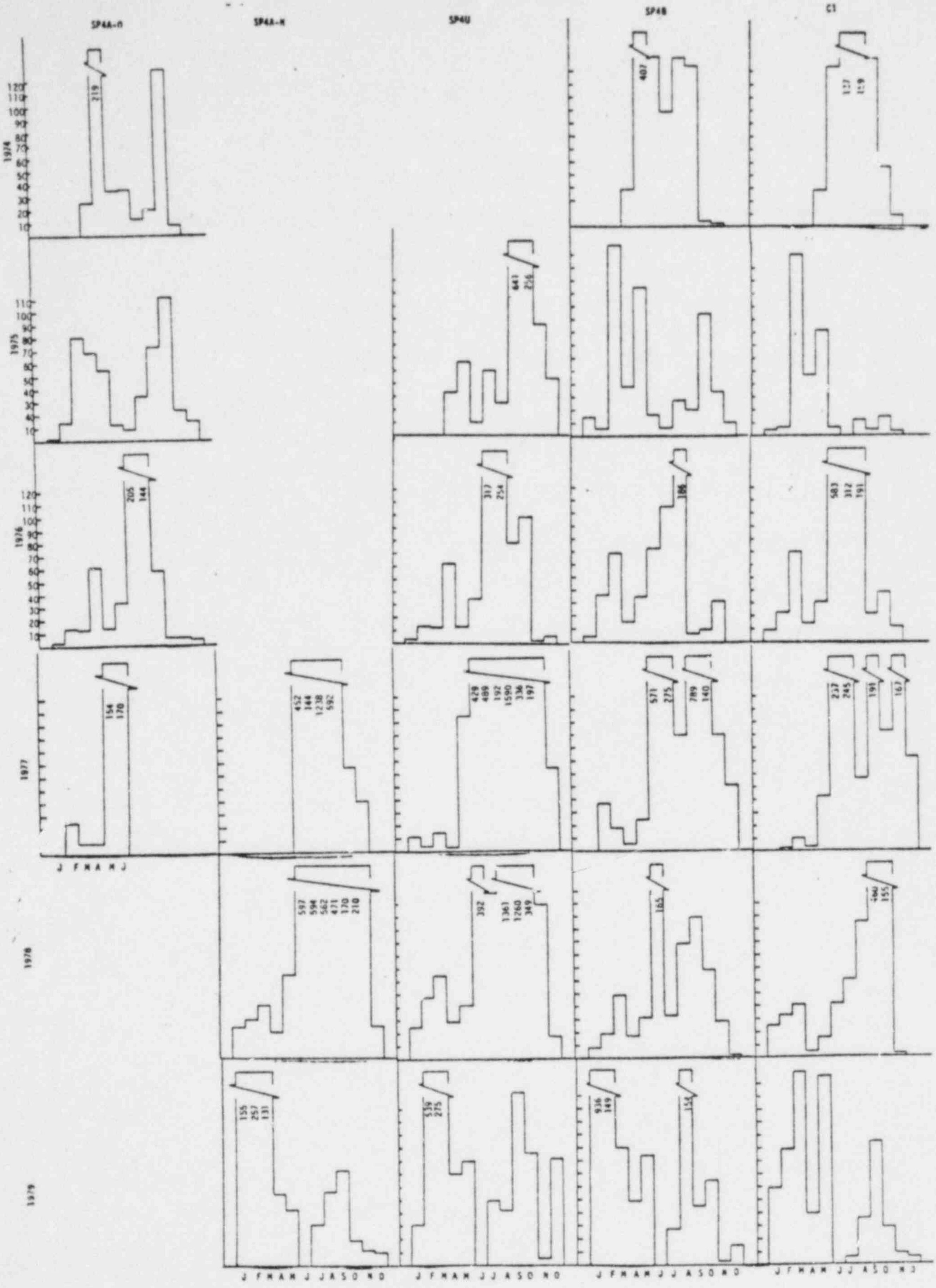

Figure 4. Number of Cricotopus sp. collected each month at four stations on the South Platte River, 1974-1979.

POOR ORIGINAL

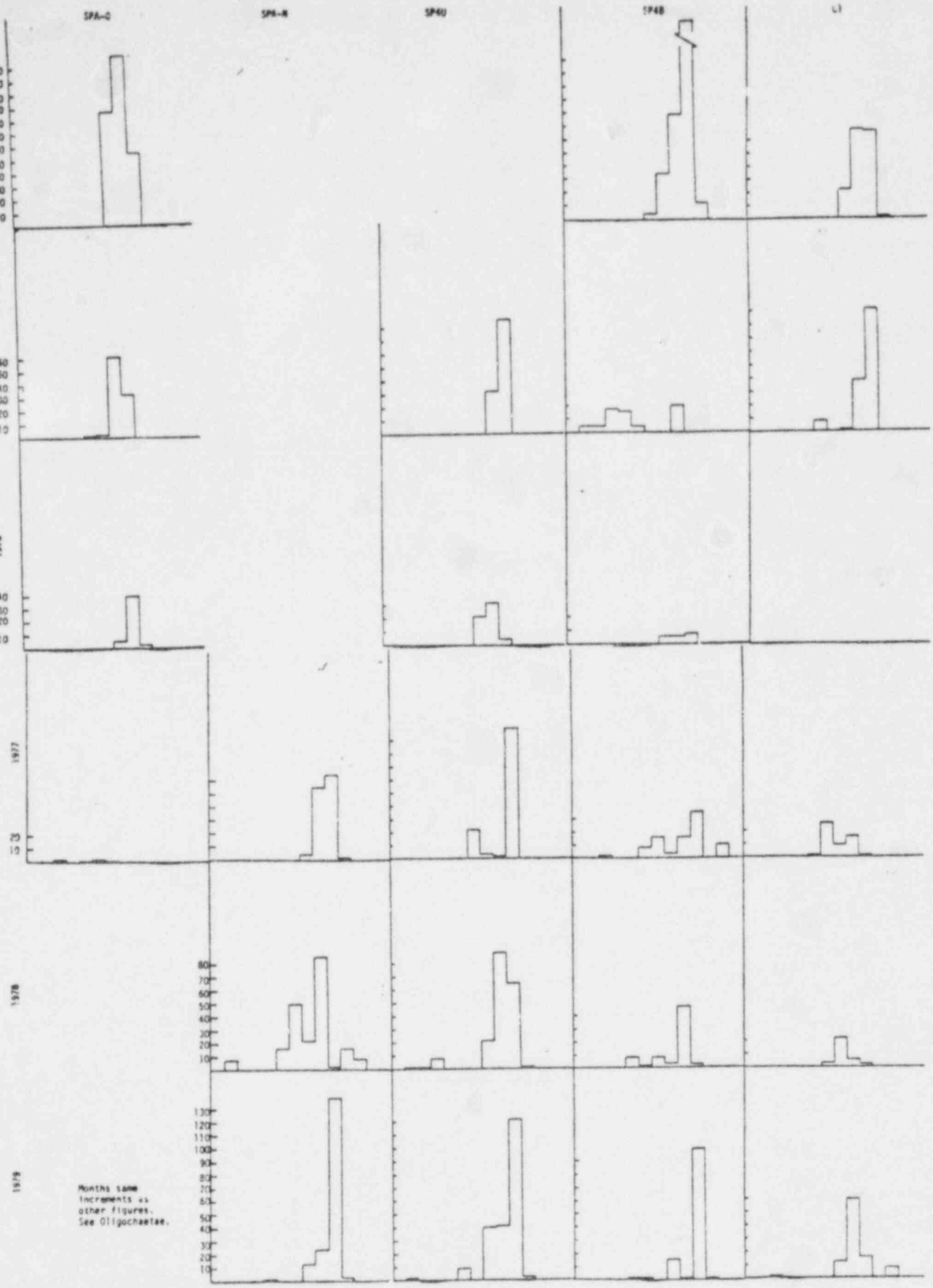

Figure 5. Number of Polypedilum sp. collected each month at four stations on the South Platte River, 1974-1979.

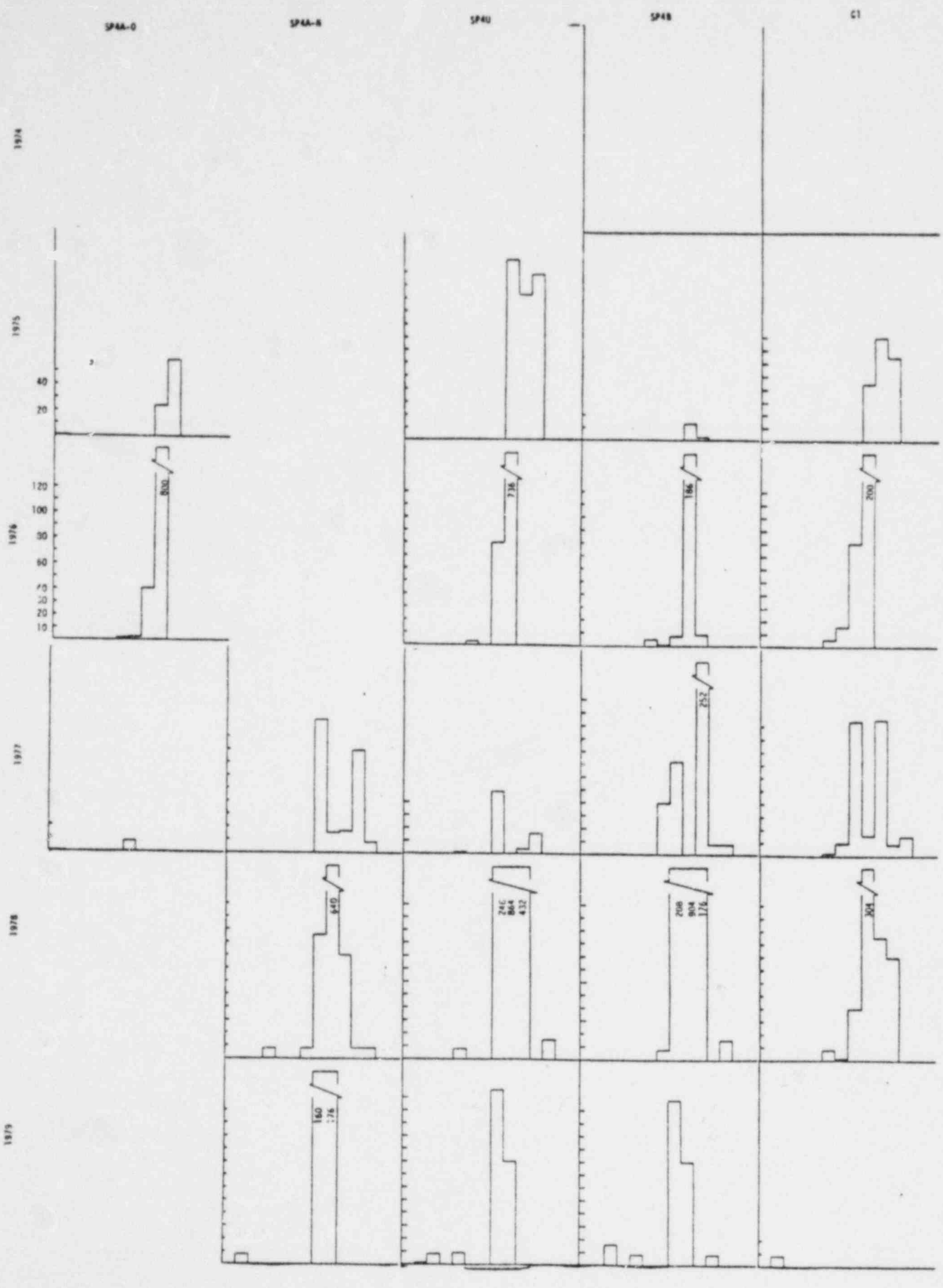

Figure 6. Number of Paralauterborniella sp. collected each month at four stations on the South Platte River, 1974-1979.

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Figure 7. Number of Chironomus sp. collected each month at four stations on the South Platte River, 1974-1979.

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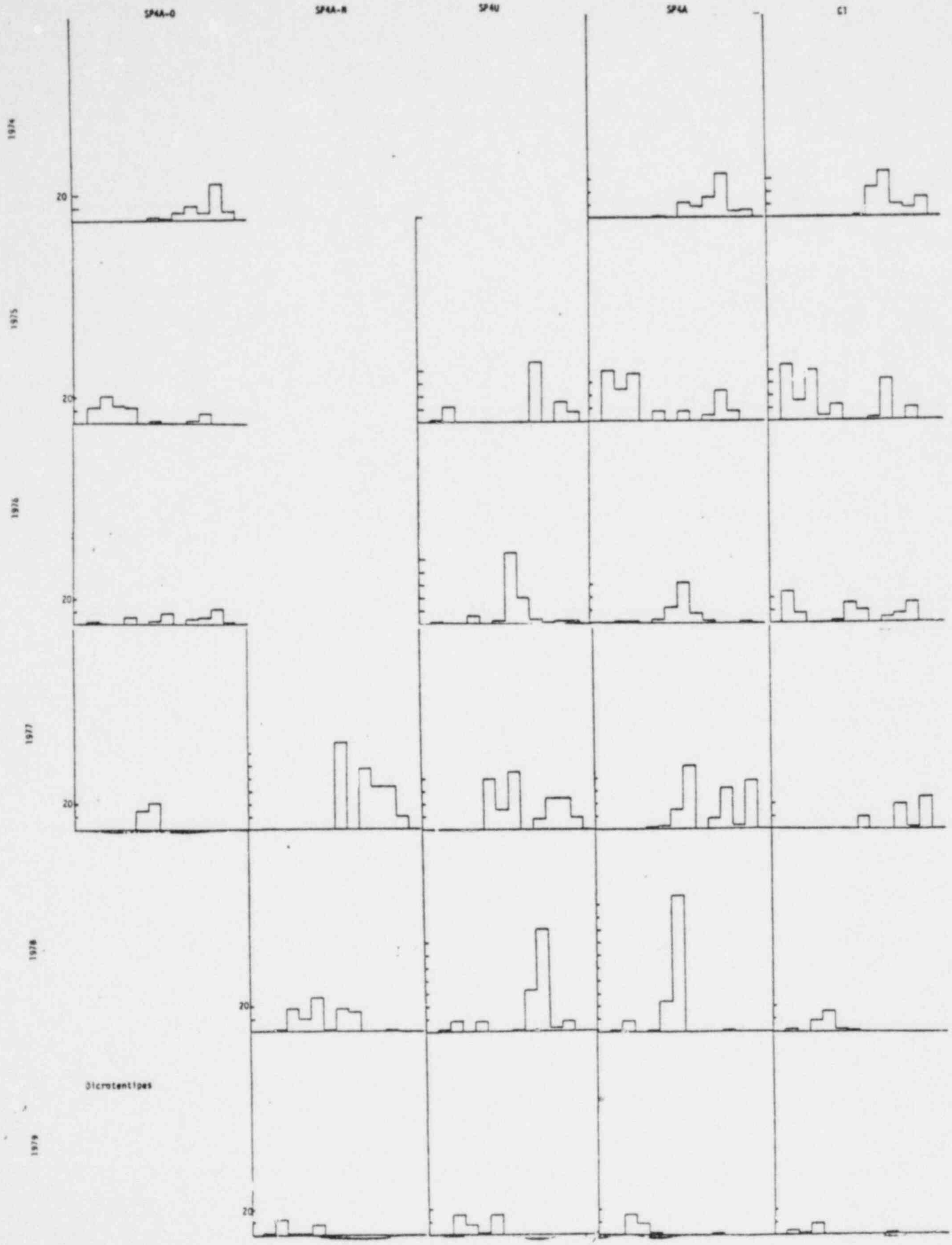

Figure 8. Number of Dicrotendipes sp. collected each month at four stations on the South Platte River, 1974-1979.

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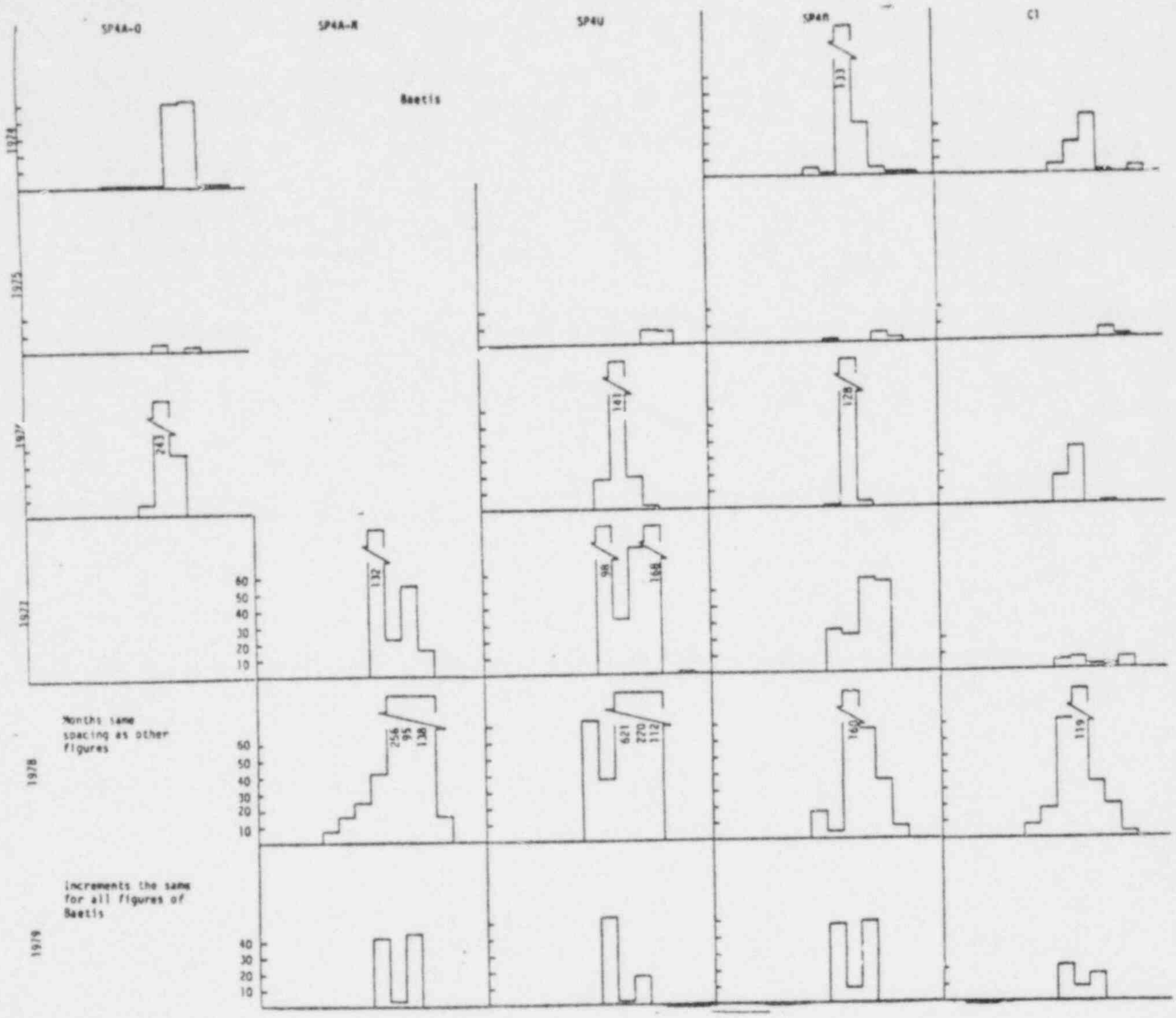

Figure 9. Number of Conchapelopia sp. collected each month at four stations on the South Platte River, 1974-1979.

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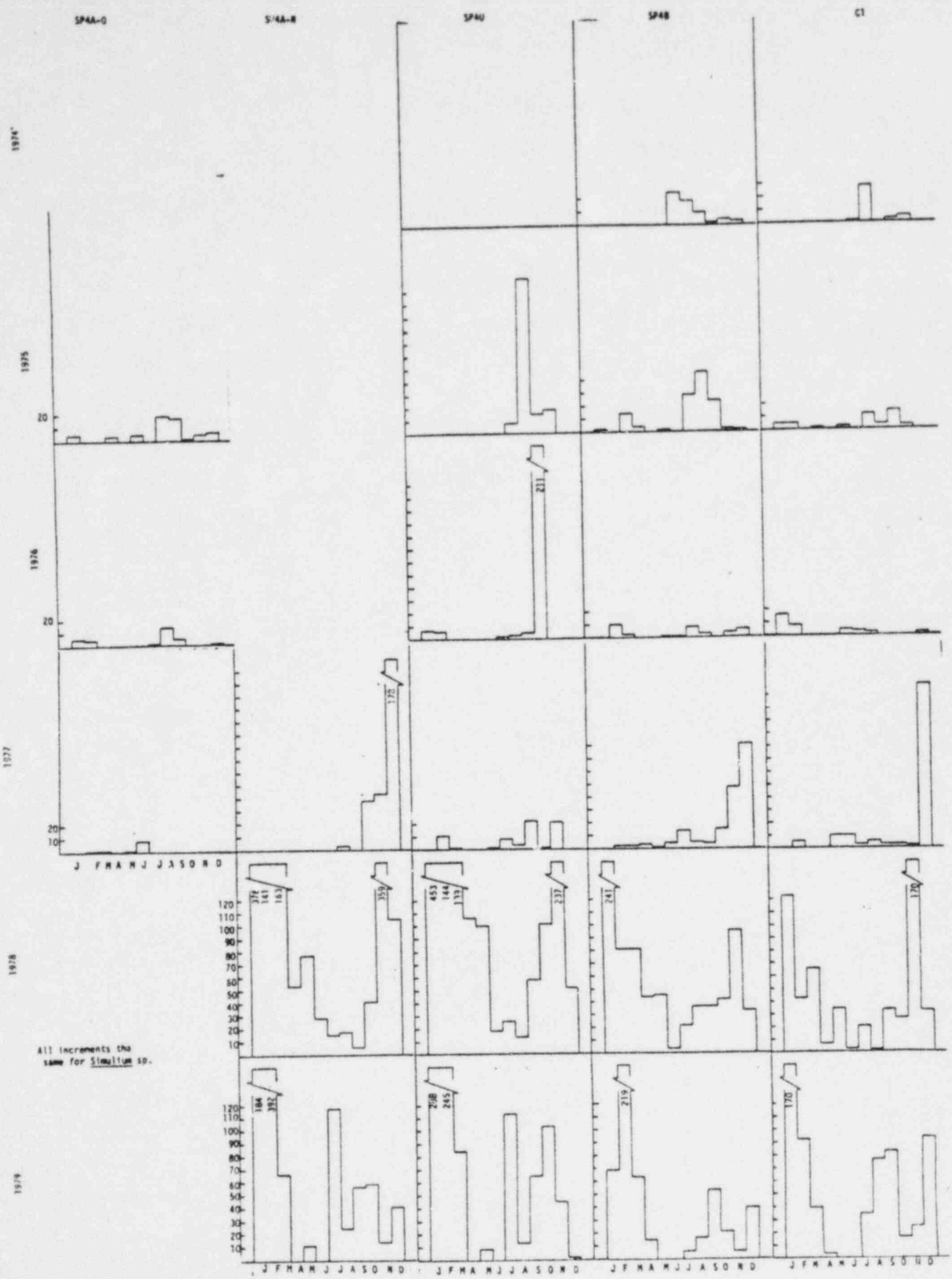

Figure 10. Number of Simulium sp. collected each month at four stations on the South Platte River, 1974-1979.

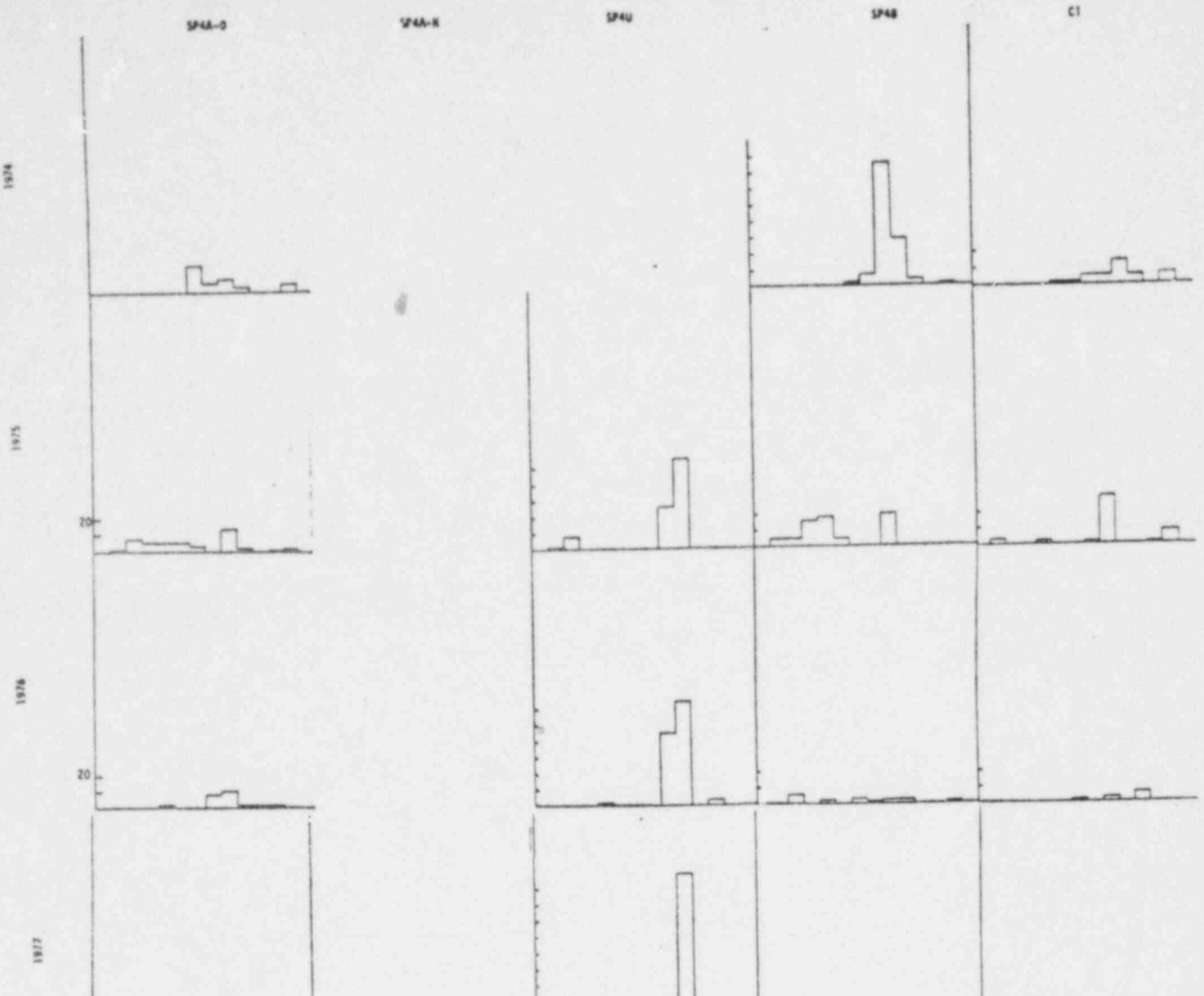

Figure 11. Number of Baetis sp. collected each month at four stations on the South Platte River, 1974-1979.

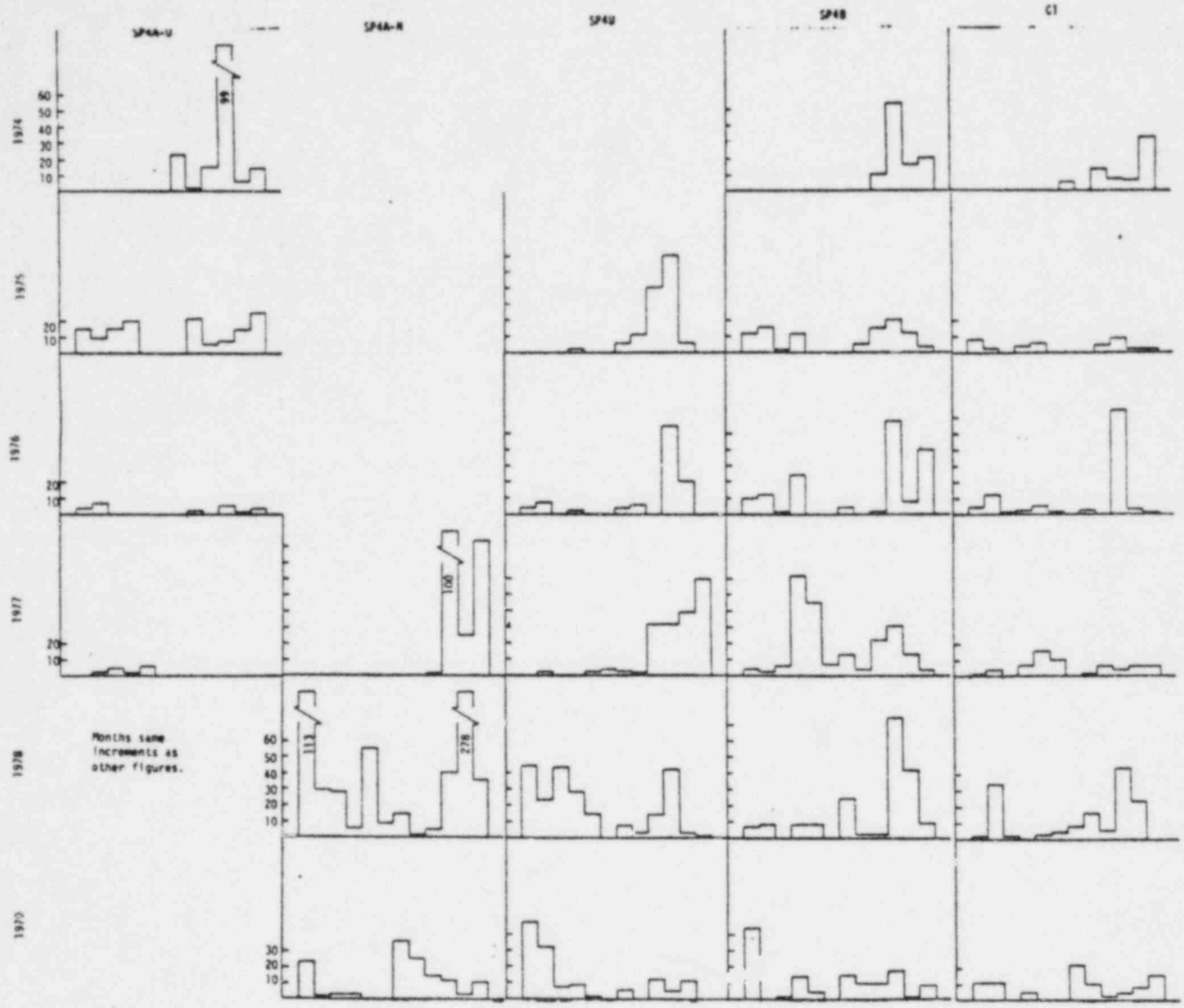

Figure 12. Number of Hydropsyche sp. collected each month at four stations on the South Platte River, 1974-1979.

Hyalella azteca and Oligochaeta were the only non-insect macroinvertebrates commonly collected. Hyalella azteca was found throughout the year at both sites, and bimodal cycles were evident in most years at both sites (Figure 13). At SP4A-O, Oligochaeta had distinct bimodal annual cycles with the second peak much narrower and lower than the first and preceeded by very brief periods of extremely-low numbers. At SP4A-N, peaks were considerably lower than at SP4A-O. The annual pattern at SP4A-N was similar to that at SP4A-O but less distinct (Figure 14).

Odonata, Hemiptera, and Coleoptera had relatively few representatives at SP4A, and none was common. One representative of Plecoptera (Perlodidae) was collected at SP4A-N in 1977. Cladocerans were found in very high numbers in October 1979.

Slightly more taxa were found at SP4A-N than at SP4A-O. Most taxa found at SP4A-O were found at SP4A-N, but most rare taxa at SP4A-N were not collected at SP4A-O. Taxon numbers were normally greater in the second half of the year at both sites.

Community diversity index values were usually highest in the third quarter and lowest in the second (but occasionally the fourth) quarter of the year. Biotic index values approximated diversity index values. The patterns were similar at both sites.

SP4U --

Data collection was initiated at SP4U in 1974. The site was selected to provide a control site above any possible influence of effluent from Goosequill Pond. Unfortunately, seepage from the pond was observed in the vicinity of the site in June 1977. Since then, flow has only been detected a few times entering the South Platte near SP4U.

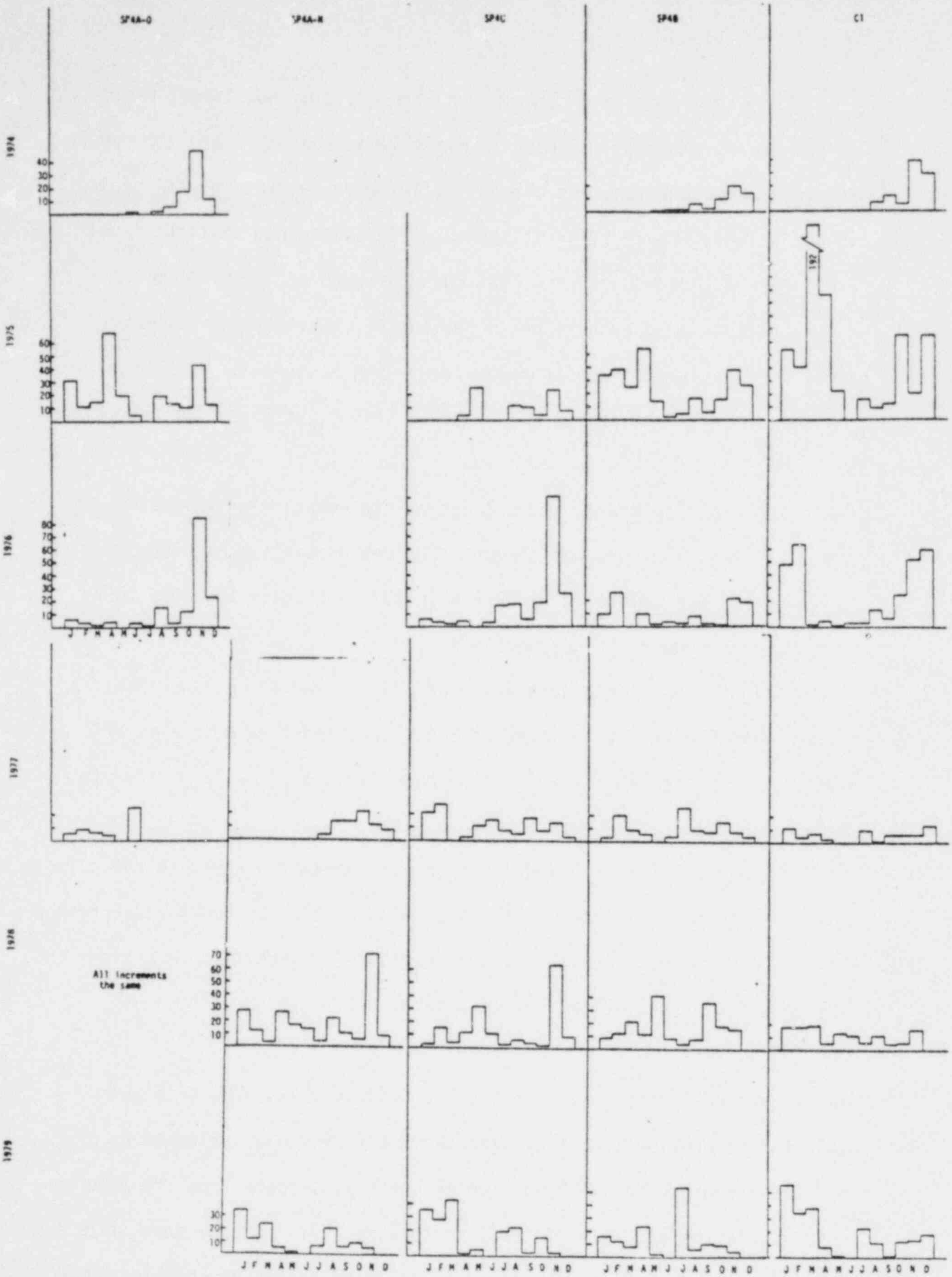

Figure 13. Number of Hyalella azteca collected each month at four stations on the South Platte River, 1974-1979.

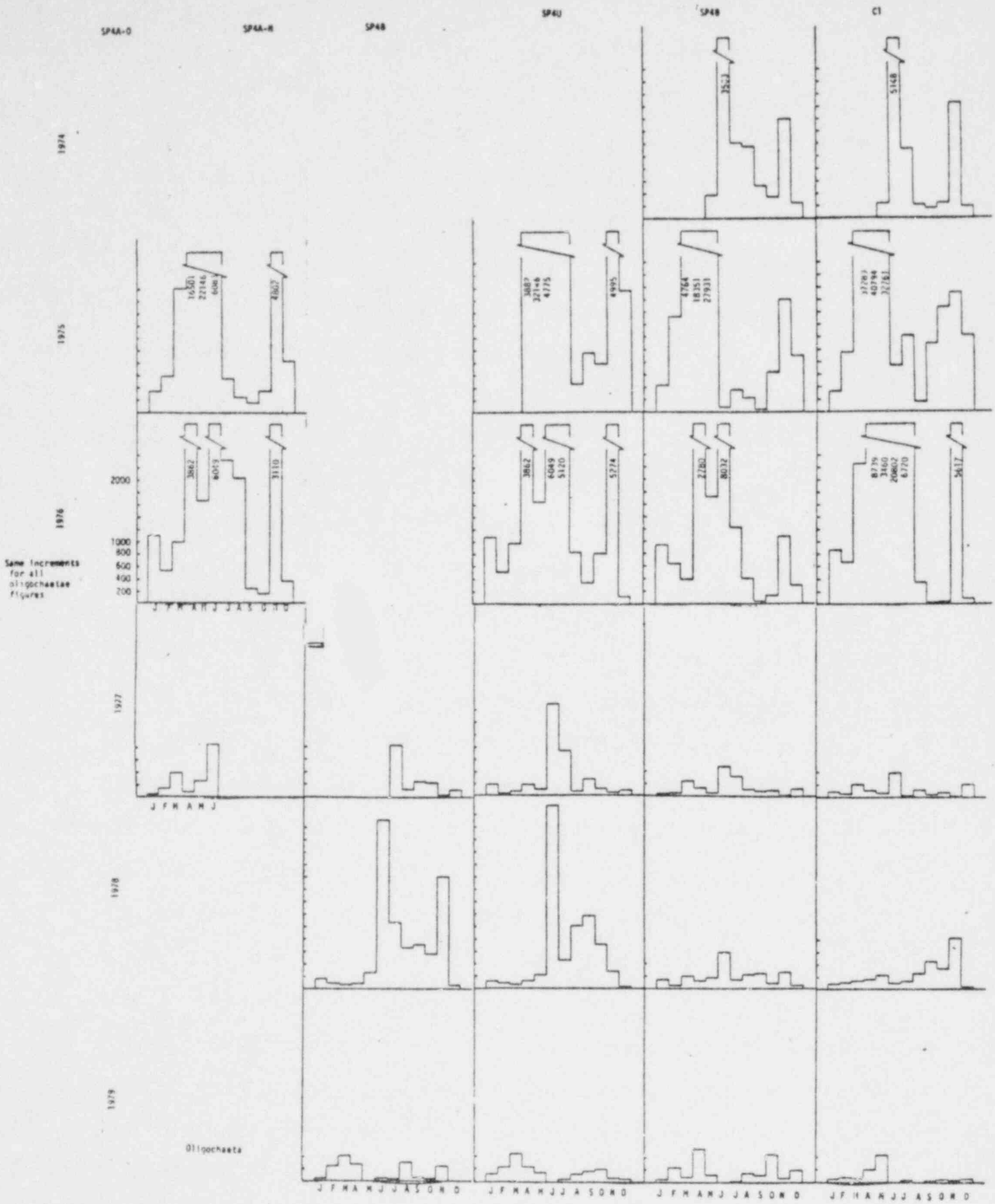

Figure 14. Number of Oligochaeta collected each month at four stations on the South Platte River, 1974-1979.

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Despite possible contamination by water from Goosequill Pond, the effect was probably negligible.

Station SP4U was the least speciose of the four stations, which is at least partially a function of the short time samples have been taken from it. However, the channelized bed morphology would tend to make the environment less tenable for many forms. Numbers of taxa collected each year at SP4U were similar to all other stations every year (except SP4B, 1979).

In most respects, SP4U was similar to all other stations. Dipterans, particularly Chironomidae, and oligochaetes dominated the invertebrate fauna. A relatively-high proportion of the chironomid genera present at SP4U were classified as common. Six of 22 genera occurred every year, and two were common in all years except 1975 (Table 3). Thus, SP4U had a rather small number of very rare genera of Chironomidae. Cricotopus sp. was found in all months of every year but was quite abundant June - November; in 1979 the greatest number of Cricotopus sp. was collected in February and March. Thus, except for 1979, Cricotopus sp. abundance followed a constant pattern through the study (Figure 4). Polypedilum sp., Paralauterborniella sp. and Dicrotendipes sp. had distinct, short periods of occurrence, when their numbers were high. Their periods of abundance remained relatively invariable throughout the study (Figures 5, 6 and 8). Conchapelopia sp. followed a similar pattern during the study, but in 1979 they were collected more randomly and in generally low numbers (Figure 9). Chironomus sp. had a pattern of peak abundance similar to those of the above genera, but its periods of abundance were not as sharply delineated and tended to vary among years (Figure 7).

Early in the study, Simulium sp. occurred in relatively-low numbers and demonstrated no readily-discernable pattern. However, in 1978 and 1979 they were significantly more abundant and had two periods of peak abundance each year (Figure 10).

Baetis sp. had a fairly-consistent, strict, seasonality of appearance. However, numbers were much greater in 1978 than in other years (Figure 11). Hydropsyche sp. were most abundant in the winter months (Figure 12).

Hyalella azteca did not follow any obvious pattern at SP4U. A trend detectable one year would be essentially reversed the next (Figure 13). Oligochaetes were extremely abundant in several months in 1975 and 1976. Their numbers were quite high in early summer in all years except 1979 (Figure 14).

All groups found at SP4U had few taxa per group. Community diversity was normally greatest in the third quarter of each year and lowest in the second. Biotic index values roughly paralleled diversity index values (Figure 5).

SP4B --

Station SP4B, located immediately below the discharge point of Goosequill Ditch, was considered to be the site at which the possible effects of effluent upon the macroinvertebrate community would be most readily detectable. More taxa (108) were collected from SP4B than any other site. However, in each year the number of taxa collected at SP4B was not significantly different from the numbers collected at other stations.

All major groups had representatives at SP4B. As at other stations, dipterans were the most speciose group; they and oligochaetes dominated the invertebrate community. A rather large number of dipteran families were collected at SP4B, but only Simuliidae and Chironomidae were commonly collected. Cricotopus sp. was frequently the most common organism collected. They were found throughout the year in large numbers but were most abundant during the summer and early autumn (Figure 4). Other chironomids typically had more distinct periods of seasonal appearance. Polypedilum sp. and Paralauterborniella sp. were collected primarily in the summer and in high numbers (Figure 5 and 6). The timing of their short period of abundance did not appear to change over the years. In contrast, Chironomus sp. and Dicrotendipes sp. were present in low numbers when found early in the study; they generally became more seasonally restricted but present in much higher numbers later in the study (Figures 7 and 8). Conchapelopia sp. occurred throughout the year but in rather low numbers (Figure 9).

Simulium sp. abundance during the study followed a more complex pattern. Early, they were present in most months but in low numbers. In 1977, they were distinctly more abundant in November and December. However, in 1978 and 1979 they were most abundant in January and February, indicating a slight shift in time of hatching (Figure 10).

Baetis sp. were present in relatively large numbers only in the summers of all years (Figure 11). Hydropsyche sp. were usually present throughout the year in varying numbers. A tendency towards peak abundance in early spring and late autumn-winter was noted (Figure 12).

Among non-insect invertebrates, only Hyalalla azteca and Oligochaeta occurred consistently throughout the study. Oligochate numbers were extremely high in the spring and early summer of 1975-76. In subsequent years, numbers decreased and were roughly similar in all seasons (Figure 14). Hyalella azteca was normally present during all seasons but typically had two peaks of abundance; late spring and early-to-late-autumn (Figure 13). Cladocerans were extremely abundant in October 1979 but were not collected in any other year.

Odonata, Hemiptera, and Coleoptera had no representative that was found every year. Most taxa within these groups were found irregularly and often only once. Heptagenia sp. (Ephemeroptera: Heptageniidae) and Tricorythodes sp. (Ephemeroptera: Tricorythidae) were considered uncommon inhabitants of SP4B but were collected in the summers of all years in low numbers. Ochrotrichia sp. (Trichoptera: Hydroptilidae) were collected only in the autumn of 1978 at SP4B.

The mean number of taxa collected per month during the study was generally slightly greater at SP4B than at other stations. An early peak in taxon numbers occurred in February and was followed by a low in March. Subsequently, taxon numbers steadily rose through September and then declined to a December low comparable to the January low (Figure 2). When the average number of taxa per month before initiation of Generating Station operation was compared to the number after initiation, the patterns of abundance were the same but the phase was different (Figure 2b).

Community diversity as measured by EQUIT and DBAR followed a seasonal pattern similar to taxon numbers, as would be expected. Prior to Station operation, diversity was lowest in the second quarter and increased to a maximum in the third quarter. After Station operation began, the trend changed. Beginning in 1977, the lowest diversity index values were in the first quarter and steadily increased through the year. However, in 1979 the fourth quarter values were lower than the third quarter values (Figure 3). Except for 1977, TCI values followed the same pattern every year.

SP4B had a lower percentage of very rare taxa than recorded for all other stations but a higher proportion of rare and uncommon taxa.

C1 --

The location of C1, immediately below the confluence of the South Platte and St. Vrain Rivers, is such that possible effects of the effluent would be mitigated by the St. Vrain River. Thus, thermal and nutrient introductions to the South Platte via Goosequill Ditch are diluted by the St. Vrain River. C1 had the most monotonous substrate (sand) of any station, the highest average flow, and the lowest deposition of organic debris. For these reasons, it might be expected to have the fewest taxa and the lowest diversity of the stations sampled. However, C1 harbored the second-highest number taxa of the stations, and community diversity there was comparable to or higher than at all other stations except SP4B. All major groups had representatives at C1, but total number of organisms collected was generally lower than the number collected at other stations for any specific sampling date.

Dipterans were the most speciose group at C1, and Chironomidae had the most genera (27). With oligochates, chironomids normally dominated the macroinvertebrate community of C1. Cricotopus sp. were generally present throughout the year but in widely-fluctuating numbers. No obvious pattern of seasonal abundance was discernable prior to 1979; peak abundance periods changed from year to year in a rather random manner. In 1978, Cricotopus sp. numbers increased to a late-summer or early-autumn high and rapidly decreased in November (Figure 4). Polypedilum sp. occurred from May to November. However, in any particular year they were collected during a much briefer period (except in 1976, when none were collected) (Figure 5). Paralauterborniella sp. was usually collected in a short period of the year in high numbers.

However, in 1979 they were only collected in January in low numbers (Figure 6). The Dicrotendipes sp. abundance pattern changed perceptibly during the study. In 1974, 1975, and 1976, they were collected throughout the year. In 1977, there was a marked shift to October-December. In 1978 and 1979, they were found only in the early months of the year (except one species collected in August 1979) (Figure 8). Chironomus sp. were irregularly present in high numbers prior to 1978. However, in 1978 they appeared more consistently throughout the year in moderate numbers. In 1979, they occurred less frequently in rather low numbers (Figure 7). Conchapelopia sp. were found in all years in low numbers in most seasons. No discernible pattern was observed in their occurrence (Figure 9).

The Simulium sp. abundance pattern underwent rather distinct changes during the study. Early (1974, 1975, and 1976), they were present most of the year in low numbers. From 1977 through 1979, peak abundance occurred in the winter (Figure 10).

Hydropsyche sp. generally were found throughout the year, but rarely in high numbers. Their abundance increased slightly in the later years of the study (Figure 12). Baetis sp. generally had a rather restricted period of occurrence (July-October) and were not particularly common.

Hyalalla azteca had bimodal cycles of abundance in most years, but the pattern was more evident early in the study (1975 and 1976). In 1978, they appeared throughout the year in relatively constant numbers. In 1979, a bimodal pattern appeared to be re-established (Figure 13).

In 1974, 1975, and 1976, oligochaetes were extremely abundant in several months of each year; they decreased to comparatively low numbers in 1977 and never occurred in excessively high numbers in the remaining years of the study. Relative late-summer or early-autumn and early (January-March) lows were noticeable in all years (Figure 14).

No Odonata, Hemiptera, or Coleoptera taxa were commonly collected or found every year. Other than taxa discussed, none was found regularly during the study in significant numbers. Heptagenia sp., Tricorythodes sp., Crangonyx sp. (Amphipoda: Gammaridae) and Physa sp (Mollusca: Physidae) were the only other organisms to occur every year. However, their presence was generally irregular and their abundance normally quite low. Cladocerans were found in very high numbers only in October 1979.

Monthly taxon numbers followed a pattern similar to that at other stations. Prior to Generating Station operation, periods of high taxon numbers were slightly more restricted than they were after (Figure 2a). Diversity index values followed a pattern similar to taxon numbers. Index values were generally higher for comparable quarters after Station operation began than before (Figure 3).

SV2 and SV5 --

Regular, biweekly monitoring of the aquatic macroinvertebrate communities of two sites on the St. Vrain River was initiated in July 1979. All major groups except Coleoptera and Hemiptera had representation at both sites, but SV5 was considerably less speciose than SV2. Forms common in the South Platte River were also dominant in the St. Vrain River. No taxon found in the St. Vrain River was unique to it. No further analysis is possible because of the brief St. Vrain collection period of 6 months.

Water Chemistry and Water Temperatures

Analysis of the chemical parameters of the South Platte and St. Vrain Rivers did not reveal any abnormal or unexpected conditions (Table 8). Monthly water temperature means (am and pm) were calculated for above and below effluent discharge (Table 9).

Analysis of variance tests revealed significant differences in water temperatures for each month (am and pm, above and below effluent discharge) among all years (1974-1979) (Table 10). Water temperatures were not significantly different above and below effluent discharge (am and pm) when temperatures were compared for each month, singly (Table 11). Water temperature differences were significantly different among months prior to the initiation of Generating Station operation (June 1974-November 1976) and after power generation began at the Fort St. Vrain Nuclear Generating Station (December 1976-December 1979) (Table 12). However, the temperature data were often questionable and frequently deemed inaccurate. Some obviously-incorrect data could be eliminated, but the remainder could be accepted only with extreme reservation. Much was probably improperly recorded. Thus, analysis of water temperature regimes did not reveal if Generating Station operation (and the associated effluent from Goosequill Pond) had a measurable effect upon the aquatic macroinvertebrate community of the South Platte River.

Table 8. Mean chemical and physical parameters at four stations on the South Platte River, Colorado, 1974-1979.

	SP4A-O	SP4A-N	SP4U	SP4B	C1
Air Temp. (C)	13.4	16.6	15.0	15.1	15.3
Water Temp. (C)	11.0	12.4	11.7	11.8	11.9
Dissolved O_2 (mg/l)	7.5	7.3	7.2	7.3	7.4
Dissolved CO_2 (mg/l)	13.7	29.1	20.2	18.6	18.4
pH	7.9	7.6	7.7	7.8	7.9
Hardness (mg/l)	339	331	339	338	319
Total Alkalinity (mg/l)	255	395	318	301	312
Filtrable Solids (mg/l)	774	498	572	644	647
Dissolved Solids (mg/l)	--	805	785	808	815
Conductivity (micromhos/cm)	1272	540	867	928	948
Turbidity (JTU)	31.5	15.8	29.5	22.2	24.7

Table 9. South Platte River water temperature (°C) recorded by Public Service Company of Colorado in the vicinity of Fort St. Vrain Nuclear Generating Station, 1974-1979.

		JANUARY				FEBRUARY				MARCH				APRIL			
		am		pm		am		pm		am		pm		am		pm	
		A*	B**	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1974	Mean																
	Range																
	N																
1975	Mean	0.4		2.4		2.3		4.7		5.8		8.4		8.2		12.8	
	Range	0.6 3.9		0.0 8.9		-0.3 6.4		0.0 10.0		0.0 12.0		0.0 13.3		0.6 15.0		2.2 19.4	
	N	30		29		28		28		30		30		27		26	
1976	Mean	2.2	2.1	3.3	2.7	4.3	4.5	6.3	6.7	5.4	6.0	7.8	8.3	9.4	9.3	13.5	13.4
	Range	-0.6 6.4	-0.6 6.7	-0.6 8.9	0.0 8.6	-0.6 8.0	-0.8 8.5	-0.6 10.0	-0.6 10.0	0.0 12.2	-0.3 11.9	1.1 13.3	1.1 13.3	0.0 14.4	1.1 13.6	5.6 18.6	5.6 18.6
	N	31	22	29	22	27	27	26	25	29	29	31	31	30	30	30	30
1977	Mean	-1.0	-1.0	-0.2	-0.3	2.6	2.6	4.8	4.6	4.1	3.8	5.8	5.6	7.3	7.2	10.1	10.1
	Range	-3.3 3.1	-3.3 3.1	-3.3 3.3	-3.3 3.3	-0.6 5.0	-0.6 5.0	0.0 8.9	0.0 7.8	-3.3 10.0	-3.3 9.4	0.6 10.8	0.6 10.8	1.1 13.3	0.8 12.8	2.8 16.7	2.8 16.7
	N	30	30	30	30	28	28	28	28	31	31	31	31	30	30	30	30
1978	Mean	1.4	0.9	1.2	0.9	3.1	2.9	3.1	2.9	8.4	8.1	10.1	9.8	11.9	11.9	12.9	12.9
	Range	0.0 3.9	0.0 2.5	-4.4 2.8	-5.0 2.2	0.3 5.0	0.3 5.0	1.1 6.7	1.1 6.7	0.3 17.8	0.3 17.8	1.1 18.3	1.1 18.3	7.2 15.8	7.2 15.8	7.8 17.2	7.8 17.8
	N	31	31	30	30	28	28	28	28	31	31	30	30	30	30	30	30
1979	Mean	1.7	1.4	1.9	1.2	4.4	3.9	6.0	5.1	9.1	8.5	11.0	10.3	13.1	12.6	15.3	15.1
	Range	-0.6 3.9	0.0 3.3	0.6 4.4	-6.7 3.9	1.1 8.9	0.6 9.4	1.7 17.2	-6.1 16.1	5.0 12.8	4.4 12.5	5.0 16.7	4.4 15.6	5.6 18.9	5.8 17.8	5.6 21.1	4.4 22.2
	N	31	31	31	31	28	29	28	28	31	31	30	30	30	30	28	28
GRAND MEAN		1.0	0.9	1.7	1.1	3.3	3.5	5.0	4.8	6.6	6.6	8.6	8.5	10.0	10.3	12.9	12.9
GRAND RANGE		-1.0 4.2	-0.9 3.9	-1.5 5.7	-3.0 5.4	0.0 6.7	-0.2 6.9	0.4 10.6	-1.1 10.1	0.4 13.0	0.2 12.7	1.6 14.5	1.4 14.3	2.9 15.5	3.1 15.0	4.8 18.6	4.6 18.7

* Above effluent discharge.
** Below effluent discharge.

Table 9. Continued

Year		MAY am A*	MAY am B**	MAY pm A	MAY pm B	JUNE am A	JUNE am B	JUNE pm A	JUNE pm B	JULY am A	JULY am B	JULY pm A	JULY pm B	AUGUST am A	AUGUST am B	AUGUST pm A	AUGUST pm B
1974	Mean					18.8		24.0		20.1		24.2		18.1		22.4	
	Range					15.8 23.3		21.1 27.8		16.4 24.2		18.9 28.3		15.3 22.2		17.8 26.7	
	N					10		7		23		22		26		27	
1975	Mean	12.9	13.0	12.6	12.7	16.1	16.0	20.3	20.3	21.3	21.4	24.5	24.5	18.9	18.9	22.5	22.5
	Range	9.4 20.6	9.4 20.6	8.9 16.7	8.9 16.7	11.1 20.3	11.7 20.3	14.4 25.0	14.4 25.0	18.1 26.7	18.1 26.7	17.8 31.1	17.8 29.4	14.4 23.1	14.4 23.1	17.8 28.3	17.8 28.3
	N	11	11	11	10	25	25	28	28	27	28	27	28	29	29	30	30
1976	Mean	12.5	12.6	16.4	16.3	16.3	16.2	19.4	19.5	17.8	17.8	22.4	22.3	17.4	17.4	21.7	21.6
	Range	7.2 16.9	7.2 17.2	10.0 22.8	10.0 22.8	10.0 21.1	10.0 21.1	13.1 25.3	13.1 25.8	13.3 21.7	13.3 21.1	17.8 28.3	17.8 28.3	12.8 20.8	11.7 20.8	17.7 26.1	16.7 25.6
	N	29	29	30	30	25	25	30	30	31	31	28	28	31	31	31	31
1977	Mean	13.9	13.6	16.6	16.4	18.2	18.2	22.0	21.8	19.5	19.5	22.9	22.7	20.5	20.4	22.8	22.6
	Range	8.3 20.0	8.3 19.4	10.0 25.6	10.0 25.6	10.0 21.1	10.0 21.1	12.8 26.9	12.8 26.9	15.6 24.2	15.6 24.2	18.3 27.2	18.3 26.1	16.9 24.2	16.9 24.2	18.3 27.8	17.8 27.8
	N	31	31	31	31	30	30	30	30	27	27	25	25	31	31	30	30
1978	Mean	14.0	13.8	14.8	14.6	18.2	18.2	19.5	19.4	23.0	23.0	24.7	24.7	20.3	20.3	22.0	22.1
	Range	7.2 20.6	6.7 20.6	6.7 21.1	6.7 21.1	14.4 22.2	14.4 22.2	16.1 25.6	16.1 25.6	20.0 25.8	20.0 25.8	21.1 27.2	21.1 27.2	16.9 24.2	16.9 24.2	15.6 27.2	16.7 27.2
	N	31	31	29	29	29	29	30	30	31	31	30	30	31	31	29	29
1979	Mean	15.9	14.5	18.4	16.7	18.9	17.6	20.0	18.6	20.7	20.4	21.1	20.6	18.3	18.2	19.5	19.3
	Range	7.8 23.1	7.8 22.8	8.3 26.7	8.3 25.0	11.7 22.5	4.4 21.1	12.8 24.4	9.4 23.9	18.1 24.2	17.2 23.6	18.3 25.6	17.2 24.4	8.9 22.2	8.9 22.2	15.6 24.4	15.6 25.0
	N	31	31	28	27	29	29	30	29	31	31	31	31	30	30	30	30
GRAND MEAN		13.8	13.5	15.8	15.3	17.8	17.2	20.9	19.9	20.4	20.4	23.3	23.0	18.9	19.0	21.8	21.6
GRAND RANGE		8.3 19.5	8.1 19.4	9.1 22.3	9.1 22.1	12.2 21.7	11.1 21.4	15.1 25.8	14.5 25.8	16.9 24.5	16.8 24.3	18.7 28.0	18.5 27.3	14.2 22.8	14.2 22.8	17.0 26.8	17.1 26.8

* Above effluent discharge.
** Below effluent discharge.

Table 9. Continued

		SEPTEMBER am		SEPTEMBER pm		OCTOBER am		OCTOBER pm		NOVEMBER am		NOVEMBER pm		DECEMBER am		DECEMBER pm	
		A*	B**	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1974	Mean	15.3		19.2		11.3		14.8		5.6		7.1		1.1		2.5	
	Range	8.9 19.2		13.3 24.4		6.9 15.6		8.3 20.6		0.0 8.3		1.1 12.2		-0.6 5.3		0.0 6.7	
	N	30		27		29		28		28		28		30		31	
1975	Mean	15.4	15.4	18.7	18.7	11.8	12.0	15.2	15.2	5.1	[illegible]	6.9	6.6	3.4	3.3	4.8	4.5
	Range	11.9 19.4	11.9 19.4	11.7 22.8	11.7 23.3	5.3 17.2	5.6 19.7	7.2 20.6	7.2 21.1	0.0 11.1	0.0 11.1	-0.6 14.4	-0.6 14.4	0.0 6.7	0.0 6.7	0.0 9.4	0.0 9.4
	N	28	28	30	30	31	31	30	30	27	26	28	28	31	31	29	29
1976	Mean	16.3	16.3	18.3	18.0	10.2	10.0	12.8	12.6	5.9	5.7	7.9	7.8	2.4	2.1	3.1	2.9
	Range	11.0 24.2	11.0 24.2	12.8 22.5	12.8 22.5	6.1 15.0	4.4 14.7	6.0 19.0	6.0 19.0	0.0 12.5	0.0 11.7	0.10 14.4	0.0 14.4	-1.4 6.7	-1.4 5.[illegible]	-1.1 6.7	-1.1 6.7
	N	28	28	28	28	31	31	29	29	28	28	27	27	30	30	29	29
1977	Mean	15.3	15.4	18.7	18.5	8.4	8.3	10.9	10.8	4.0	3.9	6.3	6.2	2.9	2.8	2.9	2.3
	Range	7.2 21.4	7.2 21.4	13.9 23.1	13.9 23.3	4.2 15.6	3.1 15.6	3.9 17.8	3.9 17.8	0.0 6.1	0.0 6.1	2.8 12.2	2.8 12.2	0.0 6.7	0.0 6.1	0.0 7.2	0.0 7.8
	N	30	30	30	30	31	31	30	30	30	30	28	28	31	31	28	28
1978	Mean	17.1	17.0	19.2	19.1	12.5	12.4	13.4	13.3	5.7	5.6	5.9	6.0	2.1	2.0	2.1	1.9
	Range	11.9 23.6	11.9 23.3	10.6 26.7	10.0 26.7	8.9 17.5	8.9 17.2	7.2 18.3	7.2 18.3	1.7 11.1	1.4 11.1	2.2 12.2	2.2 13.3	0.0 4.[illegible]	0.0 4.4	0.0 5.0	0.0 6.1
	N	30	30	28	28	31	31	31	31	30	30	29	29	31	31	31	31
1979	Mean	16.1	16.0	17.1	16.9	11.5	11.3	12.8	12.7	3.8	3.8	5.1	5.1	2.4	2.4	3.3	3.4
	Range	13.1 18.9	12.5 19.4	13.9 23.3	13.3 22.8	3.6 15.6	3.1 15.6	3.9 17.8	3.9 16.7	-0.3 7.5	-0.3 7.5	-1.1 10.0	-0.6 10.0	-1.1 4.7	-1.1 4.4	-1.1 6.1	-1.1 7.2
	N	30	30	29	29	31	31	31	31	31	31	29	29	31	31	30	30
GRAND MEAN		15.9	16.0	18.5	18.2	11.0	10.8	13.3	12.9	5.0	4.8	6.5	6.3	2.4	2.5	3.1	3.0
GRAND RANGE		10.7 21.1	10.6 21.2	12.7 23.9	12.5 23.8	5.8 16.1	5.3 16.4	6.1 19.0	6.1 18.9	0.2 9.4	0.2 9.3	0.7 12.6	0.8 12.8	-0.5 5.7	-0.5 5.3	-0.4 6.9	-0.4 7.3

* Above effluent discharge.
** Below effluent discharge.

Table 10. Analysis of variance (AOV) of water temperature of the South Platte River in the vicinity of the Fort St. Vrain Nuclear Generating Station, Colorado, among the years (1974-1979) for each month (am and pm, above and below effluent discharge).

	H_o[1]	F_s[2]	F_t[3]	Reject
January (am) above effluent discharge, 1975-1979	There is no temp. difference among years	18.9809	2.37	Yes
January (pm) above effluent discharge, 1975-1979	"	13.6242	2.37	Yes
January (am) below effluent discharge, 1976-1979	"	25.4362	2.68	Yes
January (pm) below effluent discharge, 1976-1979	"	9.9808	2.68	Yes
February (am) above effluent discharge, 1975-1979	"	6.3243	2.37	Yes
February (pm) above effluent discharge, 1975-1979	"	6.2462	2.37	Yes
February (am) below effluent discharge, 1976-1979	"	5.4141	2.68	Yes
February (pm) below effluent discharge, 1976-1979	"	7.7796	2.68	Yes
March (am) above effluent discharge, 1975-1979	"	12.0299	2.37	Yes
March (pm) above effluent discharge, 1975-1979	"	9.6184	2.37	Yes
March (am) below effluent discharge, 1976-1979	"	12.7726	2.68	Yes
March (pm) below effluent discharge, 1976-1979	"	10.87[illegible]9	2.68	Yes
April (am) above effluent discharge, 1974-1979	"	17.7985	2.37	Yes
April (pm) above effluent discharge, 1974-1979	"	7.3807	2.37	Yes
April (am) below effluent discharge, 1976-1979	"	20.1591	2.68	Yes
April (pm) below effluent discharge, 1976-1979	"	9.4003	2.68	Yes
May (am) above effluent discharge, 1975-1979	"	5.2827	2.37	Yes
May (pm) above effluent discharge, 1975-1979	"	4.0189	2.37	Yes
May (am) below effluent discharge, 1976-1979	"	1.6174	2.37	No
May (pm) below effluent discharge, 1976-1979	"	2.2800	2.37	No
June (am) above effluent discharge, 1974-1979	"	5.0874	2.21	Yes
June (pm) above effluent discharge, 1974-1979	"	5.3686	2.21	Yes
June (am) below effluent discharge, 1975-1979	"	3.7640	2.37	Yes
June (pm) below effluent discharge, 1975-1979	"	4.7728	2.37	Yes
July (am) above effluent discharge, 1974-1979	"	24.7798	2.21	Yes
July (pm) above effluent discharge, 1974-1979	"	12.0614	2.21	Yes
July (am) below effluent discharge, 1975-1979	"	31.6222	2.37	Yes
July (pm) below effluent discharge, 1975-1979	"	20.7043	2.37	Yes
August (am) above effluent discharge, 1974-1979	"	11.5165	2.21	Yes
August (pm) above effluent discharge, 1974-1979	"	7.0309	2.21	Yes
August (am) below effluent discharge, 1975-1979	"	12.4339	2.37	Yes
August (pm) below effluent discharge, 1975-1979	"	9.9568	2.37	Yes
September (am) above effluent discharge, 1974-1979	"	2.0894	2.21	No
September (pm) above effluent discharge, 1974-1979	"	2.0640	2.21	No
September (am) below effluent discharge, 1975-1979	"	1.6294	2.37	No
September (pm) below effluent discharge, 1975-1979	"	2.4929	2.37	Yes
October (am) above effluent discharge, 1974-1979	"	10.5088	2.21	Yes
October (pm) above effluent discharge, 1974-1979	"	6.2252	2.21	Yes
October (am) below effluent discharge, 1975-1979	"	11.0476	2.37	Yes
October (pm) below effluent discharge, 1975-1979	"	6.1350	2.37	Yes
November (am) above effluent discharge, 1974-1979	"	3.3642	2.21	Yes
November (pm) above effluent discharge, 1974-1979	"	2.6019	2.21	Yes
November (am) below effluent discharge, 1975-1979	"	2.9652	2.37	Yes
November (pm) below effluent discharge, 1975-1979	"	2.4528	2.37	Yes
December (am) above effluent discharge, 1974-1979	"	5.5375	2.21	Yes
December (pm) above effluent discharge, 1974-1979	"	6.7393	2.21	Yes
December (am) below effluent discharge, 1975-1979	"	2.8609	2.37	Yes
December (pm) below effluent discharge, 1975-1979	"	6.6583	2.37	Yes

[1] H_o = null hypothesis.

[2] F_s = calculated F statistic.

[3] F_t = table F statistic.

Table 11. Analysis of variance (AOV) of above and below effluent discharge water temperatures of the South Platte River for each month (1975-1979) in the vicinity of the Fort St. Vrain Nuclear Generating Station, Colorado.

	H_o[1]	F_s[2]	F_t[3]	Reject?
June, 1975 (am) Above to Below	There is no temperature difference between above and below effluent discharge	0.0697	4.04	No
June, 1975 (pm) Above to Below	"	0.0058	4.02	No
July, 1975 (am) Above to Below	"	0.0305	4.04	No
July, 1975 (pm) Above to Below	"	0.0086	4.02	No
August, 1975 (am) Above to Below	"	0.0019	4.01	No
August, 1975 (pm) Above to Below	"	0.0000	4.01	No
September, 1975 (am) Above to Below	"	0.0058	4.02	No
September, 1975 (pm) Above to Below	"	0.0066	4.02	No
October, 1975 (am) Above to Below	"	0.0405	4.01	No
October, 1975 (pm) Above to Below	"	0.0016	4.01	No
November, 1975 (am) Above to Below	"	0.0026	4.04	No
November, 1975 (pm) Above to Below	"	0.0382	4.04	No
December, 1975 (am) Above to Below	"	0.0046	4.00	No
December, 1975 (pm) Above to Below	"	0.2040	4.01	No
January, 1976 (am) Above to Below	"	0.0501	4.04	No
January, 1976 (pm) Above to Below	"	0.8665	4.04	No
February, 1976 (am) Above to Below	"	0.0710	4.04	No
February, 1976 (pm) Above to Below	"	0.0138	4.01	No
March, 1976 (am) Above to Below	"	0.0023	4.00	No
March, 1976 (pm) Above to Below	"	0.2022	4.00	No
April, 1976 (am) Above to Below	"	0.1203	4.01	No
April, 1976 (pm) Above to Below	"	0.0337	4.01	No
May, 1976 (am) Above to Below	"	0.0004	4.01	No
May, 1976 (pm) Above to Below	"	0.0253	4.01	No
June, 1976 (am) Above to Below	"	0.1226	4.04	No
June, 1976 (pm) Above to Below	"	0.0191	4.01	No
July, 1976 (am) Above to Below	"	0.0013	4.00	No
July, 1976 (pm) Above to Below	"	0.0793	4.02	No
August, 1976 (am) Above to Below	"	0.0002	4.00	No
August, 1976 (pm) Above to Below	"	0.0440	4.00	No
September, 1976 (am) Above to Below	"	0.0057	4.02	No
September, 1976 (pm) Above to Below	"	0.0848	4.02	No
October, 1976 (am) Above to Below	"	0.0802	4.00	No
October, 1976 (pm) Above to Below	"	0.0474	4.01	No
November, 1976 (am) Above to Below	"	0.0249	4.02	No
November, 1976 (pm) Above to Below	"	0.0098	4.04	No
December, 1976 (am) Above to Below	"	0.5538	4.01	No
December, 1976 (am) Above to Below	"	0.2024	4.02	No

Table 11. Continued

	H_o [1]	F_s [2]	F_t [3]	Reject?
January, 1977 (am) Above to Below	There is no temperature difference between above and below effluent discharge	0.0330	4.01	No
January, 1977 (pm) Above to Below	"	0.0637	4.01	No
February, 1977 (am) Above to Below	"	0.0272	4.03	No
February, 1977 (pm) Above to Below	"	0.2843	4.03	No
March, 1977 (am) Above to Below	"	0.1128	4.00	No
March, 1977 (pm) Above to Below	"	0.0911	4.00	No
April, 1977 (am) Above to Below	"	0.0103	4.01	No
April, 1977 (pm) Above to Below	"	0.0000	4.00	No
May, 1977 (am) Above to Below	"	0.0769	4.00	No
May, 1977 (pm) Above to Below	"	0.0610	4.01	No
June, 1977 (am) Above to Below	"	0.0043	4.03	No
June, 1977 (pm) Above to Below	"	0.0496	4.01	No
July, 1977 (am) Above to Below	"	0.0000	4.00	No
July, 1977 (pm) Above to Below	"	0.0894	4.05	No
August, 1977 (am) Above to Below	"	0.0905	4.00	No
August, 1977 (pm) Above to Below	"	0.0480	4.01	No
September, 1977 (am) Above to Below	"	0.0059	4.01	No
September, 1977 (pm) Above to Below	"	0.0513	4.01	No
October, 1977 (am) Above to Below	"	0.0201	4.00	No
October, 1977 (pm) Above to Below	"	0.0205	4.01	No
November, 1977 (am) Above to Below	"	0.0995	4.01	No
November, 1977 (pm) Above to Below	"	0.0128	4.02	No
December, 1977 (am) Above to Below	"	0.0718	4.00	No
December, 1977 (pm) Above to Below	"	0.2169	4.02	No
January, 1978 (am) Above to Below	"	4.9189	4.00	Yes
January, 1978 (pm) Above to Below	"	0.5584	4.01	No
February, 1978 (am) Above to Below	"	0.3879	4.02	No
February, 1978 (pm) Above to Below	"	0.2195	4.02	No
March, 1978 (am) Above to Below	"	0.0344	4.00	No
March, 1978 (pm) Above to Below	"	0.0639	4.01	No
April, 1978 (am) Above to Below	"	0.0123	4.01	No
April, 1978 (pm) Above to Below	"	0.1327	4.01	No
May, 1978 (am) Above to Below	"	0.0815	4.00	No
May, 1978 (pm) Above to Below	"	0.0172	4.02	No
June, 1978 (am) Above to Below	"	0.0102	4.02	No
June, 1978 (pm) Above to Below	"	0.0090	4.01	No
July, 1978 (am) Above to Below	"	0.0124	4.00	No
July, 1978 (pm) Above to Below	"	0.0254	4.01	No

Table 11. Continued

	H_o[1]	F_s[2]	F_t[3]	Reject?
August, 1978 (am) Above to Below	There is no temperature difference between above and below effluent discharge	0.0177	4.00	No
August, 1978 (pm) Above to Below	"	0.0167	4.02	No
September, 1978 (am) Above to Below	"	0.0187	4.01	No
September, 1978 (pm) Above to Below	"	0.0113	4.02	No
October, 1978 (am) Above to Below	"	0.0255	4.00	No
October, 1978 (pm) Above to Below	"	0.0525	4.00	No
November, 1978 (am) Above to Below	"	0.0330	4.01	No
November, 1978 (pm) Above to Below	"	0.0130	4.02	No
December, 1978 (am) Above to Below	"	0.1343	4.00	No
December, 1978 (pm) Above to Below	"	0.3037	4.00	No
January, 1979 (am) Above to Below	"	1.7407	4.00	No
January, 1979 (pm) Above to Below	"	3.6670	4.00	No
February, 1979 (am) Above to Below	"	0.7981	4.02	No
February, 1979 (pm) Above to Below	"	0.8543	4.02	No
March, 1979 (am) Above to Below	"	0.8076	4.00	No
March, 1979 (pm) Above to Below	"	0.5309	4.01	No
April, 1979 (am) Above to Below	"	0.2217	4.01	No
April, 1979 (pm) Above to Below	"	0.0611	4.02	No
May, 1979 (am) Above to Below	"	2.0702	4.00	No
May, 1979 (pm) Above to Below	"	1.5805	4.03	No
June, 1979 (am) Above to Below	"	2.1788	4.02	No
June, 1979 (pm) Above to Below	"	2.3569	4.01	No
July, 1979 (am) Above to Below	"	0.9778	4.00	No
July, 1979 (am) Above to Below	"	1.3280	4.00	No
August, 1979 (am) Above to Below	"	0.0207	4.01	No
August, 1979 (pm) Above to Below	"	0.1547	4.02	No
September, 1979 (am) Above to Below	"	0.0246	4.01	No
September, 1979 (pm) Above to Below	"	0.0930	4.02	No
October, 1979 (am) Above to Below	"	0.0329	4.00	No
October, 1979 (pm) Above to Below	"	0.0060	4.00	No
November, 1979 (am) Above to Below	"	0.0000	4.00	No
November, 1979 (pm) Above to Below	"	0.0036	4.02	No
December, 1979 (am) Above to Below	"	0.0027	4.00	No
December, 1979 (pm) Above to Below	"	0.0238	4.01	No

[1] H_o = null hypothesis.

[2] F_s = calculated F statistic.

[3] F_t = table F statistic.

Table 12. Analysis of variance (AOV) of water temperature in the vicinity of the Fort St. Vrain Nuclear Generating Station, Colorado, for each month above and below effluent discharge (am and pm) before Station operation (January 1975-November 1976) and after Station operation (December 1976-December 1979).

	H_o[1]	F_s[2]	F_t[3]	Reject?
January, 1975-1976 (am) above effluent discharge	There is no temp. difference between years for the same temp. collection site	7.4876	4.00	Yes
January, 1975-1976 (pm) above effluent discharge	"	3.2631	4.00	No
February, 1975-1976 (am) above effluent discrhage	"	10.4267	4.00	Yes
February, 1975-1976 (pm) above effluent discharge	"	4.8545	4.00	Yes
March, 1975-1976 (am) above effluent discharge	"	0.0664	4.00	No
March, 1975-1976 (pm) above effluent discharge	"	0.2038	4.00	No
April, 1975-1976 (am) above effluent discharge	"	1.7187	4.00	No
April, 1975-1976 (pm) above effluent discharge	"	0.5729	4.00	No
May, 1975-1976 (am) above effluent discharge	"	0.0000	4.00	No
May, 1975-1976 (pm) above effluent discharge	"	3.6533	4.00	No
June, 1974-1976 (am) above effluent discharge	"	3.8947	3.15	Yes
June, 1974-1976 (pm) above effluent discharge	"	7.3644	3.15	Yes
June, 1974-1976 (am) below effluent discharge	"	0.0550	3.15	No
June, 1974-1976 (pm) below effluent discharge	"	1.1655	3.15	No
July, 1974-1976 (am) above effluent discharge	"	21.4519	3.15	Yes
July, 1974-1976 (pm) above effluent discharge	"	5.5664	3.15	Yes
July, 1975-1976 (am) below effluent discharge	"	43.6828	3.15	Yes
July, 1975-1976 (pm) below effluent discharge	"	13.7327	3.15	Yes
August, 1974-1976 (am) above effluent discharge	"	4.0375	3.15	Yes
August, 1974-1976 (pm) above effluent discharge	"	1.8280	3.15	No
August, 1975-1976 (am) below effluent discharge	"	7.9461	3.15	Yes
August, 1975-1976 (pm) below effluent discharge	"	2.4062	3.15	No
September, 1974-1976 (am) above effluent discharge	"	1.3647	3.15	No
September, 1974-1976 (pm) above effluent discharge	"	0.5799	3.15	No
September, 1975-1976 (am) below effluent discharge	"	1.8921	3.15	No
September, 1975-1976 (pm) below effluent discharge	"	0.9942	3.15	No
October, 1974-1976 (am) above effluent discharge	"	3.8333	3.15	Yes
October, 1974-1976 (pm) above effluent discharge	"	3.4883	3.15	Yes
October, 1975-1976 (am) below effluent discharge	"	7.2620	3.5	Yes
October, 1975-1976 (pm) below effluent discharge	"	7.6086	3.15	Yes
November, 1974-1976 (am) above effluent discharge	"	0.387	3.15	No
November, 1974-1976 (pm) above effluent discharge	"	0.5358	3.15	No
November, 1975-1976 (am) above effluent discharge	"	0.3262	3.15	No
November, 1975-1976 (pm) below effluent discharge	"	1.0280	3.15	No
December, 1974-1975 (am) above effluent discharge	"	20.5839	3.12	Yes
December, 1974-1975 (pm) above effluent discharge	"	16.7355	3.12	Yes
January, 1977-1979 (am) above effluent discharge	"	43.1377	3.12	Yes
January, 1977-1979 (pm) above effluent discharge	"	14.7188	3.12	Yes
January, 1977-1979 (am) below effluent discharge	"	36.2471	3.11	Yes
January, 1977-1979 (pm) below effluent discharge	"	6.3438	3.11	Yes
February, 1977-1979 (am) above effluent discharge	"	7.2803	3.12	Yes
February, 1977-1979 (pm) above effluent discharge	"	9.0839	3.12	Yes
February, 1977-1979 (am) below effluent discharge	"	3.9063	3.13	Yes
February, 1977-1979 (pm) below effluent discharge	"	4.3764	3.13	Yes

Table 12. Continued

	H_o[1]	F_s[2]	F_t[3]	Reject?
March, 1977-1979 (am) above effluent discharge	There is no temp. difference between years for the same temp. collection site	20.7935	3.11	Yes
March, 1977-1979 (pm) above effluent discharge	"	17.0337	3.11	Yes
March, 1977-1979 (am) below effluent discharge	"	19.5550	3.11	Yes
March, 1977-1979 (pm) below effluent discharge	"	14.8039	3.11	Yes
April, 1977-1979 (am) above effluent discharge	"	28.7645	3.12	Yes
April, 1977-1979 (pm) above effluent discharge	"	13.7148	3.12	Yes
April, 1977-1979 (am) below effluent discharge	"	27.2842	3.12	Yes
April, 1977-1979 (pm) below effluent discharge	"	12.9279	3.12	Yes
May, 1977-1979 (am) above effluent discharge	"	3.0531	3.11	No
May, 1977-1979 (pm) above effluent discharge	"	4.7467	3.12	Yes
May, 1977-1979 (am) below effluent discharge	"	0.5588	3.11	No
May, 1977-1979 (pm) below effluent discharge	"	2.5605	3.13	No
June, 1977-1979 (am) above effluent discharge	"	0.7131	3.12	No
June, 1977-1979 (pm) above effluent discharge	"	6.0639	3.12	Yes
June, 1977-1979 (am) below effluent discharge	"	0.4412	3.12	No
June, 1977-1979 (pm) below effluent discharge	"	8.4953	3.12	Yes
July, 1977-1979 (am) above effluent discharge	"	29.3634	3.12	Yes
July, 1977-1979 (pm) above effluent discharge	"	26.0263	3.13	Yes
July, 1977-1979 (am) below effluent discharge	"	29.9934	3.12	Yes
July, 1977-1979 (pm) below effluent discharge	"	35.1136	3.13	Yes
August, 1977-1979 (am) above effluent discharge	"	10.2649	3.11	Yes
August, 1977-1979 (pm) above effluent discharge	"	14.1640	3.12	Yes
August, 1977-1979 (am) below effluent discharge	"	26.7108	3.11	Yes
August, 1977-1979 (pm) below effluent discharge	"	16.7154	3.12	Yes
September, 1977-1979 (am) above effluent discharge	"	2.8545	3.11	No
September, 1977-1979 (pm) above effluent discharge	"	3.7462	3.13	Yes
September, 1977-1979 (am) below effluent discharge	"	2.1056	3.12	No
September, 1977-1979 (pm) below effluent discharge	"	3.8262	3.13	Yes
October, 1977-1979 (am) above effluent discharge	"	16.9197	3.11	Yes
October, 1977-1979 (pm) above effluent discharge	"	4.1161	3.11	Yes
October, 1977-1979 (am) below effluent discharge	"	19.0860	3.11	Yes
October, 1977-1979 (pm) below effluent discharge	"	4.3455	3.11	Yes
November, 1977-1979 (am) above effluent discharge	"	5.5778	3.11	Yes
November, 1977-1979 (pm) above effluent discharge	"	1.5040	3.13	No
November, 1977-1979 (am) below effluent discharge	"	5.0858	3.11	Yes
November, 1977-1979 (pm) below effluent discharge	"	1.4489	3.13	No
December, 1976-1979 (am) above effluent discharge	"	1.2488	2.68	No
December, 1976-1979 (pm) above effluent discharge	"	2.4397	2.68	No
December, 1976-1979 (am) below effluent discharge	"	1.3239	2.68	No
December, 1976-1979 (pm) below effluent discharge	"	3.4498	2.68	Yes

[1] H_o = null hypothesis.
[2] F_s = calculated F statistic.
[3] F_t = table F statistic.

DISCUSSION

Exact delineation of specific effects of Generating Station operation are virtually impossible. Several factors obfuscate an examination of cause and effect relationships, not the least of which is the unreliability of the temperature data for the South Platte River collected by Public Service Company of Colorado. Slight differences between above-effluent readings and below-effluent readings were frequently recorded and were not abnormal. However, many extreme readings reported seemed improbable (e.g., -3.3 C and lower in winter months, 26.0 C and higher in summer months). The rapidity with which water temperatures often changed in less than 12 hours (e.g., a 10.0 C or more change was frequently noted) indicated what was considered to be an unreasonable water temperature variation. Because of such vagaries, the temperature data were treated circumspectly. For example, temperatures at high or low extremes can be immediately detected as faulty, but mid-range values cannot be categorically discounted. For example, a value of 8.0 C in March is not unusual, nor is a value of 4.0 C or 12.0 C. Sometimes only one value was recorded for a scheduled measurement with no indication as to whether the reading was above or below the effluent discharge. Occasionally, no readings were made for one day or several days in succession. Some greater-than-anticipated differences in temperature were reported between stations above and below effluent discharge when there was no discharge from Goosequill Ditch. These differences were probably because of a lack of uniformity in selecting temperature-measuring sites. If the inconsistencies in the data are ignored, most differences among the same month of different years may be explained by different meteorological conditions.

The possible unrealiability of the temperature data makes detailed analysis of the effects of temperature changes upon the aquatic macroinvertebrate community largely conjectural. Significant differences among months (am and pm, above and below effluent discharge) and among months before and after initiation of power generation would normally be expected because of varying meteorological conditions. If the discharge from Goosequill Pond altered the thermal regime of the South Platte River, the change should have been detected by comparing water temperatures above and below (am and pm) effluent discharge. However, no significant differences were found. Nevertheless, some discernible changes in the macroinvertebrate community were detected after Station operation began.

A discussion of observed changes in this community requires recognition of several factors that may qualify the results. Changes in personnel definitely were reflected in the data. However, the length of the study tended to average aberrations and diminish the affect of problems that might arise in the final analysis. The level of taxonomic identification masks, to a certain extent, the diversity of the macroinvertebrate communities. For example, Cricotopus is a very speciose genus, and some representatives normally would be expected throughout the year. In contrast, Paralauterborniella has relatively few species and would naturally be present for a restricted period. Nor can the fact that some species occur throughout the year be ignored (e.g., Hyalella azteca). Cycling of populations is certainly a natural phenomenon. Thus, a group abundant one year may be rather rare the next, and changes in abundance may be explained by natural cycling. Drift may account for the repopulation of the area (Hynes 1970). Associated with drift population is the constantly-shifting substrate. Within a station, required (or preferred) habitat components may be lacking (or in short supply) one year but present the next. Import of upstream components (organic and/or inorganic) influences the structure of the community (Vannote et al. 1980).

The effect of the heated effluent depends largely upon the differential between the discharge and the ambient water temperature of the South Platte River and the ratio of discharge volume to within-stream volume. Obviously, the season is an important consideration. Associated with physical considerations is the category of the invertebrate. Elevated temperatures may accelerate the development of summer species but retard or stop development of winter species.

The salient features of the 6-year study are the increased number of macroinvertebrate taxa and greater community diversity of the below-discharge-point stations after initiation of power generation. Annual patterns of community diversity changed markedly after Station operation began. At SP4B, diversity was lowest in the first quarter and greatest in the last, with a steady increase in the intervening quarters. The altered pattern was not so obvious at C1, but changes did occur. The dilution effect of the St. Vrain River mitigated the affect of the Station's effluent.

The increase in macroinvertebrate taxon numbers may be explained by either improved identification or an actual increase in number. Both factors may be invoked to explain the change. However, slight temperature increases above normal levels and nutrient introduction may have altered the environment to the benefit of previously-marginal or absent forms but not caused sufficient deterioration to preclude typical forms. Since discharge was intermittent and certainly did not cause severe eutrophication of the South Platte River, it seems reasonable to suppose that slight alterations enabled some forms to successfully invade the area. As unusual forms were responsible for the increased taxon numbers, this explanation does not seem implausible. Fish species indigenous to the area were found in fairly constant numbers during the study. Historically, most forms found in the area were warm-water species. Slight changes in temperature and nutrient load would typically have little effect upon them. The mobility of fishes enhances their ability to escape unfavorable conditions if such should occur. However, more constant and greater effluent discharge may significantly change the patterns observed to date.

Station operation was more constant in 1978 than 1977 or 1979, and observed changes in macroinvertebrate community structure were most marked in 1978. The relatively low level of plant operation in 1979 was reflected in the diversity indices. Patterns similar to those prior to Station operation were rapidly re-established. It appeared that the community was able to revert to its pre-operational structure after only a short period of operation.

Interestingly, plotting the cycles of abundance of individual macroinvertebrate taxa did not generally reveal any altered patterns. Patterns within one site changed for several forms during the study; but, if the pattern for a particular year was compared to the pattern for that species at other stations, differences were negligible. Only

Polypedilum sp. and Chironomus sp. had obviously different patterns at stations affected by effluent. Such observations support the axiom concerning the trees and the forest.

Virtually no comparison can be made between the EIS and the data collected from 1974 through 1979. Information on macroinvertebrates in the EIS is very vague.

The data derived from the annual fish collections offered no unexpected results. All forms present were those to be expected in a high-plains stream. Most forms mentioned as possible denizens in the area in the EIS were found during the study.

Altered temperature regimes and increased nutrient load were postulated to be the most probable causes of any detected changes in aquatic macroinvertebrate communities in the study area. However, the unreliability of the temperature data essentially negates any intelligent interpretation of changed temperature patterns and aquatic macroinvertebrate community responses. No effort was made to relate nutrient loads to aquatic macroinvertebrate community structure changes. Thus, virtually nothing can be said about whether altered thermal regime or increased nutrient load was responsible for the observed changes in the aquatic macroinvertebrate community. No evaluation of the effect of the effluent will be possible until the Generating Station operates on a more continuous basis, water temperature is reliably collected, and effects of nutrient introductions are evaluated.

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ALGAL MONITORING

by

Paul Kugrens

INTRODUCTION

For eight years algal data have been collected from aquatic habitats utilized by the Ft. St. Vrain Nuclear Generating Station. This study has followed the objectives outlined by Public Service Company in the original environmental impact statement (1972). The objectives for algae were the following:

1. To include detailed investigation of algae.
    a) Baseline evaluation of important species
    b) Inventory of algal species
    c) Effects of effluent on biota, including algae, to be of prime consideration
2. Growth of algae which might be toxic to livestock will be identified.
3. Specific studies of the effects of NALCO water treatment chemicals will be included in the ecological program.

All of these objectives, except 1c, have been fulfilled for the algal program. Additional data on algal ecology and possible toxin production have also been provided.

The reason for the lack of data for 1c is obvious. The Generating Station has been operational only for intermittent, limited times during the course of this study. Therefore it is difficult to ascertain what direct environmental impact continual operation of the Generating Station has on the algal component of the biota. Nevertheless, there were some notable alterations in habitat at specific river sites that influenced or changed algal populations.

Predictions for changes in algal composition were also made in the original impact statement. Many of these predictions were not correct.

Furthermore, from the initial, cursory observations taken in 1971 it is now apparent that different algal groups should have been sampled and this was done in subsequent years. However, the macroscopic forms that were identified initially show that some significant changes in algal populations may have taken place.

This report includes a summary of findings from the past eight years, a discussion of the validity of initial predictions, possible reasons for observed changes, whether the objectives have been met, and an evaluation of the methodology.

MATERIALS AND METHODS

Concrete blocks were set up at seven river sites for sampling periphyton, because these are most indicative of local conditions. Monthly collections consisted of scrapings from 25 cm^2 areas of the blocks and adjacent natural substrates such as mud, bricks, etc. Identification and counts were made immediately following collection, using a Leitz compound microscope with phase optics. Counts were taken in a Palmer counting chamber or a Sedgwick-Rafter counting chamber using a Whipple ocular micrometer. Actual numbers and living:dead cell ratios were recorded. Photographic verification accompanied all counts and identifications.

Phytoplankton samples were taken in Goosequill Pond and the rivers by collecting water in one gallon bottles. Direct counts were taken from the water since sedimentation involves a long time period and the counts, thus, might not be representative of the actual sample due to cell death or reproduction. Furthermore, killing cells for sedimentation interfere with determining which algae are living.

Phytoplankton populations are most reliable in Goosequill Pond because periphyton are often eliminated due to lack of light penetration because of large numbers of phytoplankton. Periphyton, however, were sampled for qualitative reasons. Conversely, phytoplankton were sampled in the rivers for the same reason.

Specific lists and counts were correlated with temperature, pH, turbidity and current velocity. Of these, currents and extremes in temperature were most useful.

There were four sites that potentially could be affected by Generating Station activities in several ways. Either water removal or discharge would occur at these sites. As a result of water removal or discharge, the six sampling stations were selected to determine the effects of generating activities. The potentially affected sites are Goosequill Pond (GQ), the South Platte River above plant-effluent entrance (SPI) and below effluent entrance into the river from Goosequill Pond (SP), and St. Vrain River at pumping station (SVI).

CONCLUSIONS AND DISCUSSION

1. Species Inventory

A total of 280 species has been identified during the eight year information gathering period. There were 130 species of diatoms, 91 green algae, 27 blue-green algae, 14 euglenoids, 9 golden-brown algae, four yellow-green algae, two cryptomonads, two dinoflagellates, and one red alga (Table I). Many of the algae are either representative of upstream areas and were carried in by the current, or they did not constitute significant growths in any population sampled. Most of the algae are pollution tolerant organisms that can adjust to a wide range of temperatures.

Only seven algal species are common and important in local algal populations (Table II) and are present in samples throughout most of the year. These algae are the diatoms Navicula cryptocephala, Nitzschia palea and Stephanodiscus hantzschii; the green algae, Cladophora glomerata, Rhizoclonium hieroglyphicum and Scenedesmus quadricauda; and the euglenoid, Euglena viridis. A description of these algae is provided in Table II.

Distinct algal populations (indicator species) were recorded for all sampling sites. For instance, a diatom, Nitzschia palea was the most dominant periphyton in the South Platte River, followed by another diatom, Navicula cryptocephala. While the St. Vrain River also had the same dominants, the order of the two diatoms was often reversed. Furthermore, during the warmer months, large, benthic populations of Cladophora glomerata, a filamentous green alga, grew profusely on any available rock or concrete substrates. On the other hand, during the winter, large populations of Euglena viridis were evident at all sites, although its appearance is delayed one or two months in the St. Vrain River when compared to the South Platte River. Other algae commonly found in certain river sites during late summer included Enteromorpha intestinalis, Rhizoclonium hieroglyphicum and Hydrodictyon reticulatium.

2. River Habitats

There are basically three localized habitats in both rivers that support distinctive algal populations--standing water, moving water (current)

Table I. Algal Species List for Aquatic Habitats Near St. Vrain Nuclear Generating Station

Division Bacillariophyta (Diatoms)

Achnanthes conspicua
Achnanthes exigua
Achnanthes inflata
Achnanthes lanceolata
Achnanthes linearis
Achnanthes minutissima
Actinella punctata
Amphipleura pellucida
Amphiprora ornata
Amphiprora paludosa
Amphora ovalis
Amphora pediculus
Asterionella formosa
Biddulphia laevis
Brebbissonia sp.
Caloneis amphisbaena
Caloneis silicula
Cocconeis disculus
Cocconeis placentula
Cyclotella compta
Cymatopleura elliptica
Cymatopleura solea
Cymbella affinis
Cymbella lanceolata
Cymbella minuta
Cymbella tumida
Cymbella turgida
Cymbella ventricosa
Diatoma elongatum
Diatoma hiemale
Diatoma vulgare
Diploneis elliptica
Entomoneis ornata
Epithemia sorex
Eunotia pectinalis
Eunotia vanheurckii
Fragilaria capucina
Fragilaria construens
Fragilaria crotonensis
Fragilaria vaucheriae
Fragilaria virescens
Gomphoneis erieuse
Gomphonema sp.
Gomphonema acuminatum
Gomphonema affine
Gomphonema angustatum
Gomphonema constrictum
Gomphonema intricatum
Gomphonema lanceolatum
Gomphonema parvulum
Gomphonema subclavatum
Gomphonema truncatum
Gyrosigma sp.
Gyrosigma acuminatum
Gyrosigma attenuatum
Gyrosigma exilis
Gyrosigma macrum
Gyrosigma obtusatum
Gyrosigma scalproides
Hannea arcus
Hantzschia amphioxis
Melosira ambigua
Melosira granulata
Melosira italica
Melosira varians
Meridion circulare
Navicula sp.
Navicula acus
Navicula capitata
Navicula cryptocephala
Navicula cuspidata
Navicula exigua
Navicula graciloides
Navicula iridis
Navicula minima
Navicula pupula
Navicula pygmaea
Navicula radiosa
Navicula rhynchocephala
Navicula tripunctata
Navicula viridula
Neidium iridis
Nitzchia acicularis
Nitzschia amphibia
Nitzschia apiculata
Nitzschia dubia
Nitzchia fonticola
Nitzschia gracilis
Nitzschia holsatica
Nitzschia ignorata
Nitzschia linearis
Nitzschia palea
Nitzschia paleacea
Nitzschia sigmoidea

Nitzschia sublinearis
Nitzschia triblionella
Nitzschia vermicularis
Pinnularia sp.
Pinnularia gibba
Pinnularia latevittata
Pinnularia microstauron
Pinnularia viridis
Pleurosigma sp.
Pleurosigma delicatulum
Pleurosigma elongatum
Pleurosigma strigosum
Rhizosolenia eriensis
Rhizosolenia longiseta
Rhoicosphenia curvata
Rhopalodia gibba
Stauroneis anceps
Stauroneis phoenicentron
Stephanodiscus hantzschii
Surirella angustata
Surirella biseriata
Surirella capronii
Surirella elegans
Surirella ovalis
Surirella ovata
Surirella patella
Synedra acus
Synedra actinoides
Synedra amphicephala
Synedra delicatissima
Synedra filiformis
Synedra minuscula
Synedra rumpens
Synedra tabulata
Synedra ulna
Tabellaria fenestrata

Division Chlorophyta (Green Algae)

Actinostrum hantzschii
Ankistrodesmus convolutus
Ankistrodesmus falcatus
Carteria sp.
Characium ambigua
Chlamydomonas sp.
Chlorella sp.
Chlorogonium sp.
Chlorogonium elongatum
Chlorogonium euchlorum
Chlorogonium spirale
Chlorococcum sp.
Chodatella sp.
Cladophora glomerata
Closteriopsis longissima
Closterium sp.
Closterium acerosum
Closterium lunula
Closterium setaceum
Coelastrum microporum
Coelastrum sphaericum
Cosmarium sp.
Cosmarium botrydis
Cosmarium costatum
Cosmarium subreniforme
Crucigenia irregularis
Crucigenia quadrata
Dactylococcus infusionum
Dichotomosiphon sp.
Dictyosphaerium planktonicum
Dictyosphaerium pulchellum
Dimorphococcus lunatus
Dysmorphococcus sp.
Enteromorpha intestinalis
Francia ovalis
Gloeocystis botryoides
Gloeocystis gigas
Gonium pectorale
Golenkinia radiata
Haematococcus lacustris
Hyalotheca mucosa
Hydrodictyon reticulatum
Lobomonas rostrata
Micractinium pusillum
Microspora floccosa
Oedogonium sp.
Oocystis sp.
Oocystis borgei
Oocystis lacustris
Pandorina morum
Pediastrum boryanum
Pediastrum duplex
Pediastrum sculpatum
Pediastrum simplex
Pediastrum tetras
Phacotus lenticularis
Planktosphaeria gelatinosa
Pleurotaenium sp.
Protosiphon botrydioides
Pteromonas aculeata
Pteromonas farotidrus
Pteromonas sinuosa
Pyramimonas tetrarhynchos
Rhizoclonium hieroglyphicum
Scenedesmus acuminatus
Scenedesmus armatus
Scenedesmus bijuga

Scenedesmus dimorphus
Scenedesmus quadricauda
Selenastrum gracile
Selenastrum lacustris
Selenastrum westii
Sorastrum sp.
Spirogyra spp.
Spondylosium plana
Staurastrum sp.
Staurastrum chaetoceros
Staurastrum paradoxum
Stichococcus bacillaris
Stigeoclonium tenure
Stephanosphaera pluvialis
Tetraedron lunula
Tetraspora sp.
Thoracomonas phacotoides
Ulothrix sp.
Ulothrix subtilissima
Ulothrix tenerrima
Ulothrix zonata
Volvulina steinii
Wislouschiella planktonica
Zygnema sp.

Division Chrysophyta (Golden-Brown Algae)

Anthophysa vegetans
Chrysameba radians
Dinobryon sp.
Dinobryon acuminatum
Dinobryon campanulostipitatum
Gonyostomum semen
Heliapsis mutabilis
Synura sp.
Synura sphagnicola

Division Cryptophyta (Cryptomonads)

Chilomonas sp.
Cryptomonas ovata

Division Cyanophyta (Blue-green Algae)

Anabaena sp.
Anabaena circinalis
Anabaena flos-aquae
Anabaena limnetica
Anacystis nidulans
Aphanizomenon flos-aquae
Chaemosiphon curvatus
Chaemosiphon incrustans
Chroococcus sp.
Gloeocapsa sp.
Gomphosphaeria sp.
Lyngbya sp.
Lyngbya nana
Lyngbya spirulineides
Merismopedia sp.
Merismopedia punctata
Microcystis aeruginosa
Nostoc sphaericum
Oscillatoria sp.
Oscillatoria limnetica
Oscillatoria limosa
Oscillatoria minnesotensis
Oscillatoria princeps
Phormidium sp.
Phormidium tinctorium
Rivularia sp.
Spirulina major

Division Euglenophyta (Euglenoids)

Astasia sp.
Euglena acus
Euglena caudata
Euglena viridis
Hyalophacus sp.
Phacus brevicauda
Phacus helicoides
Phacus longicauda
Phacus pyrum
Phacus tortus
Peranema sp.
Trachelomonas sp.
Trachelomonas gibberosa
Trachelomonas hispida

Division Pyrrophyta (Dinoflagellates)

Ceratium hirundinella
Massartia-like sp. (unident.)

Division Rhodophyta

Batrachospermum (Chantransia) sp.

Division Xanthophyta

Botrydiopsis sp.
Ophiocytium sp.
Tribonema sp.
Vaucheria sp.

Table II

Description and Occurrence of Common Algal Species

Species	Description	Habitat
Cladophora glomerata	Course, branched, filamentous green alga.	Grows on submerged rocks or other substrates
Euglena viridis	Fusiform, unicellular, microscopic alga; green pigmentation. Euglenoid, changes shape.	Grows encysted on exposed mud or submerged fine silt. Found as extensive green patches along banks of rivers during late winter months.
Navicula cryptocephala	Diatom. Golden-brown bilaterally-symmetrical unicell. Boat-shaped with round, inflated ends. Motile. Raphe (groove) along midline of top and bottom of cell wall.	Grows on mud or submerged areas. Golden-brown patches on surface of substrates. Grows in same areas as Nitzschia palea.
Nitzschia palea	Diatom. Narrow, fusiform unicell. Raphe (groove) along edges of cell wall.	Same as Navicula cryptocephala.
Rhizoclonium hieroglyphicum	Unbranched, coarse filamentous green alga.	Form free-floating, extensive mats in Goosequill Pond and in stationary waters in the rivers.
Scenedesmus quadricauda	Four-celled colony with two spines eminating from end cells.	Planktonic in Goosequill Pond.
Stephanodiscus hantzschii	Radially symmetrical diatom. Thin spines along edge of cell walls.	Usually planktonic as in Goosequill Pond. Sometimes growing in Cladophora populations.

and riffle areas. The most common habitat involves current over sand or fine silt. These areas support large diatom populations throughout the year and include euglenoids during late winter months. Most samples were taken from this extensive habitat.

Standing water occurred in backwater areas or behind dams. In addition to having a diatom flora characteristic of flowing water, these sites formed large floating mats of the green algae Hydrodictyon, Rhizoclonium, and Spirogyra. Such was the situation at sites SVI, SV and backwater areas at other sites during late summer.

The riffle areas are shallow water areas passing over rocky substrates. These rocks supported large populations of Cladophora glomerata which in turn might support epiphytic diatoms such as Diatoma vulgare and Stephanodiscus hautzschii. During the colder months or periods of swift currents only the basal portions of Cladophora survived. Quantitative sampling of this alga was not feasible due to its restricted growth patterns within a given area.

3. Goosequill Pond

Goosequill Pond represented an unusual habitat since it was man-made and manipulated more than any river site. Scenedesmus quadricauda was the dominant alga through most of the year (Fig. 3). In addition, from April to October, the filamentous green alga, Rhizoclonium hieroglyphicum, formed extensive floating mats around the edges of Goosequill Pond. Some possible deleterious effects from these algae on other living organisms have been observed and will be discussed later.

4. Species Diversity

Species diversity was low in all aquatic habitats, indicating polluted conditions. As mentioned in the initial environmental impact statement, the rivers collect large quantities of industrial and municipal wastes and dissolved solids before reaching the site. This was reflected not only in low species indices but also the types of dominant algae.

5. Fluctuations and Seasonal Succession in Algal Populations

Figures 1-6 represent algal population numbers from 1977-1979. The fluctuations are representative of previous years. As reported previously, the rivers primarily have diatom populations dominated by *Nitzschia palea* and *Navicula cryptocephala*, although sporadic, temporary increases in other diatom species might occur. These sporadic increases were insignificant during a year's sampling period.

The figures for sites showed that warmer temperatures tended to increase population numbers but these did not show any optimum temperature ranges. The diatoms have a wide tolerance for different conditions. Rather, it appeared to be an interaction between temperatures and current that affected the populations.

The figures also showed a general similarity in population numbers and species composition. This indicated that the sites and method of sampling were valid. This was particularly true for 1979 where there was a general decline in algal populations. Even the sites that were not affected by Generating Station activities displayed similar declines. If the Generating Station would have been responsible for this decline at specific sites, the other sampling sites should have shown significantly higher population numbers. Furthermore, there were no correlations between Generating Station operation dates and population fluctuations.

Another interesting feature of river populations was the appearance of the euglenoid, Euglena viridis during late winter months (Figs. 1, 2, 4-6). This also was a common feature of preceding sampling years.

6. Effects of Generating Station on Aquatic Habitats

There are four sites that are apparently affected by Generating Station activities: the areas behind the dams in both rivers, which create stationary water environments when the dams are in place; Goosequill Pond which receives Generating Station effluent; and the area downstream from the discharge of Goosequill Pond water to the South Platte River, which is affected by Goosequill Pond.

The lake-like conditions behind the dams created areas of debris deposition which provided unfavorable growth conditions for most organisms. Anaerobic conditions were created causing death of algae and consequently further sedimentation. The sediments might reach several feet in depth. Other features of this habitat included large growths of large pond or lake algae such as Hydrodictyon, Enteromorpha and Rhizoclonium.

Since Goosequill Pond received effluent from the Generating Station, obviously the fluctuations of water levels, nutrients and temperatures were affected by the Generating Station activity. The conditions seemed to favor Scenedesmus quadricauda. However, if the pond remained unfrozen during the winter, a shift to the diatom, Stephanodiscus hantzschii, took place.

The site downstream from the entry of Goosequill Pond water into the South Platte River often had significant numbers of algae representative of Goosequill Pond. Other river sites did not show this tendency.

7. NALCO Effects

While NALCO was identified as a toxicant in the original environmental impact statement, this did not appear to be the case in laboratory studies on algae, which were conducted in 1973. Under different conditions--axenic, unialgal, autoclaved vs. non-autoclaved NALCO media--we obtained several results. In axenic non-autoclaved conditions, there was no increased growth of algae. However, using autoclaved NALCO or NALCO media in which bacteria had been grown, a significant increase in the test alga Scenedesmus quadricauda occurred. The results indicated that NALCO is biodegradeable (by bacteria in our experiments) and heat labile. It also is an organophosphate, thus the phosphates are released upon degradation and utilized by Scenedesmus. Using phosphate-free media with autoclaved NALCO enhanced the growth of Scenedesmus. Therefore the release of NALCO into aquatic systems could promote the rate of algal growth.

8. Toxic Algae

Three species of blue-green algae that have been reported to be toxic to livestock were identified during the course of this study. These algae were Anabaena flos-aquae, Aplanizomenon flos-aquae, and Microcystis aeruginosa. However, none of these grew to "bloom" proportions during the past eight years, so there was no danger to livestock.

Other algae that were not considered toxin producers have recently been determined to produce phytotoxins. For instance, Scenedesmus quadricauda, the dominant alga in Goosequill Pond, Hydrodictyon reticulatum, and Nitzschia palea release compounds that can affect other organisms in various ways. Scenedesmus, Hydrodictyon, and Nitzschia have been shown to produce plant toxins that affect growth and development of higher plants. This could be a factor in stressing plants and reducing plant growth in areas irrigated with water from Goosequill Pond. Knowing that this parameter exists would permit proper identification of biological vs. Generating Station effects.

9. Comparison of Environmental Impact Statement (1972) With Recent Data

The following observations were made prior to 1972:

A. The farm pond (Goosequill Pond) had a heavy growth of Hydrodictyon reticulatum, Oedogonium sp. and Rhizoclonium hieroglyphicum during the 1971 season.

B. Cladophora glomerata (found during all seasons), Stigeoclonium flagelliferum, Olothrix tenuissima and Spirogyra sp. were dominant in the rivers and clogged the riffles of the river when the water level was low.

C. St. Vrain River was similar to South Platte River. The greatest obvious difference was in the presence of Enteromorpha intestinalis--the dominant algal species. This grass-like alga is normally found in saltwater habitats. It grew in the irrigation ditches. No Enteromorpha was found below confluence of streams.

D. Below confluence of South Platte and St. Vrain, water was swift; attached algae were not as abundant; Chadophora glomerata was dominant. Some diatoms and zooplankton were collected but not identified.

E. Salinities of the rivers were high, as evidenced by growth of *Enteromorpha intestinalis*. The initial samples involved only macroscopically identifiable algae at all sites. For instance, the identified large green algae were slow growing and not reliable indicators of rapidly changing conditions and were restricted to a few months of growth each year. Rather, the diatom flora, which was mentioned in statement D, should have been sampled since these have been the most reliable indicators of lotic ecosystems. Consequently, the listing of green algae did not provide a good data base for comparison with recent data.

10. Comparison of Predictions with Actual Results

A. Algae are subject to thermal impact. High temperatures tend to restrict the number of species of periphyton. Each species has an optimum temperature range.

B. Blue-green algae likely would become the dominant species in irrigation ditches and discharge areas.

C. The biocide (NALCO 321) is toxic.

D. Blue-green algal toxicity. *Anabaena* sp. potentially serious problem for livestock.

As indicated in the previous sections, these predictions did not come true. One component that remained untested was the effect of high temperature on algal populations. It was predicted in 1972 that excessively warm temperatures (99°F) would cause a drastic shift in algal populations to blue-green algae. Since such temperatures were never reached, this population change still remains speculative.

11. Environmental Trends and Changing Situations

The abundance of green algae in the rivers prior to 1972 indicated some changes since that time. The only alga that grew abundantly after 1972 was *Cladophora glomerata*. *Enteromorpha* occurred sporadically in localized areas. If *Enteromorpha* is an indicator of salinity as stated in #5 then the salinities of the rivers have decreased.

Stigeoclonium flagelliferum may have been misidentified since our samples yielded only *S. tenue*. *Stigeoclonium* was never a significant component of the river flora.

Goosequill Pond has undergone a drastic change with regard to *Hydrodictyon reticulatum* and *Oedogonium* sp. Our initial observations in the summers of 1972 and 1973 also indicated large growths of these two algae. In subsequent years, however, both algae disappeared from Goosequill Pond. Whether the current dominant, *Scenedesmus quadricauda*, was present prior to 1972 is not known.

Obviously there have been some changes in these aquatic habitats since 1972 and it might be due to a change in current velocity. As recent data suggest, *Hydrodictyon*, *Enteromorpha* and *Rhizoclonium* are quiet water algae, therefore the observations prior to 1972 in the rivers may be due to slower currents and lower water levels.

Since 1972 algal populations have not shown much change throughout the years and no changes in dominants have occurred. Fluctuations in populations can be explained by temperature, current, ice formation, water levels and shifting substrates in the rivers. Goosequill Pond probably is more affected by temperatures, water levels, nutrient availability, and diversion of water.

12. Generating Station Effects on Environment

There are no direct effects of the Generating Station on the algal flora. As mentioned previously this critical aspect is lacking due to intermittent operation of the Generating Station. Influences other than operation of the Generating Station have been noted in preceding sections.

13. Factors Influencing Environmental Quality

There do not appear to be any new factors that influenced algal populations. The stability of the populations over an eight year study indicate that conditions have remained the same.

Non-generating station influences include municipal waste discharge, upstream sedimentation, farm drainage, and drastic changes in currents. All these conditions contribute to a polluted stream.

Figure Legends

Fig. 1. SVI - St. Vrain Intake

Fig. 2. SV - St. Vrain Below Intake

Fig. 3. GQ - Goosequill Pond

Fig. 4. SPI - South Platte Above Intake

Fig. 5. SPGQ - South Platte Below Intake

Fig. 6. SP - South Platte Below Intake and Discharge from Goosequill Pond

Abbreviations used in Figures.

EL - Extremely slow currents

ES - Extremely swift currents

L - Slow currents

M - Average current flow

S - Swift currents

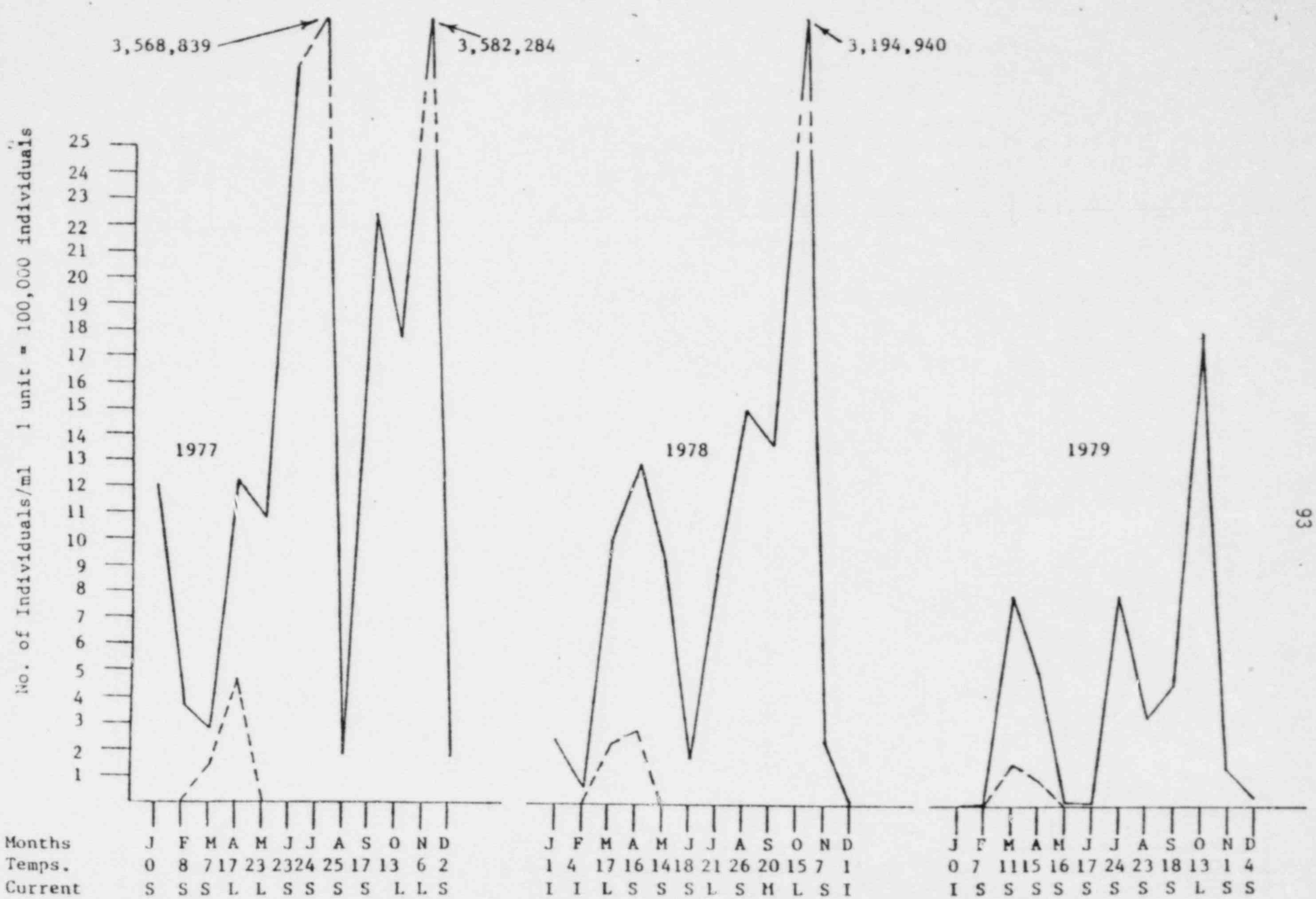
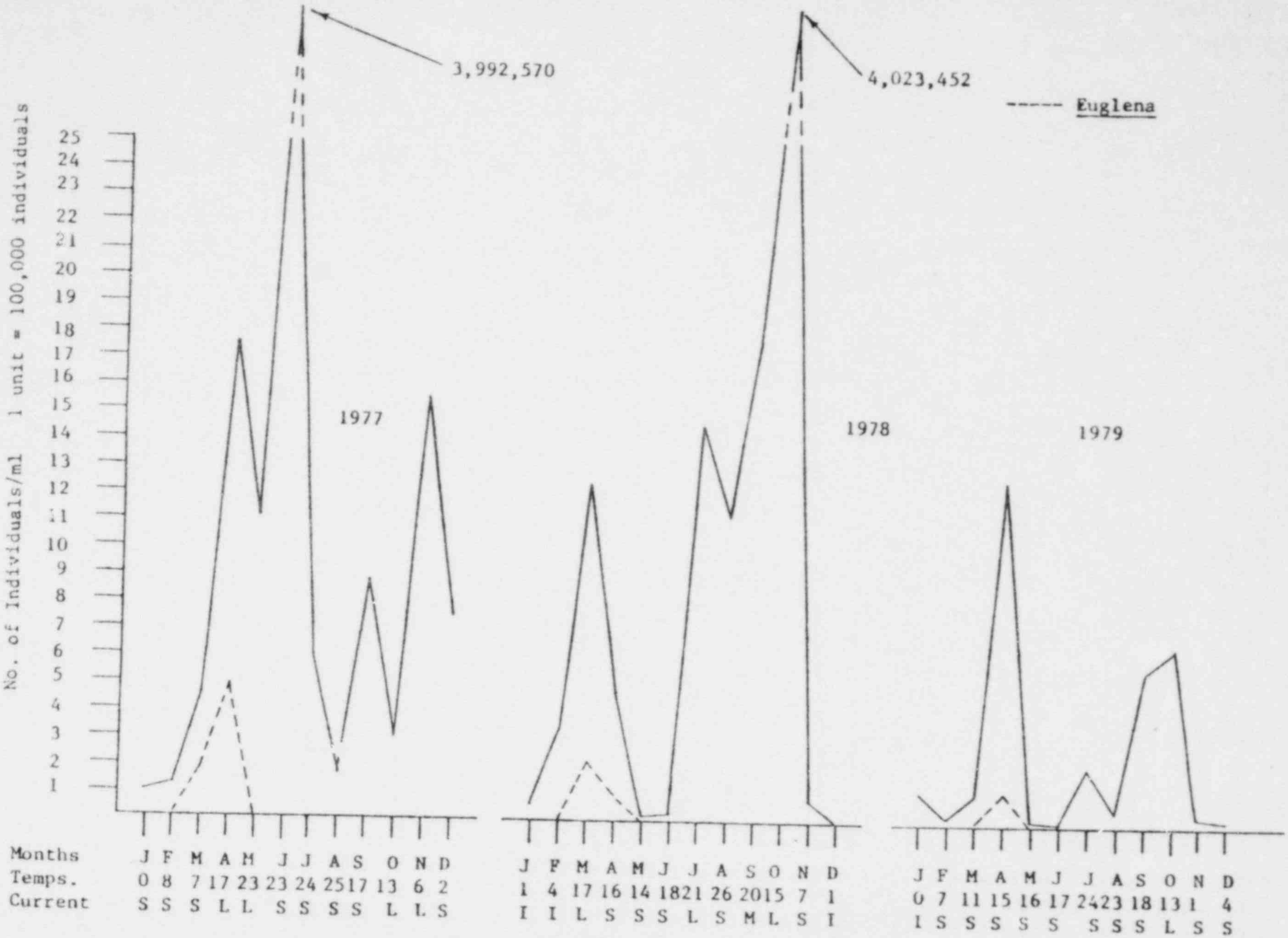

3,568,839
3,582,284
3,194,940
No. of Individuals/ml   1 unit = 100,000 individuals
1977
1978
1979
Months
Temps.
Current
J F M A M J J A S O N D
0 8 7 17 23 23 24 25 17 13 6 2
S S S L L S S S S L L S
J F M A M J J A S O N D
1 4 17 16 14 18 21 26 20 15 7 1
I I L S S S L S M L S I
J F M A M J J A S O N D
0 7 11 15 16 17 24 23 18 13 1 4
I S S S S S S S S L S S

FIG. 1


3,992,570
4,023,452
----- Euglena
No. of Individuals/ml 1 unit = 100,000 individuals
25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
1977
1978
1979
Months
Temps.
Current
J F M A M J J A S O N D
0 8 7 17 23 23 24 25 17 13 6 2
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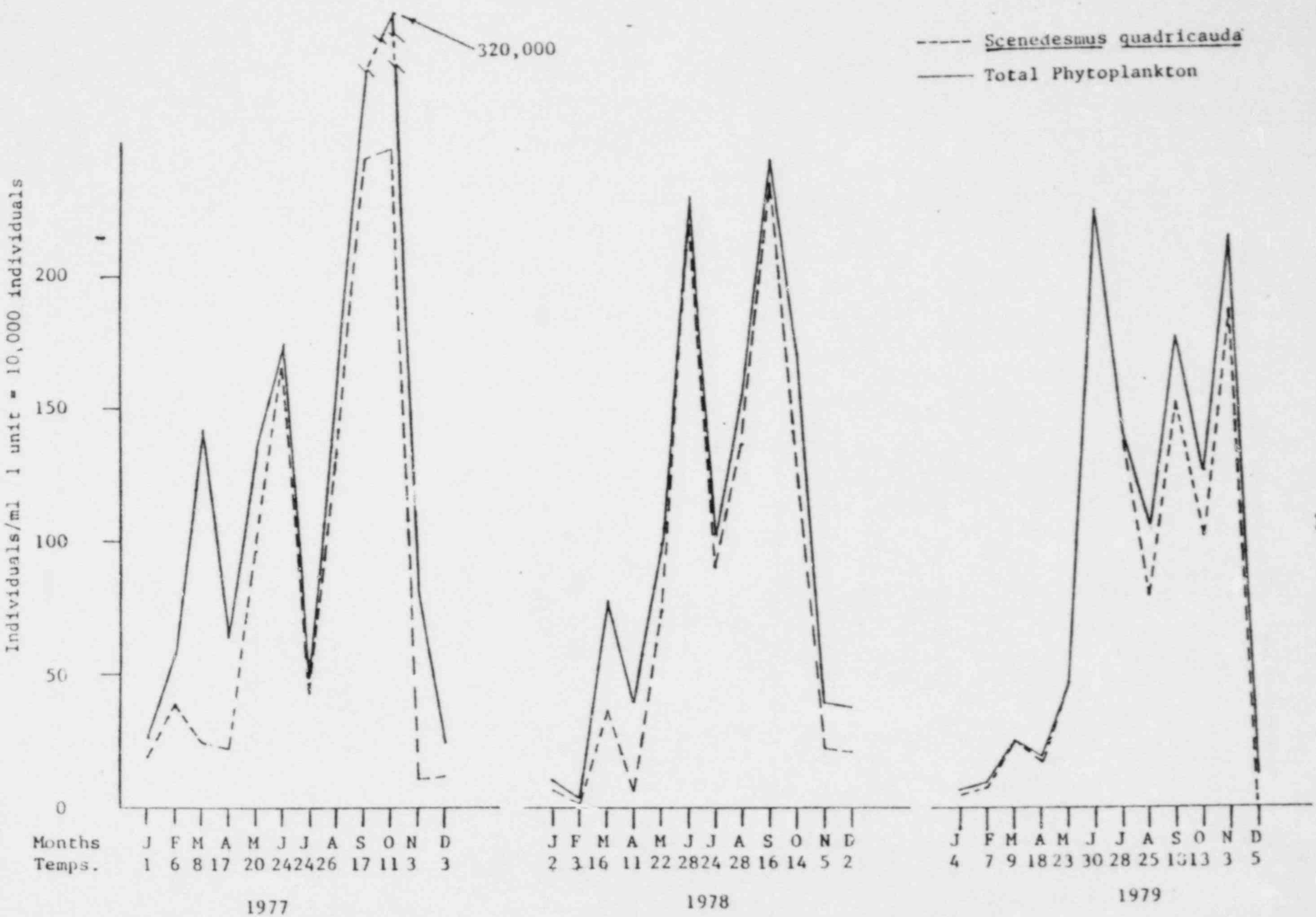
1 4 17 16 14 18 21 26 20 15 7 1
I I L S S S L S M L S I
J F M A M J J A S O N D
0 7 11 15 16 17 24 23 18 13 1 4
I S S S S S S S S L S S

FIG. 2



Scenedesmus quadricauda
Total Phytoplankton
320,000
Individuals/ml 1 unit = 10,000 individuals
200
150
100
50
0
Months
Temps.
J F M A M J J A S O N D
1 6 8 17 20 24 24 26 17 11 3 3
1977
J F M A M J J A S O N D
2 3 16 11 22 28 24 28 16 14 5 2
1978
J F M A M J J A S O N D
4 7 9 18 23 30 28 25 13 13 3 5
1979

FIG. 3

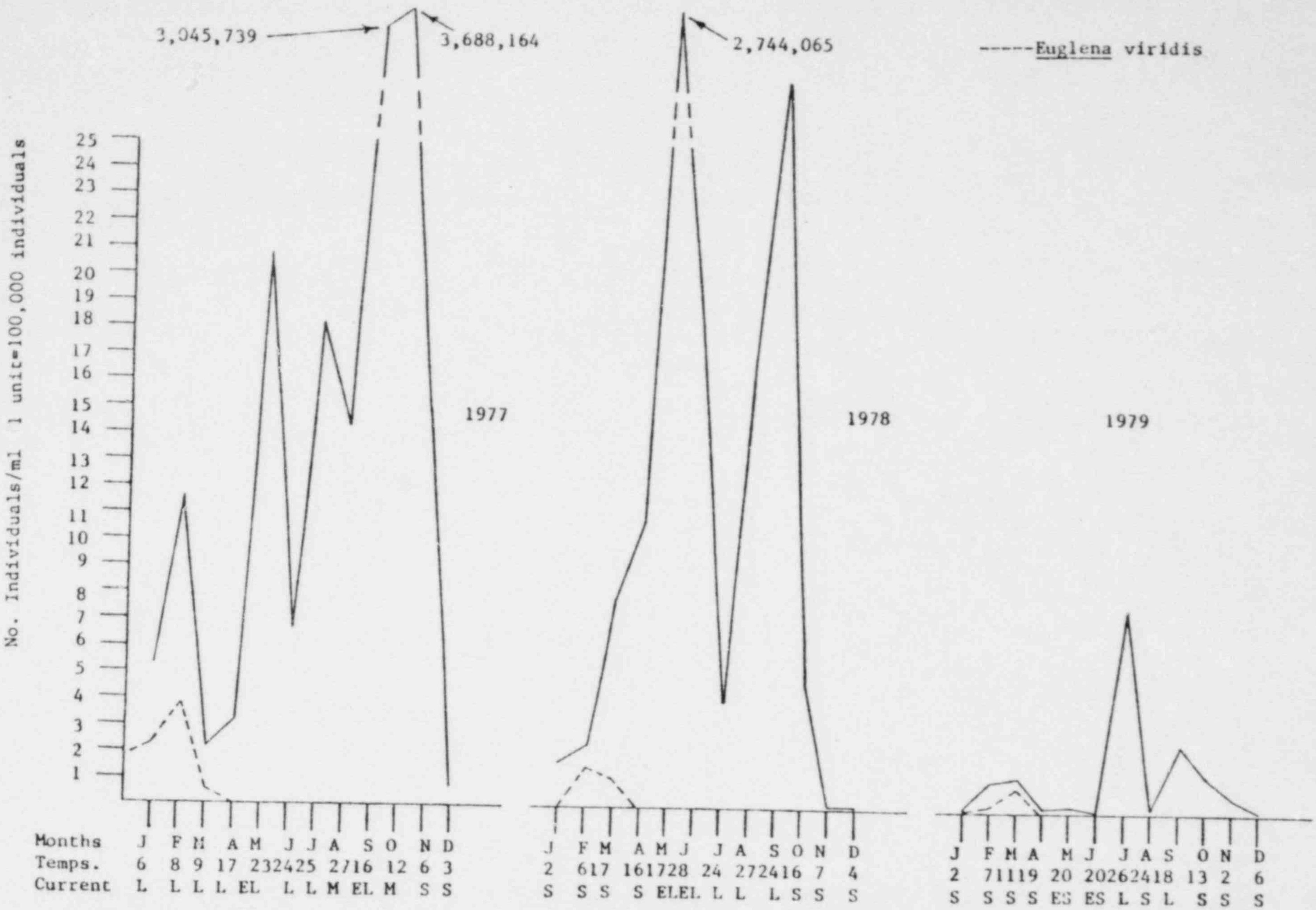
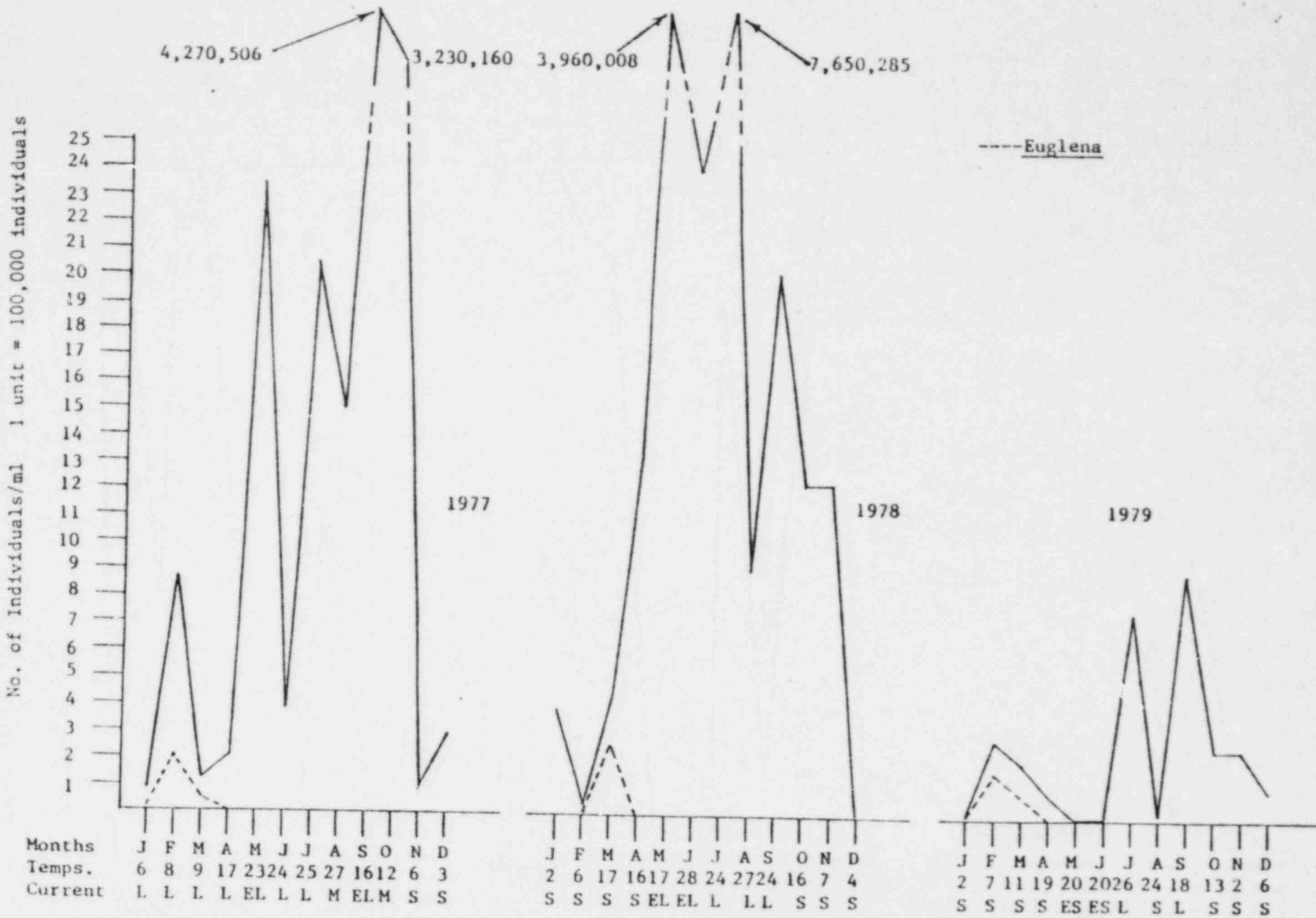

3,045,739
3,688,164
2,744,065
-----Euglena viridis
No. Individuals/ml 1 unit=100,000 individuals
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1977
1978
1979
Months J F M A M J J A S O N D
Temps. 6 8 9 17 232425 2716 12 6 3
Current L L L L EL L L M EL M S S
J F M A M J J A S O N D
2 617 161728 24 272416 7 4
S S S S ELEL L L L S S S
J F M A M J J A S O N D
2 71119 20 20262418 13 2 6
S S S S ES ES L S L S S S

FIG. 4



No. of Individuals/ml 1 unit = 100,000 individuals
4,270,506
3,230,160
3,960,008
7,650,285
----Euglena
1977
1978
1979
Months J F M A M J J A S O N D
Temps. 6 8 9 17 23 24 25 27 16 12 6 3
Current L L L L EL L L M EL M S S
J F M A M J J A S O N D
2 6 17 16 17 28 24 27 24 16 7 4
S S S S EL EL L L L S S S
J F M A M J J A S O N D
2 7 11 19 20 20 26 24 18 13 2 6
S S S S ES ES L S L S S S

FIG. 5

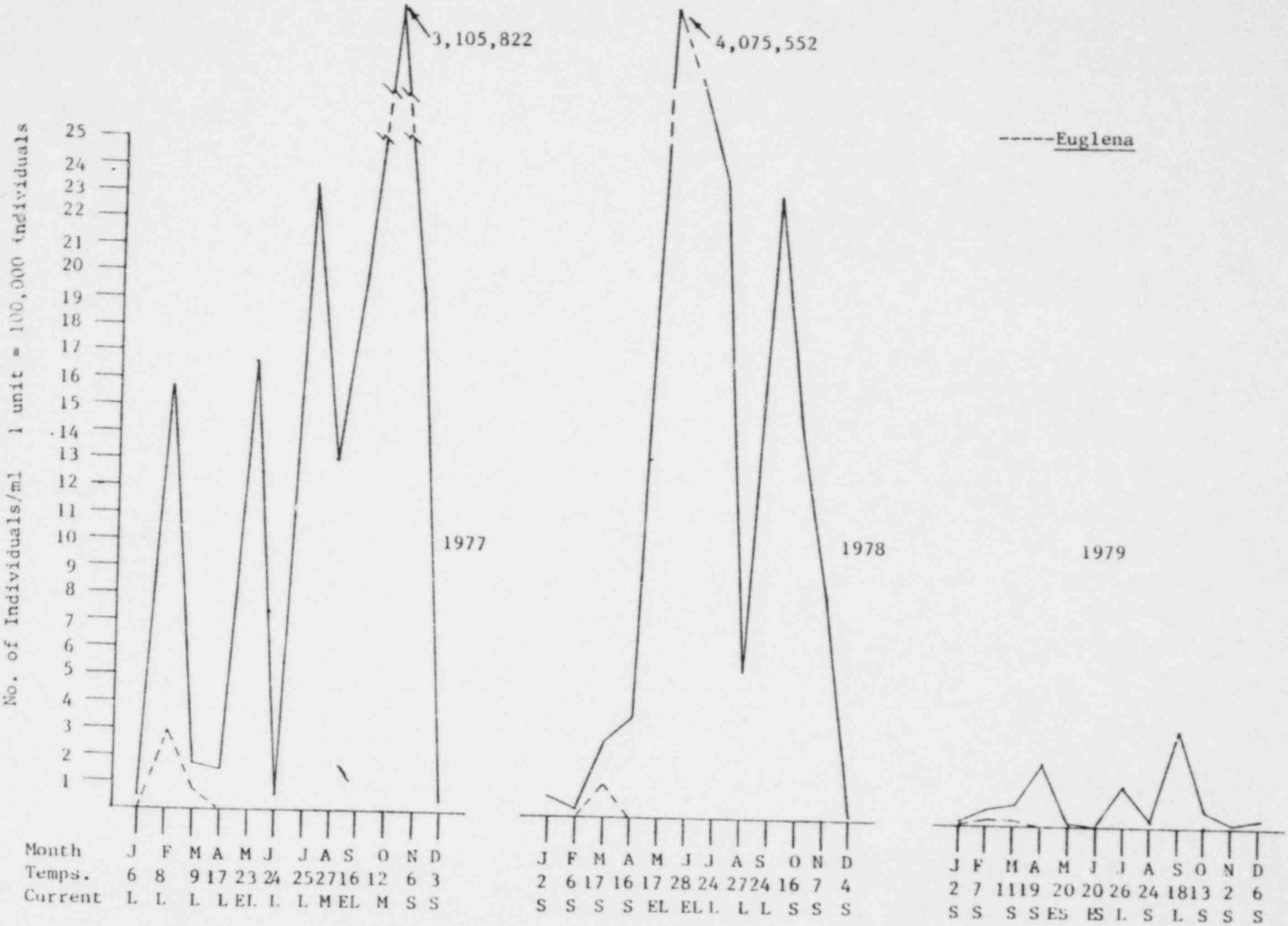

No. of Individuals/ml 1 unit = 100,000 individuals
3,105,822
4,075,552
-----Euglena
1977
1978
1979
Month
Temps.
Current
J F M A M J J A S O N D
6 8 9 17 23 24 25 27 16 12 6 3
L L L L EL L L M EL M S S
J F M A M J J A S O N D
2 6 17 16 17 28 24 27 24 16 7 4
S S S S EL EL L L L S S S
J F M A M J J A S O N D
2 7 11 19 20 20 26 24 18 13 2 6
S S S S ES ES L S L S S S

FIG. 6

AVIAN SECTION

AVIAN MONITORING

by

Ronald A. Ryder

Introduction

Studies of avian populations were conducted at the Fort St. Vrain Nuclear Power Generating Station Site near Platteville, Colorado, from April 8, 1972 to December 1, 1979. This investigation was part of a multidisciplinary research program to gather baseline information about the biota near the nuclear facility (Ryder 1976).

The goals of this study were to determine the status of the avian population and possible pathways of contaminants through that population in the cottonwood riverbottom ecosystem surrounding the nuclear facility. Hopefully, data from this study would provide a means to evaluate environmental quality in the environs of the facility and contribute to the knowledge of avian populations. Also, if collected after the plant reached full operation, these data would give an indication of the impact of the Fort St. Vrain Nuclear Generating Station on the avian populations.

Objectives

The objectives of this study were as follows:

1. To prepare (or acquire) maps showing the dominant vegetation and surface water to facilitate identification of habitats important to birds at the site;
2. To establish procedures for periodic counting of the various species of birds utilizing the site;
3. To prepare, by means of field studies and subsequent analysis of the data, annotated lists of the avifauna.
4. To gather information on nesting success of dominant species of birds utilizing the site;

5. Where possible, to gather information on food habits of dominant avian species. Food sources may be pathways for contaminants to the avian population; and
6. To determine the impact of the Fort St. Vrain Nuclear Generating Station on the indigenous avian populations and their habitats.

Study Areas

Bird populations were monitored on three study areas within 3 km of the Nuclear Generating Site which are referred to as St. Vrain River, Goosequill Pond, and South Platte River areas, consisting of 71.6, 8.5 and 52.2 hectares (177, 21 and 129 acres) respectively (Fig. 1). See Ryder (1976) for a more detailed description.

Methods

Standard avi n census methods were used with some adaptations (Ryder 1976). Data were gathered and analyzed in accordance with the widely-used North American Breeding-Bird Survey (International Bird Census Committee 1970) and the Audubon Winter Bird Population Study (Kolb 1965).

Censuses began at sunrise. The St. Vrain River and South Platte River areas were systematically searched by ground reconnaissance aided by 7 X 35 or 7 X 50 binoculars, and the pond was censused with binoculars and a spotting scope, observations being made from the surrounding dike. Birds flying into, from, and contained within the study area were recorded. Spot maps were kept for territorial males during the breeding season. All nests encountered were marked and revisited to record nesting attempts and success.

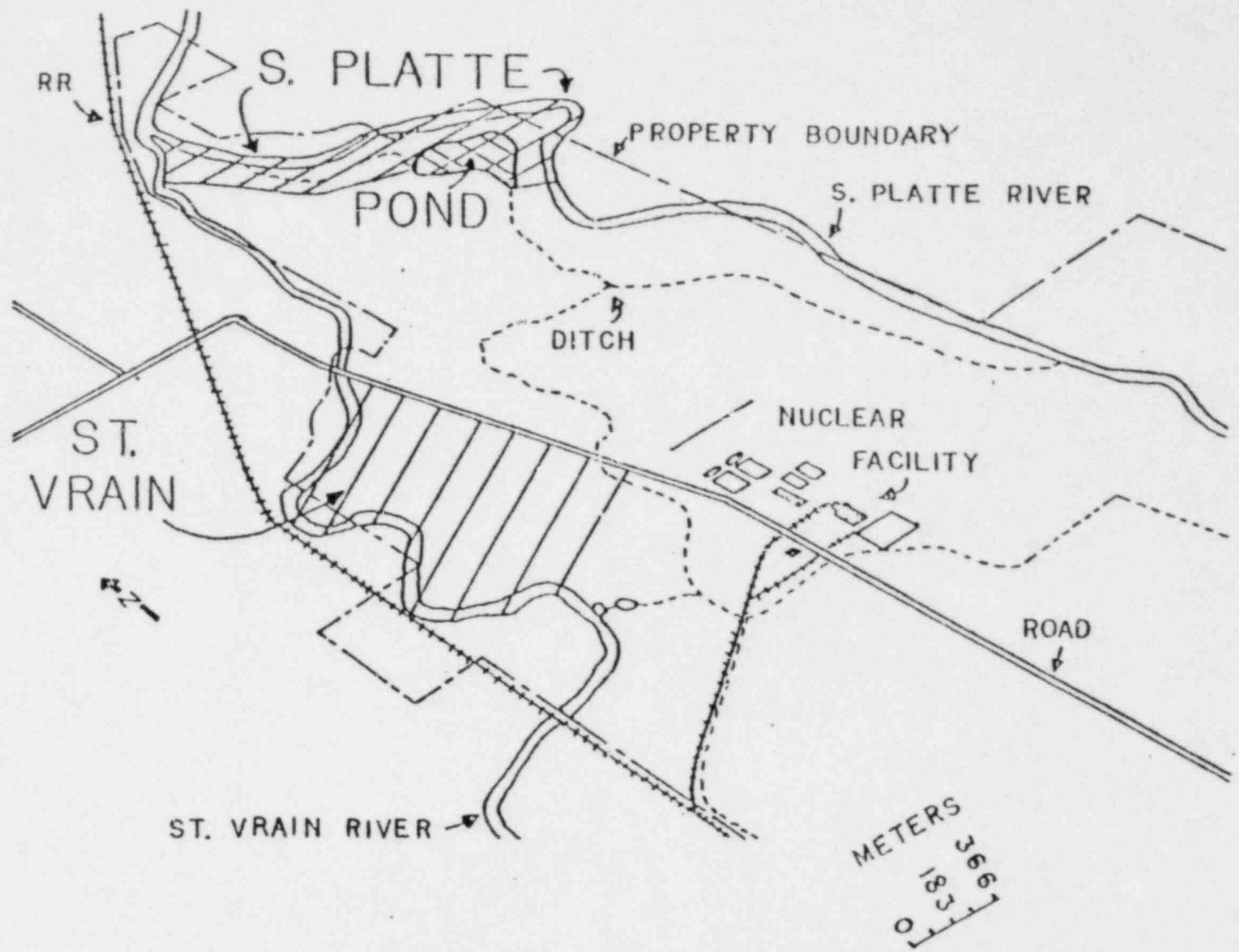


Figure 1. Location of three bird census areas (St. Vrain River, South Platte River and Goosequill Pond).

An intensive search for Red-winged and Yellow-headed Blackbird nests was conducted at Goosequill Pond and a slough and pond complex on the St. Vrain unit.

Censuses were made with varied frequency throughout the year. Basically, weekly counts were made from May to mid-June and bimonthly counts during spring and fall migrations. Monthly or less frequent counts were made in the winter. All three areas were censused 16 times each in 1977, 1978 and 1979. Earlier censuses numbered over 20 per year.

RESULTS

Avian Abundance and Species Composition

One hundred eighty-seven species (plus 3 subspecies) were encountered during the eight years of study (Appendix A). This is 34 species more than reported in the initial "Biological Survey" (Ryder 1976).

Species present were usually highest in May just prior to nesting, somewhat lower but consistent during nesting, and lowest during winter. Avian species diversity was calculated using Simpson's formula,

$$D = 1 - \sum_{i=1}^{s} (pi)^2$$

where pi = proportion of sample belonging to ith species, s = number of species, and D = index of diversity.

A seasonal pattern was evident for total diversity among the three study areas. In 1972, for example, diversity consistently ranged from 0.88 through 0.93 with a median of 0.91 for 15 counts from April 25 to August 3 (also see Benson 1973). Other periods showed a lower diversity index (as low as 0.55 in October). Diversity indices in 1979 were not much different from those in 1972 (Tables 1, 2, 3, and 4).

Table 1. Species Diversity Indices for Goosequill Pond.

Dates	1972	1979
1st week in May	0.73	0.88
2nd week in May	0.76	0.84
3rd week in May	0.76	0.64
4th week in May	0.83	0.80
1st week in June	0.81	0.56
2nd week in June	0.85	0.64

Table 2. Species Diversity Indices for the South Platte River Area

Dates	1972	1979
1st week in May	0.89	0.83
2nd week in May	0.89	0.84
3rd week in May	0.86	0.83
4th week in May	0.87	0.90
1st week in June	0.90	0.38
2nd week in June	0.91	0.86

Tables 3. Species Diversity Indices for the St. Vrain River Area

Dates	1972	1979
1st week in May	0.89	0.88
2nd week in May	0.89	0.88
3rd week in May	0.92	0.99
4th week in May	0.88	0.89
1st week in June	0.91	0.90
2nd week in June	0.91	0.93

Table 4. Species Diversity Indices for all Three Study Areas Combined

Dates	1972	1979
1st week in May	0.91	0.90
2nd week in May	0.92	0.91
3rd week in May	0.91	0.91
4th week in May	0.91	0.91
1st week in June	0.93	0.90
2nd week in June	0.93	0.91

Species diversity indices reflect not only number of species but "evenness" of individuals within species. Thus, a few species and many of one species would yield a low diversity index. Many species with a uniform number of individuals for each species would result in a high species diversity. Many ecologists believe communities with high species diversity are more stable (less sensitive to ecological changes) than communities with low indices but this concept is being challenged.

Common Grackles, Red-winged Blackbirds, Yellow-headed Blackbirds and Starlings were difficult to census because they were often seen in large flocks, or some of the latter three species were on nests and not visible during the census periods. However, Starlings and Red-winged Blackbirds were abundant permanent residents, and Yellow-headed Blackbirds were abundant on marsh habitats from their first occurrence in spring until departure in fall.

Starlings were usually the most abundant nesting species throughout the study and, in general, increased whereas red-wings and yellowheads decreased as nesters (see Table 7). Starlings are better adapted to disturbed sites, abandoned buildings, and probably to heavy grazing and large numbers of livestock. They commonly feed around cattle, especially following fledging of the young starlings, and in winter are a serious pest in nearby feedlots. The native blackbirds seem less attracted to grazing cattle although redwings, but not yellowheads, commonly visit feedlots to the west of the Fort St. Vrain Nuclear Generating Site.

Total individuals and species seen are summarized in Table 5. Summer, fall and winter populations have fluctuated widely, and no specific trend is apparent. Spring populations, however, show a fairly distinct pattern of an overall decline in avifauna in 1973 followed by a steady recovery to 1977, with declines in 1978 and 1979. The sharp decline in 1973 can probably be attributed to habitat deterioration due to flooding. The recovery is probably attributable to a natural return to pre-flood conditions. Grazing of livestock was reduced in 1977 but increased in 1978 and 1979 when a marked decline in redwings and yellowheads was noted (Table 7).

The non-breeding seasons for all eight years were marked by irregular fluctuations of populations, but breeding bird numbers are believed to be a more sensitive indicator of the state of the habitat. Breeding birds declined during the last two years of the study. Yellow-headed and Red-winged Blackbirds, particularly, had a very poor breeding season in 1979 with low hatching success. Most other species fared somewhat better. See Tables 6 and 7.

The only obvious differences noted in the habitat in 1978 and 1979 were the reduction in vegetative cover due to grazing, and perhaps lack of runoff water either from irrigation practices or operation of the Fort St. Vrain Nuclear Generationg Station. No data were collected on the

Table 5. Eight-year tabulation of species numbers and population levels from monitoring at the Fort St. Vrain Nuclear Generating Station (number of species seen per count followed by total individuals).

Time Period	1972	1973	1974	1975	1976	1977	1978	1979
January	No count	19(762)	19(319)	20(335)	10(340)	No count	No count	No count
February	No count	29(847)	19(2884)	24(15,474)	No count	23(422)	24(478)	30(1121)
March	No count		32(709)	25(14,063)	29(709)	33(627)	30(715)	31(546)
early April	28(823)	26(326)	32(487)	34(688)	38(720)	No count	43(622)	34(498)
late April	50(871)	34(561)	37(441)	44(719)	46(903)	40(717)		
1st wk May	47(574)	47(410)[1/]	33(381)	45(534)	45(591)	48(729)	No count[2/]	37(488)
2nd wk May	47(583)		39(382)	62(833)	52(533)	47(777)	50(640)	54(510)
3rd wk May	48(593)	45(466)[1/]	45(543)	43(563)	55(728)	54(855)	43(522)	38(397)
4th wk May	48(691)		38(450)	46(523)	50(635)	49(656)	45(565)	44(451)
1st wk June	35(500)	39(373)	40(641)	42(491)	38(569)	49(614)	43(518)	40(426)
2nd wk June	41(558)	33(414)	42(583)	40(419)	42(513)	46(660)	42(450)	40(416)
3rd wk June	38(551)	38(426)	33(469)	34(340)	39(585)	44(635)	40(457)	43(536)
4th wk June	37(509)	32(324)	34(426)	37(373)	No count	40(589)	41(510)	37(378)
1st wk July	36(704)	33(421)	32(537)	32(483)	38(731)	No count	40(560)	No count
2nd wk July	37(681)	29(433)	34(541)	36(522)	No count	No count	No count	No count
3rd wk July	36(680)	29(409)	34(437)	37(478)	No count	41(600)	38(534)	37(503)
4th wk July	37(588)		30(779)	36(550)	40(1145)	No count	No count	No count

Table 5, continued.

Time Period	1972	1973	1974	1975	1976	1977	1978	1979
1st wk August	37(658)	38(750)	28(838)	No count	No count	No count	No count	No count
2nd wk August	38(851)		34(1123)	40(386)	No count	No count	34(571)	No count
3rd wk August	42(757)	36(377)	33(997)	35(565)	46(685)	37(2289)	No count	No count
4th wk August	No count		No count	No count	No count	No count	No count	37(1299)
1st wk September	43(1080)	38(897)	36(1287)	40(879)	No count	No count	No count	No count
2nd wk September	No count		No count	No count	43(1917)	No count	No count	No count
3rd wk September	45(605)	31(1008)	43(879)	47(2392)	No count	37(1046)	41(980)	33(468)
4th wk September	No count		39(963)	No count	No count	No count	No count	No count
October	36(1190)	29(1402)	29(532)	31(442)	46(596)	34(856)	30(1692)	25(1737)
November	32(1642)	23(455)	23(2057)	27(387)	33(580)	26(458)	26(565)	No count
December	23(611)	22(283)	No count	No count	No count	No count	No count	22(192)

1/ May 1973 counts probably not comparable to those in 1972 and 1974. Due to floods, it was not possible to complete counts of all 3 areas weekly in May 1973.

2/ Early May count in 1978 delayed by unusually late snowstorm.

Table 6. Summary of the 1979 intensive nest search on the St. Vrain Study Area and Goosequill Pond.

Area and Species	Total Nests	Percent Successful[1/]	Percent Unsuccessful	Percent Unknown
St. Vrain Study Area				
American Bittern	2	0.0	100.0	0.0
Yellow-headed Blackbird	6	0.0	83.3	16.7
Red-winged Blackbird	22	4.5	77.3	18.2
Mourning Dove	3	0.0	66.7	33.3
Goosequill Pond				
Yellow-headed Blackbird	3	0.0	0.0	100.0
Red-winged Blackbird	3	0.0	0.0	100.0

[1/] Eggs to fledglings.

Table 7. Total nestings of Red-winged and Yellow-headed Blackbirds at the Fort St. Vrain Nuclear Generating Station, 1972-1979.

Species	Number of Nests Followed							
	1972	1973[1/]	1974	1975	1976	1977	1978	1979[1/]
Red-winged Blackbird	27	25	27	16	26	68	23	25
Yellow-headed Blackbird	54	20	31	56	53	100	33	9

[1/] Goosequill Pond was drained in May 1973 and May 1979.

avian census project regarding water levels nor changes in water flow. Cattle numbers were recorded on all plots during each bird count.

Environmental disturbances increased throughout the study, particularly in 1979. Rather heavy grazing of the areas was seen in early spring and late summer. Goosequill Pond was drained in May of 1973 and 1979 "in an effort to control muskrat and beaver activity in the peripheral dike." The low water level of the pond favored migrants but not nesting birds. Waterbirds were able to feed there most of the winters and many of the falls. Waterfowl hunting probably affected local wood duck production in the South Platte area. Irrigation in the adjacent field caused pronounced fluctuations in the water levels of the beaver ponds throughout the summer. Efforts were made during at least two summers to poison prairie dogs. Prairie dog numbers, however, usually recovered by fall, so it is believed the prey base they provide for raptors such as Great Horned Owls was not seriously altered.

Food Habits of Birds

A special study of the contents of regurgitated pellets of Great Horned Owls was conducted, as they were the dominant year-round bird of prey on the areas and a study of their food habits might indicate possible pathways of contamination. No other food habits data were collected as it would have involved killing birds which would have altered census data.

The results of the Great Horned Owl will be the topic of a special report to be developed. But, it is important to note 8 species of resident mammals, 4 resident bird species as well as carp, crayfish, and insects were eaten. The invertebrates, particularly, might be the logical pathways of contaminants through the ecosystem. If abnormal levels of contaminants were reported in any of the small mammals, biomagnification could occur in the foods of owls. Production of young owls was remarkably consistent (2 to 3 young each year) so no immediate adverse effect of the Fort St. Vrain Nuclear Generating Station is suspected at this point.

Our study indicates that contrary to their primarily nocturnal habits, the Great Horned Owls fed to a large degree on the diurnal black-tailed prairie dog (21.2% biomass). Perhaps future consideration employing poisoning to control prairie dogs should recognize that Great Horned Owls are helping control these rodents and that there may be a danger of poisoning non-target species.

SUMMARY

Eight years of repeated censuses of birds indicate that avian species diversity has remained rather constant but that total numbers of individuals (especially nesters) has been declining the past 2 years from a peak in 1977. Similar declines in nesting Red-winged Blackbirds were reported in the Dakotas by U.S. Fish and Wildlife Service biologists (J. F. Besser, personl comm.). Also, reductions were noted in Yellow-headed Blackbird nesting populations in 1978, and to a lesser extent in 1979, in an intensive study of a large marsh approximately 13 miles east (Ryder, unpublished data). There drawdown, burning, and hailstorms seem responsible. Declines on Goosequill Pond were, no doubt, largely due to drawdown

during the territory-establishment phase of nesting. Continued heavy grazing of the St. Vrain River study area is considered more detrimental to nesting birds than observed effects of the Nuclear Generating Station operation so far.

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APPENDIX A. Additions to Checklist of Birds of the Fort St. Vrain Nuclear Generating Site (Ryder 1976).

Species	Status
Common Loon (*Gavia immer*)	M, r
Horned Grebe (*Podiceps auritus*)	M, u
Double-crested Cormorant (*Phalacrocorax auritus*)	R, c
Green Heron (*Butorides striatus*)	M, r
Snowy Egret (*Egretta thula*)	M, u
Common Goldeneye (*Bucephala clangula*)	M, u
Hooded Merganser (*Lophodytes cucullatus*)	M, r
Sandhill Crane (*Grus canadensis*)	M, r
Semipalmated Plover (*Charadrius semipalmatus*)	M, r
Black-bellied Plover (*Pluvialis squatarola*)	M, r
Willet (*Catoptrophorus semipalmatus*)	M, u
Pectoral Sandpiper (*Calidris melanotos*)	M, u
Baird's Sandpiper (*Calidris bairdii*)	M, u
Common Tern (*Sterna hirundo*)	M, r
Black Tern (*Chlidonias niger*)	M, u
Burrowing Owl (*Athene cunicularia*)	S, u
Poor-will (*Phalaenoptilus nuttallii*)	S, r
Tree Swallow (*Iridoprocne bicolor*)	M, u
Long-billed Marsh Wren (*Cistothorus p[illegible]ensis*)	S, u
Bewick's Wren (*Thryomanes bewickii*)	M, r
Veery (*Catharus fuscescens*)	M, r
Townsend's Solitaire (*Myadestes townsendi*)	W, u
Blue-gray Gnatcatcher (*Polioptila caerulea*)	M, r
Golden-crowned Kinglet (*Regulus satrapa*)	W, r

APPENDIX A, continued.

Species	Status
Philadelphia Vireo (*Vireo philadelphicus*)	M, r
Warbling Vireo (*Vireo gilvus*)	S, u
Tennessee Warbler (*Vermivora peregrina*)	M, r
Blackpoll Warbler (*Dendroica striata*)	M, u
Yellow-breasted Chat (*Icteria virens*)	S, c
American Redstart (*Setophaga ruticilla*)	M, u
Orchard Oriole (*Icterus spurius*)	M, r
House Finch (*Carpodacus mexicanus*)	R, u
Lesser Goldfinch (*Carduelis psaltria*)	S, r
White-throated Sparrow (*Zonotrichia albicollis*)	W, u

* R - Resident	a - abundant
M - Migrant	c - common
W - Winter Resident	u - uncommon
S - Summer Resident	r - rare

TERRESTRIAL SECTION

VEGETATION MONITORING

by

Charles D. Bonham

and

Deborah Grace Steward

INTRODUCTION

The vegetation adjacent to the St. Vrain Nuclear Power Generating Station was investigated from 1972-1979. The purpose of these investigations was to inventory and classify the vegetation, and to test for directional change in the vegetation as a result of changing environmental parameters, especially those caused by the Generating Station.

Early efforts focused on vegetation inventory and classification; from this work seven general categories of vegetation were recognized:

1.) Cottonwood
2.) Willow carr
3.) Cattail-sedge
4.) Abandoned cropland
5.) Native pasture
6.) Irrigated and seeded pasture
7.) Roadsides and fencelines

Specific information on these types can be found in the 1972 and 1973 reports as well as the Biological Survey report of 1976.

If the vegetation samples taken during the inventory period are grouped according to dominant and sub-dominant species the following classification emerges:

I. Undisturbed Lands (or, more specifically, less disturbed)
    A. Short-grass prairie with shrubs
    B. Mid-grass prairie
    C. Saltgrass communities
    D. Moist to wet communities
II. Disturbed Lands
    A. Extremely disturbed weedy communities
    B. Pastures and fields
    C. Modified short-grass prairie
    D. Modified mid-grass prairie

These groupings are very general and have a high degree of intergradation.

Western wheatgrass (Agropyron smithii) was the species with greatest mean ground cover at the time the initial inventory was made in 1972. It was followed in importance by saltgrass (Distichlis stricta), and, at a considerably lesser cover value, cheatgrass (Bromus tectorum). The relative importance of cheatgrass is a strong indication of a disturbed environment. The ten most abundant species of the St. Vrain Nuclear Power Generating Station area at the time of the 1972 inventory are given in Table 1.

The vegetation of the St. Vrain area is fairly typical of that for the region; human land use practices such as farming, livestock grazing, and irrigation have had a marked impact on the structure and composition of the vegetation. In order to separate possible effects that the St. Vrain Station might have on the vegetation from other effects of human and animal disturbance, exclosures were placed in the primary vegetation types found around the plant. These exclosures were used to measure vegetation cover, which is defined as the area of land surface upon which the shoot biomass is projected, and production (oven dry grams/M^2) of aboveground plant material. These quantities from inside the exclosures were compared with values of the same variables taken from outside, and adjacent to, the exclosures. The location and names of the exclosures are shown in Figure 1.

Ten exclosures were placed at the beginning of the research period; two were temporary and used only in the early phase of the investigation to measure the characteristics of the cattial-sedge and willow carr communities. These results have been discussed in earlier reports. Of the remaining eight exclosures, one was destroyed during the course of investigation. One study area, the St. Vrain River Loop, was not

TABLE 1.

Mean cover, standard error, and range for the ten most important herbaceous species encountered in the inventory sample.

Species	Mean	S.E.	Range
Agropyron smithii	5.1	7.1	31.0
Distichlis stricta	4.1	9.4	30.0
Bromus tectorum	2.6	6.5	40.0
Poa pratensis	2.5	5.7	29.0
Equisetum kansanum	1.6	10.2	70.0
Kochia scoparia	1.6	4.8	26.0
Sporobolus cryptandrus	1.3	2.0	10.0
Andropogon gerardi	1.0	5.4	36.0
Taraxacum officinale	1.0	1.9	8.0
Bromus inermis	0.9	4.0	26.0

KEY TO SYMBOLS:

X_1 = Confluence Exclosure
X_2 = Irrigated Pasture Exclosure
X_3 = Goosequill Exclosure
X_4 = St. Vrain River Loop
X_5 = Cooling Towers Exclosure
X_6 = Ben Houston Exclosure
X_7 = South Platte River Exclosure

▣$_1$ = Willow Carr Exclosure (temporary)
▣$_2$ = Cattail-Sedge Exclosure (temporary)
▣$_3$ = Defunct permanent exclosure site

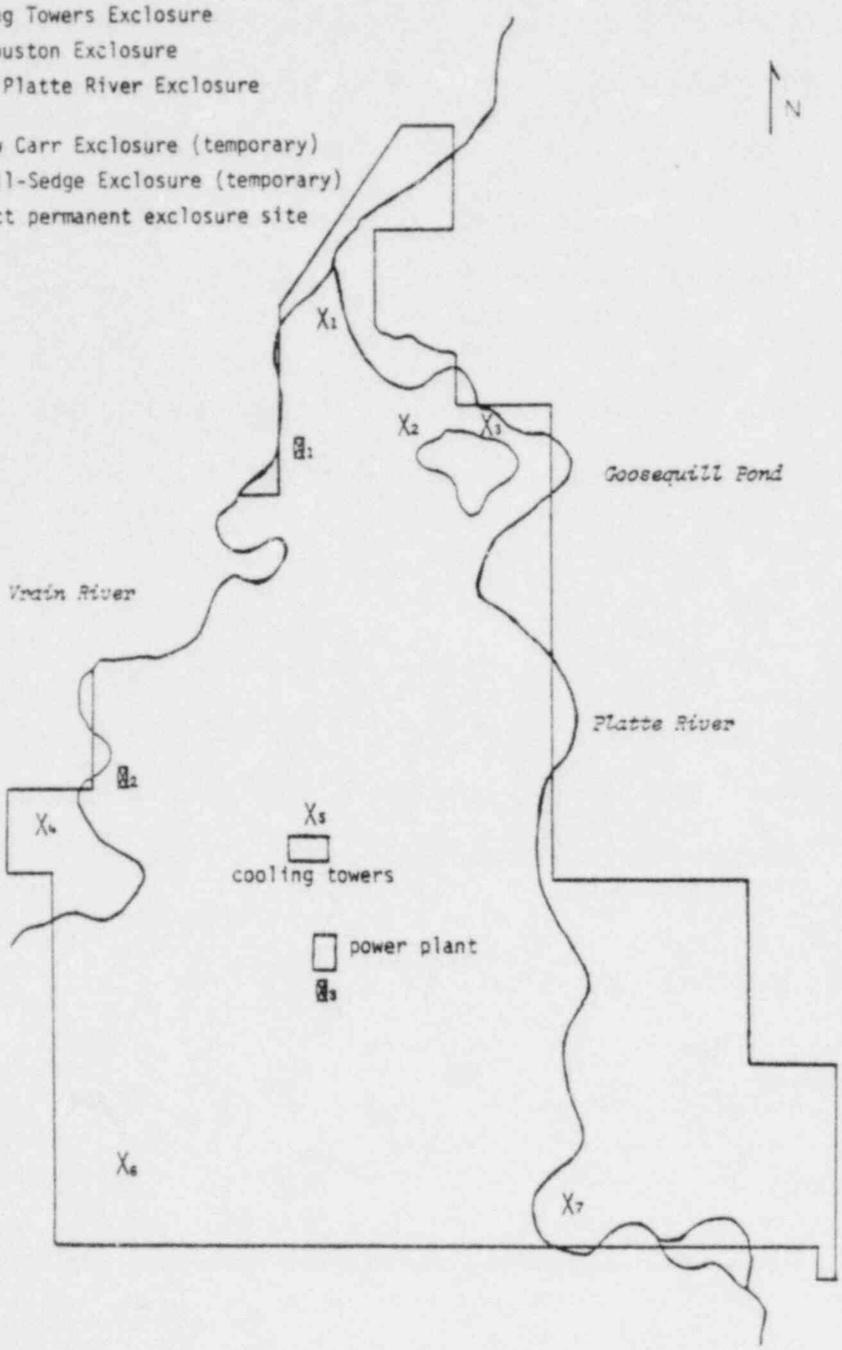


Figure 1. Line drawing of the Fort St. Vrain Nuclear Generating Station study area.

really an exclosure, but was an area naturally isolated by the St. Vrain River on one side and property boundaries on the other. This area was treated as an exclosure because of its separation from the rest of the communities and the human and livestock impact on them.

The six remaining exclosures were periodically subjected to stress during the course of investigation. All exclosures except the Cooling Tower and Irrigated Pasture were flooded in May and June of 1973. Livestock broke into some of the exclosures early in the course of the investigations as well. Because of such problems, all exclosures were re-fenced and re-established during late 1973 and early 1974. Results given in this report are based on information collected since spring of 1974.

METHODS

Fifteen plots 20 x 50 cm in size (0.1 M^2) were systematically placed on a 3 x 5 grid within each exclosure to sample herbaceous production. Fifteen 0.1 M^2 samples were also taken outside of and adjacent to the exclosure. Each of the plots were clipped in August of each monitoring year to estimate standing crop. This estimate was made by species or by growth-form. Clippings were all converted to an oven-dried basis. Results are presented as total production by g/M^2. Data from 1977-1979 were analyzed using discriminant function analysis to test for significant differences between inside and outside the exclosures.

Vegetation cover was measured by twenty-five 20 x 50 cm (0.1 M^2) plots placed on a 5 x 5 grid within the exclosures. Vegetation cover outside the exclosure was measured using the same number of plots systematically placed at 2 M apart at a 10 M distance from the exclosure. Cover was estimated using cover classes:

1 = 0-5%	4 = 51-75%
2 = 6-25%	5 = 76-95%
3 = 26-50%	6 = 96-100%

and results were tabulated using the mean value of the class (i.e. 2.5% for cover class 1) as the numerical value reported for cover. Cover sampling was conducted in June and August of each year. Results were reported by summing mean species response into the following categories:

Perennial Native Graminoids	Perennial Introduced Grasses (including those used for seeding)
Perennial Native Forbs	Perennial Introduced Forbs
Annual Native Grasses	Annual Introduced Grasses
Annual Native Forbs	Annual Introduced Forbs
Shrubs	Total

This grouping was done in order to facilitate recognition of change in community structure as a function of plant growth-form. A difference value was calculated by subtracting the sum for each category for each year outside the exclosure from the sum for each category for each year inside the exclosure. This difference value is presented in bar graphs.

RESULTS AND DISCUSSION

A number of factors influenced the vegetation results reported here. One problem with any long-term study is the turnover of field and laboratory personnel. Another confounding factor is environmental variability, which can easily mask, over short periods of time (up to fifty years), any significant changes that the vegetation might be undergoing. Environmental oscillations are reflected in the production and cover values, as well as the relative importance, of vegetation species and growth-forms. The influence of these factors cannot be easily identified, but must be considered to have an effect on the variability and error levels of the data.

The use of exclosures presents problems of another nature. Often, especially on the plains where wind is an important environmental factor, the fences themselves act as catchments for many weedy species as they are dispersed across the landscape. This, in conjunction with the moisture that may possibly be present as a result of a "snow-fence" effect, can bias the apparent response of the vegetation to release from grazing pressure. In addition, when cover classes are used to estimate vegetation cover (a technique that is used to minimize differential estimator abilities), it is necessary for a species or growth-form to show at least a 12.5% change in cover before any effects become apparent. Results presented in this section were interpreted with these factors in mind.

Production

Table 2 gives total production values during the monitor years of 1977-1979 for all exclosure sites and the St. Vrain River Loop. The most productive exclosure was the irrigated pasture; this is not surprising in light of the supplemental watering it received. Ben Houston Exclosure, located in a seeded pasture, also showed greater productivity than most sites. The remaining exclosures, and the St. Vrain Loop, showed similar production values.

Table 3 shows the result of discriminant analysis on production data for 1977-1979. The variables used to make the discriminations are given in column 2 of that table. Once, again, the Irrigated

TABLE 2.

Total production values for exclosures in grams/meter^2 for the three monitor years.

Exclosure	1977 in	1977 out	1978 in	1978 out	1979 in	1979 out
Confluence	67.5	36.3	84.1	80.0	172.8	169.6
Irrigated Pasture	525.7	209.7	277.8	165.3	312.3	285.1
Goosequill	62.5	51.1	62.2	68.4	108.7	160.1
Cooling Tower	147.3	103.5	72.4	92.6	82.0	56.4
Ben Houston	462.3	270.2	511.2	48.9	336.6	161.0
South Platte	292.9	59.5	152.1	104.4	162.6	180.4
St. Vrain Loop	333.4	*	183.0	*	72.7	*

* value not taken

Table 3.

Discriminant Analysis using two variables to show differences between inside and outside the exclosures.

Exclosure	Variables Used	Year	Significance
Confluence	*Bromus tectorum/ B. japonicus*	1977	-
	Symphoricarpos occidentalis	1978	-
		1979	-
Irrigated Pasture	*Bromus inermis*	1977	.01
	Polygonum coccineum	1978	.01
		1979	.01
Goosequill	*Bromus tectorum/ B. japonicus*	1977	.05
	Sporobolus cryptandrus	1978	-
		1979	.05
Cooling Tower	*Ambrosia coronopifolia*	1977	-
	Sporobolus cryptandrus	1978	.01
		1979	-
South Platte	*Rhus radicans*	1977	.01
	Symphoricarpos occidentalis	1978	-
		1979	-
Ben Houston	*Agropyron elongatum*	1977	.01
	Distichlis stricta	1978	.01
		1979	.01

Pasture and Ben Houston exclosures were prominent; in this case because of consistently significant differences between inside and out. These differences may confidently be ascribed to grazing practices. The South Platte River exclosure shows significant difference in 1977 based on shrub production. The Goosequill exclosure shows significant differences in 1977 and 1979 based primarily on differences in annual grass production.

Cover

St. Vrain Loop. Although not an exclosure, this area is of interest because it was not much influenced by humans or livestock. It is, however, subject to periodic flooding, which has a disturbing effect on the vegetation. Recovery from flooding is somewhat evident in the increasing total cover values (most evident in the graph of June cover values) from 1974 to 1979 (Figure 2). Native perennial grasses and introduced perennial forbs dominated this location, with a seasonal peak of annual grass cover in June.

Confluence Exclosure. The shrub category best illustrates the trend effected by release of ng pressure on the vegetation of this exclosure. With the excep of 1978, there is a general upward climb of shrub cover within the exclosure compared to cover values outside the exclosure. This is reflected by the positive difference values shown for shrubs in Figure 3. Weedy perennial forbs clearly seemed to do better inside the exclosure than outside it. A slight trend toward an increase of perennial native grasses and graminoids within the exclosure could be shown in the August graph; this should certainly not be taken as strong evidence for directional change.

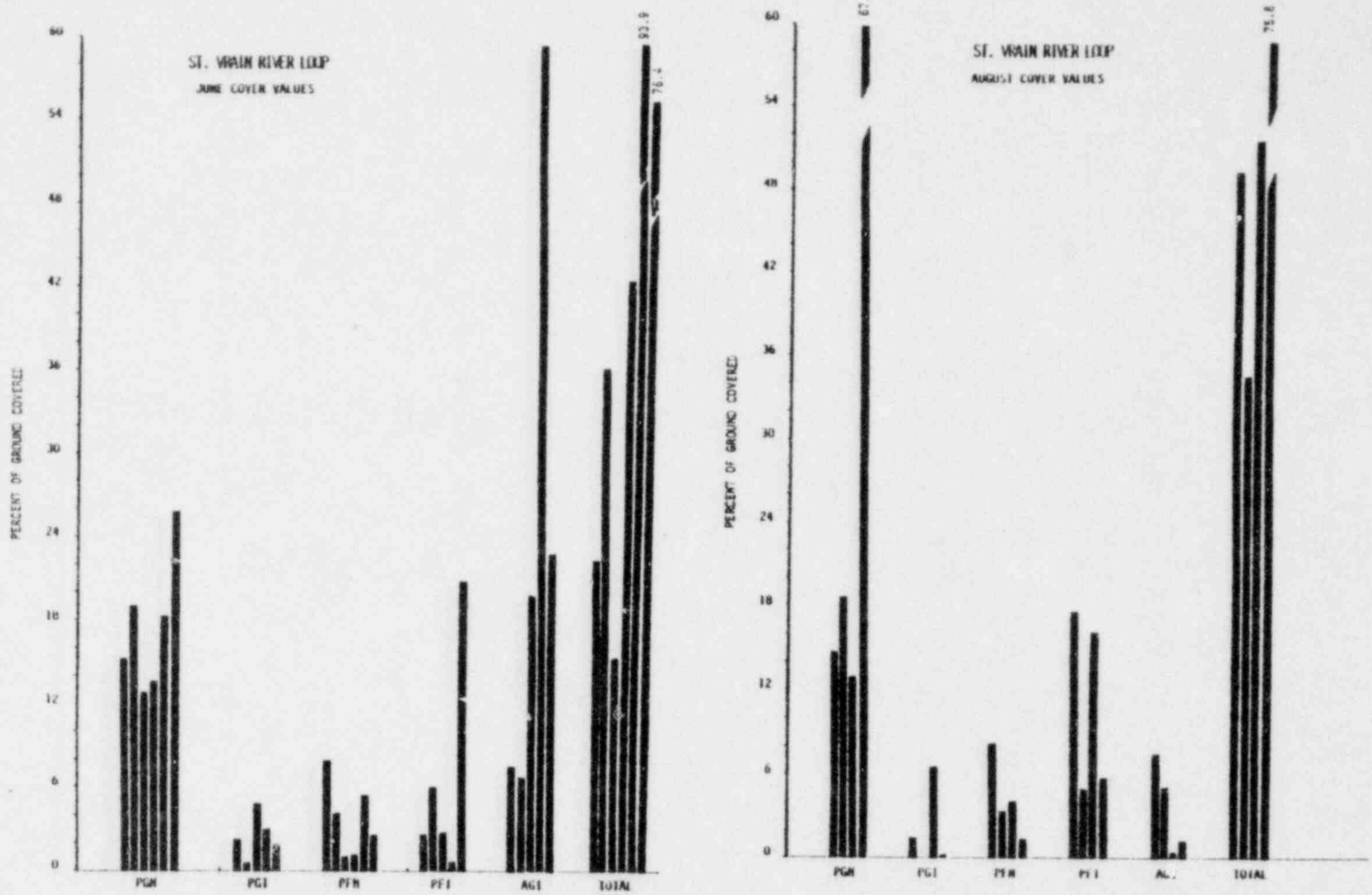
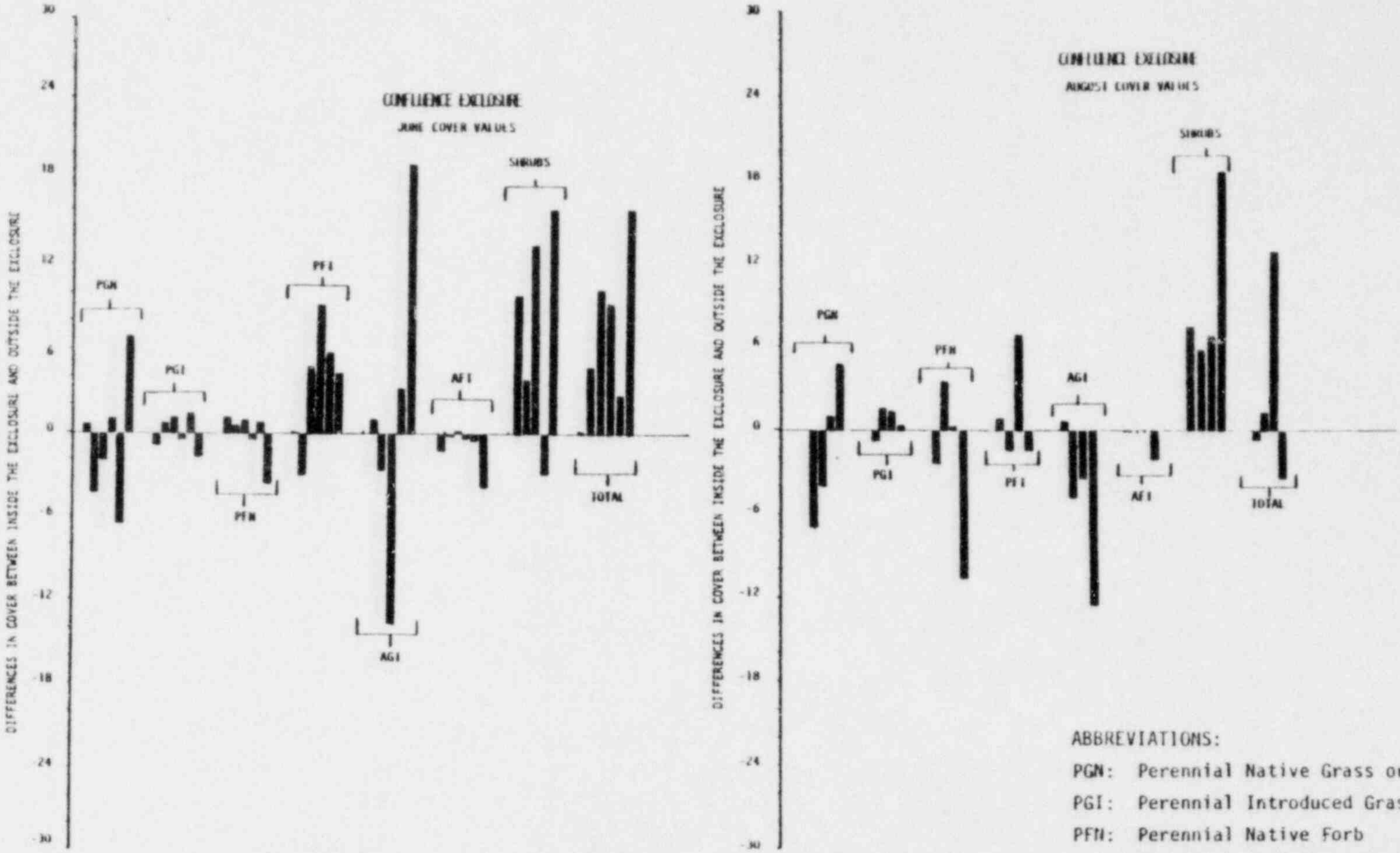


Figure 2. Percent of ground covered for St. Vrain River Loop sample. Each bar within each group represents a year in the following way:

JUNE: 1974 - 1975 - 1976 - 1977 - 1978 - 1979
AUGUST: 1975 - 1976 - 1977 - 1979

ABBREVIATIONS:

PGN: Perennial Native Grass or Graminoid
PGI: Perennial Introduced Grass
PFN: Perennial Native Forb
PFI: Perennial Introduced Forb
ABI: Annual Introduced Grass



ABBREVIATIONS:

PGN: Perennial Native Grass or Graminoid
PGI: Perennial Introduced Grass
PFN: Perennial Native Forb
PFI: Perennial Introduced Forb
AGI: Annual Introduced Grass
AFI: Annual Introduced Forb

Figure 3. Difference values for Confluence Exclosure. Each bar within each group represents a year in the following way:

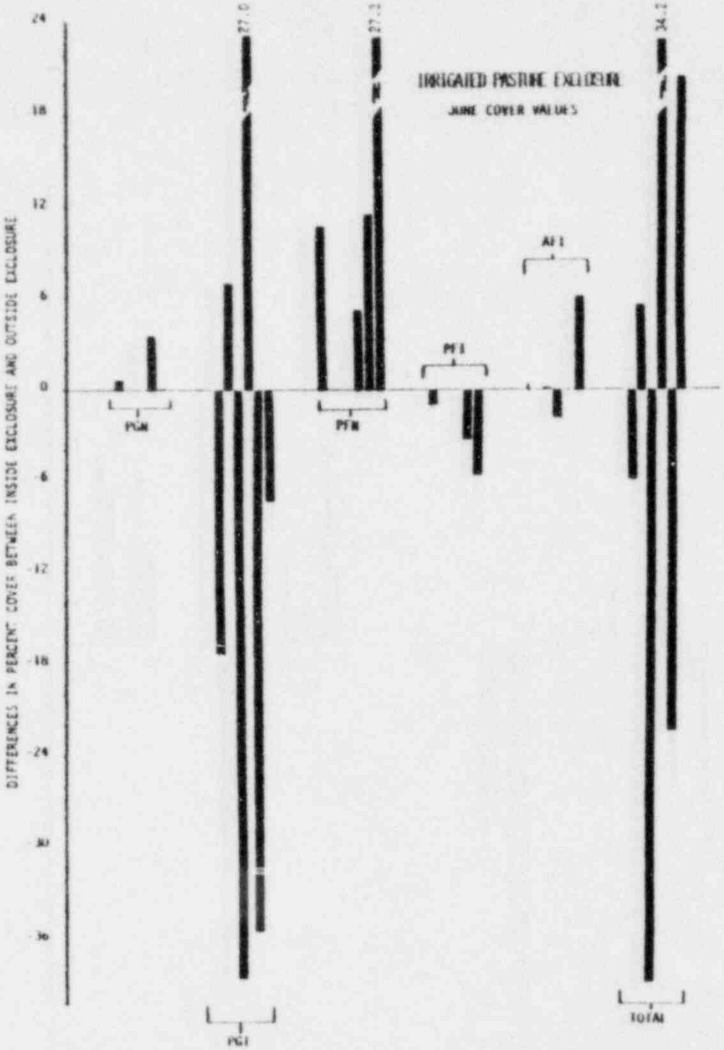
JUNE: 1974 - 1975 - 1976 - 1977 - 1978 - 1979
AUGUST: 1975 - 1976 - 1977 - 1979

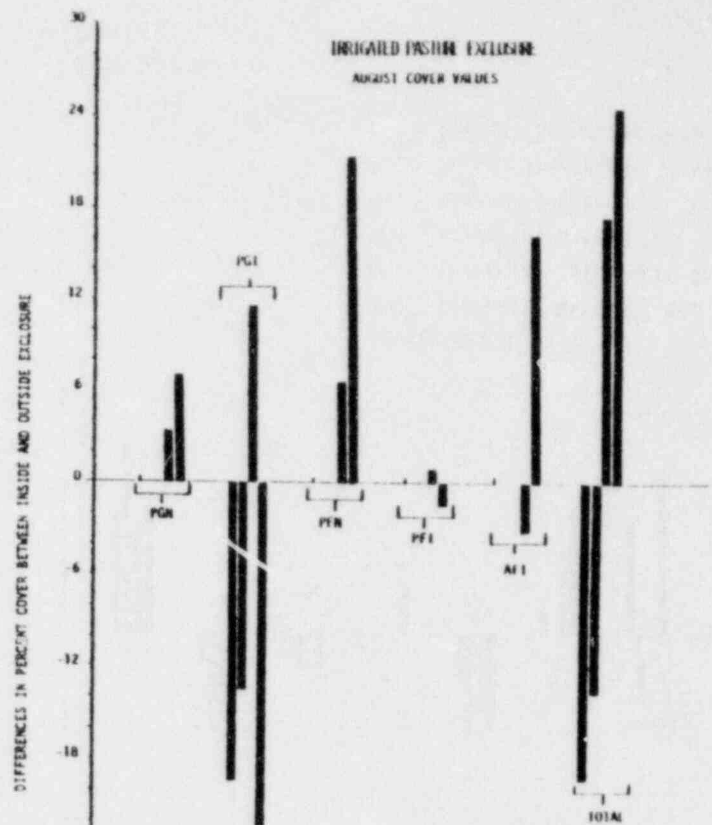
Irrigated Pasture Exclosure. It is very clear from looking at the negative difference values that the vegetation outside this exclosure is dominated by introduced perennial grasses (Figure 4), especially meadow fescue (Festuca elatior). Diversity appears to be higher inside the exclosure, as shown by the greater number of positive difference values for categories other than perennial native grasses. Perennial native forbs were uniformly more abundant inside the exclosure. A trend toward increasing cover within the exclosure can be seen by looking at total difference values in August when the early flush of perennial introduced grasses due to irrigation has been moderated.

Goosequill Exclosure. No easily interpretable information can be drawn from this exclosure. Differences in cover between inside and out are more marked in June than August; perennial introduced grasses and annual introduced grasses seem to dominate the exclosure (Figure 5). This could be attributed to the effects of the exclosure itself, as mentioned earlier.

Cooling Tower Exclosure. The data from this exclosure are inconclusive. The ambiguity of the results are perhaps due to the proximity of this exclosure to construction activity and heavy grazing. The June and August results seem contradictory (Figure 6).

Ben Houston Exclosure. The high negative difference value (Figure 7) for perennial native grasses may be due to western wheatgrass, which is being called a native grass, in a pasture seed mix. Another possibility is that saltgrass, an unpalatable range grass, had a high cover outside the exclosure because of reduced competitive pressure from other, more heavily grazed, species. Competition within the exclosure would keep the cover of this species and consequently the perennial native grass growth-form low. In general, no conclusions about the effect of the exclosure can confidently be made.





ABBREVIATIONS:

PGN: Perennial Native Grass
PGI: Perennial Introduced Grass
PFN: Perennial Native Forb
PFI: Perennial Introduced Forb
AFI: Annual Introduced Forb

Figure 4. Difference values for Irrigated Pasture Exclosure. Each bar within each group represents a year in the following way:
JUNE: 1974 - 1975 - 1976 - 1977 - 1978 - 1979
AUGUST: 1975 - 1976 - 1977 - 1979

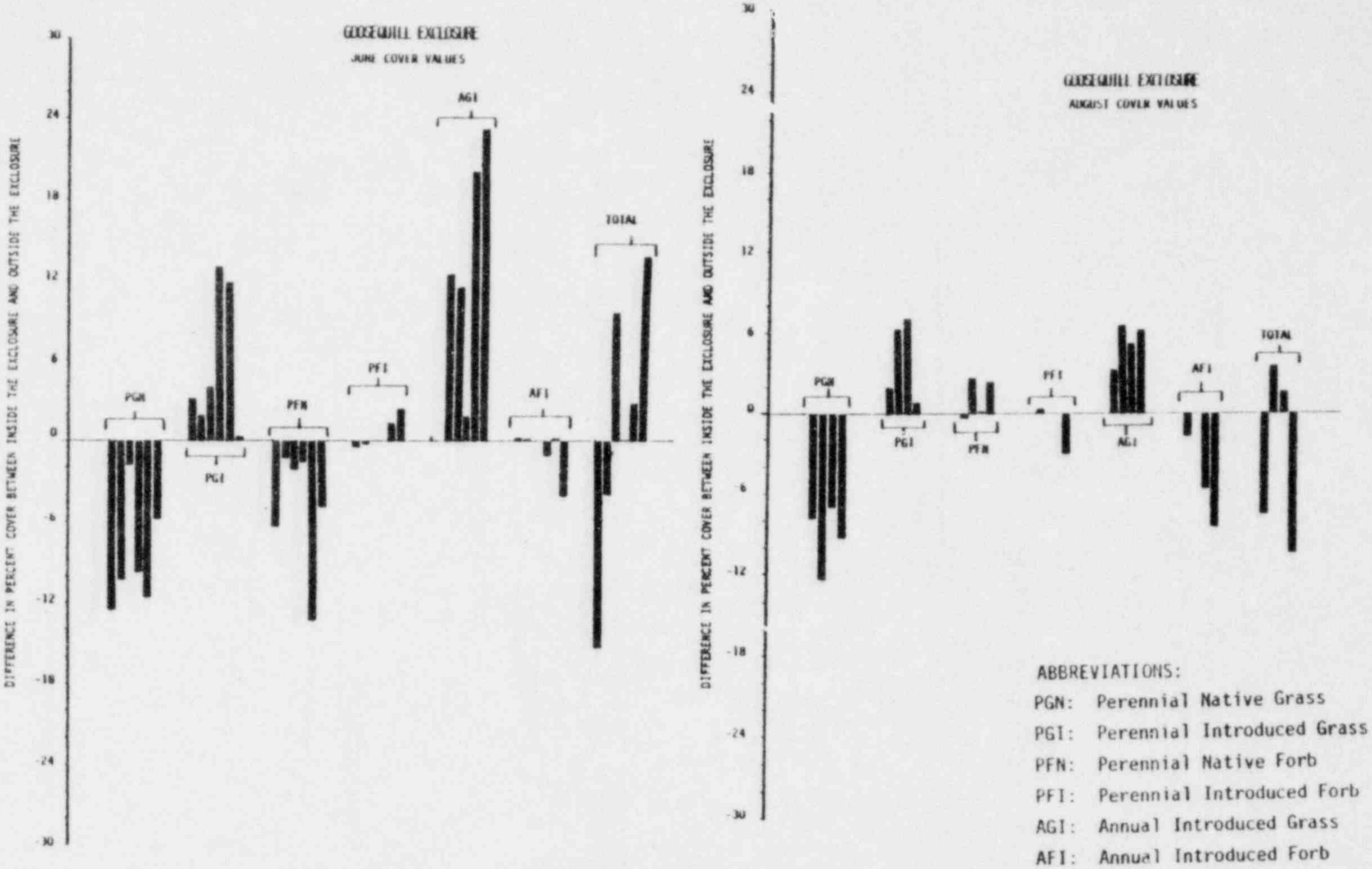


Figure 5. Difference values for Goosequill Exclosure. Each bar within each group represents a year in the following way:

JUNE: 1974 - 1975 - 1976 - 1977 - 1978 - 1979
AUGUST: 1975 - 1976 - 1977 - 1979

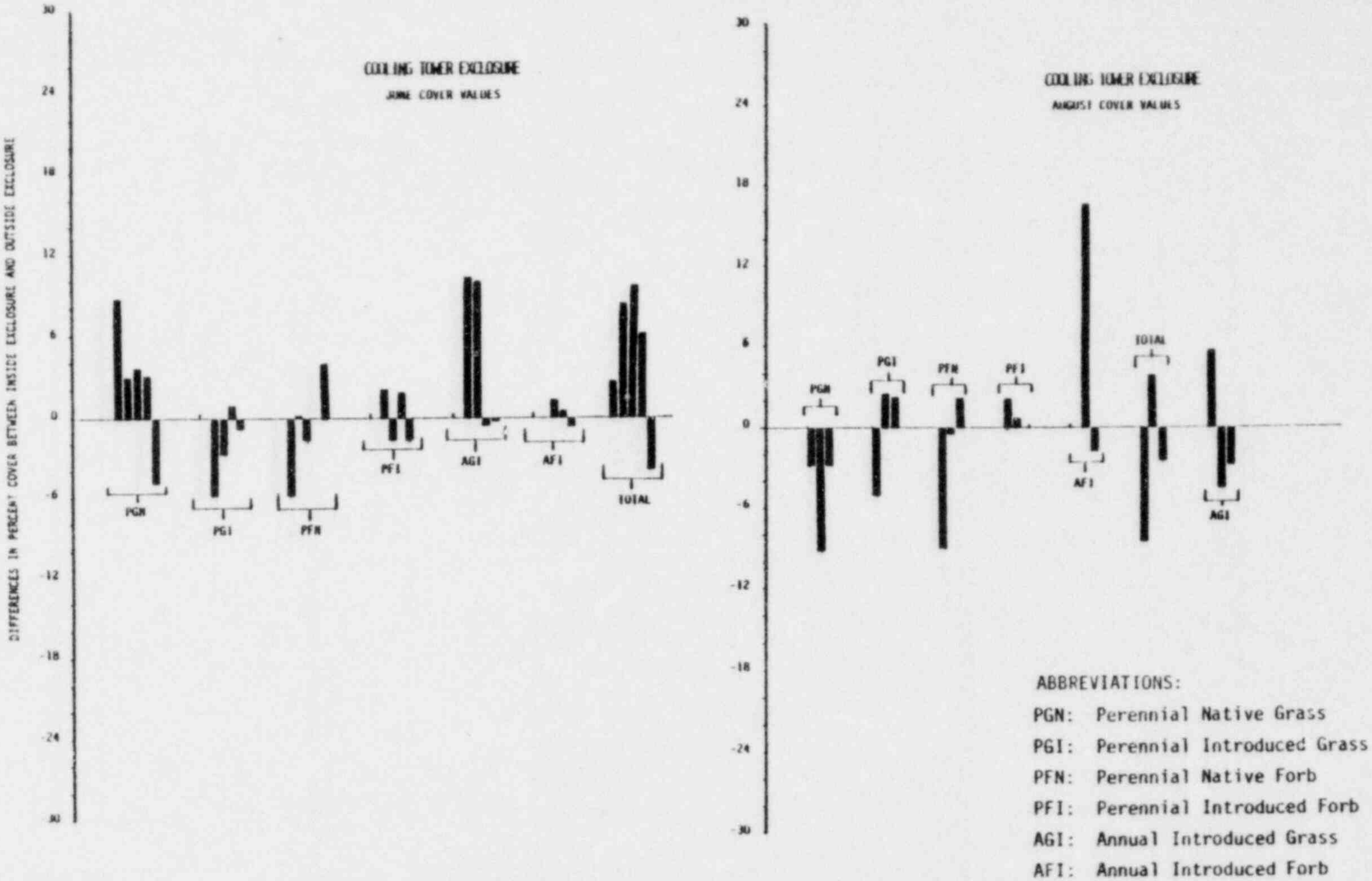
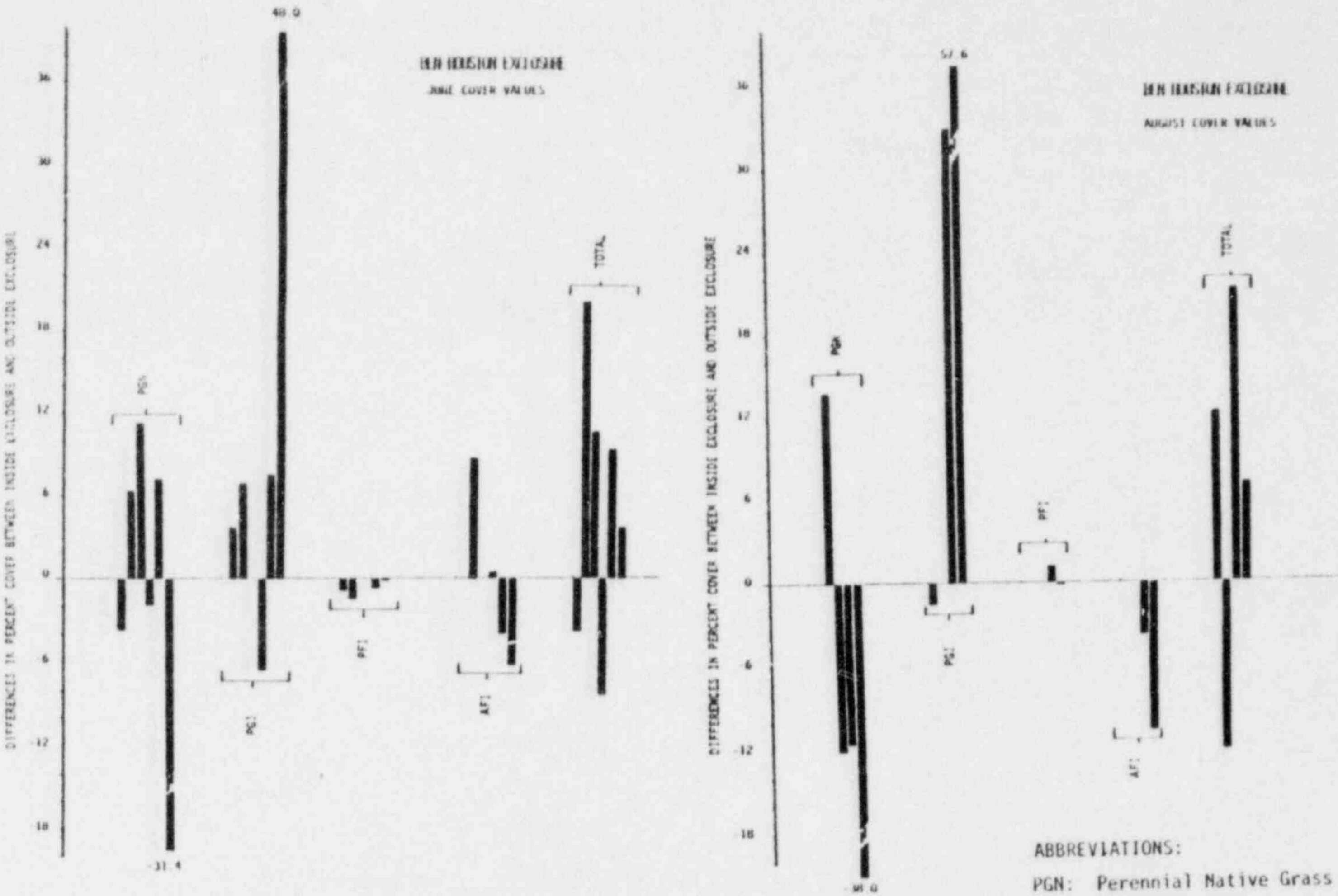


Figure 6. Difference values for Cooling Tower Exclosure. Each bar within each group represents a year in the following way:

JUNE: 1974 - 1975 - 1976 - 1977 - 1978 - 1979
AUGUST: 1975 - 1976 - 1977 - 1979



ABBREVIATIONS:

PGN: Perennial Native Grass

PGI: Perennial Introduced Grass

PFI: Perennial Introduced Forb

AFI: Annual Introduced Forb

Figure 7. Difference values for Ben Houston Exclosure. Each bar within each group represents a year in the following way:

JUNE: 1974 - 1975 - 1976 - 1977 - 1978 - 1979
AUGUST: 1975 - 1976 - 1977 - 1979

<u>South Platte River Exclosure</u>. This exclosure is similar to the Confluence exclosure in that directional change in vegetation as a response to reduced grazing pressure is evident in the positive difference values for shrubs (Figure 8). For some reason, the cover inside the exclosure in August was uniformly lower than that outside the exclosure. It may be that increased cover of shrubs leads to a more severe competitive situation for the grasses and forbs, a situation that would be more evident at the end of the growing season (August) than at the beginning (June) when resources such as water would not be so limiting.

CONCLUSIONS AND INTERPRETATION

From the information generated, it can be concluded that, to date, the St. Vrain Nuclear Power Generating Station has had little, if any, influence on the vegetation communities adjacent to it. This is excepting, of course, direct disturbance that is a function of construction activity.

Some indication of a trend toward increasing cover as a result of release from livestock grazing pressure is evidenced by the increase in production values for some of the exclosures over their adjacent outside areas. This is somewhat corroborated by the increase of shrub cover within the Confluence and South Platter River exclosures. However, long-term changes, such as an increase in importance of perennial native grasses within the exclosure, are not yet evident.

As mentioned earlier, the exclosure itself may play such a role in modifying the environment that response to reduced grazing pressure may be confounded. The only solutions to this problem would be to

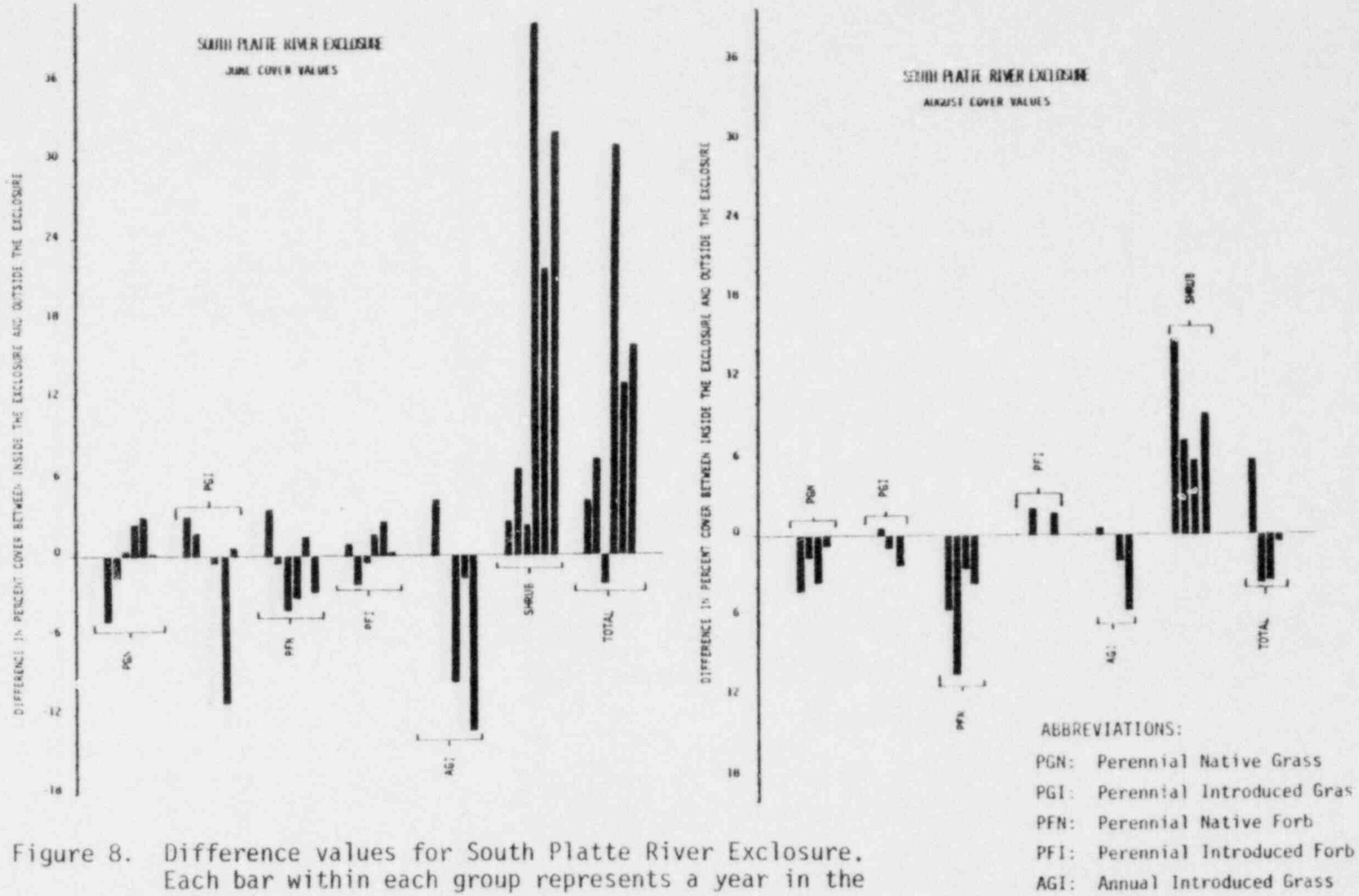


Figure 8. Difference values for South Platte River Exclosure. Each bar within each group represents a year in the following way:

JUNE: 1974 - 1975 - 1976 - 1977 - 1978 - 1979
AUGUST: 1975 - 1976 - 1977 - 1979

increase the size of the exclosures or prohibit grazing over a large portion of the study area. Even so, significant changes might not become evident for many years.

ECOPHYSIOLOGICAL CHARACTERISTICS

by

M. J. Trlica

INTRODUCTION

Terrestrial vegetation surrounding the St. Vrain Nuclear Generating Station may be directly or indirectly affected by the plant's operation. Operation of the Generating Station will probably result in releases of small amounts of radionuclides. Heat, water vapor, and salts will also be lost to the atmosphere as a result of cooling tower operation. In addition, water effluents will be released from the station which could affect vegetation along the water courses, or this water might be used for irrigation.

The environmental impact statement relating to the operation of the St. Vrain Nuclear Generating Station indicated that approximately 2300 gpm of water would be lost from the cooling towers as a result of evaporation and drift. Of course, the actual amount of evaporation and drift would be dependent upon atmospheric conditions including wind speed and direction, atmospheric stability, air and water temperatures, ambient humidity, and Station power level. Since make-up water for these towers comes primarily from the polluted South Platte and St. Vrain Rivers, concentrations of salts and other toxic chemicals could be expected to be high. These chemicals enter the rivers as a result of geological processes and because of industrial and farming activities upstream from the Generating Station. Biocides will also be injected into cooling tower water to control algae growth. These chemicals also will be a constituent of the drift and will be deposited in an area around the towers.

Drift depositions from these towers may result in changes of chemical constituents within the vegetation. For example, deposition of some salts on vegetation may result in their absorption and a reduction of root absorption of other essential nutrients. This could result in less vigorous plants. Heavy metals may also increase in vegetation as a result of drift deposition. These heavy metals may then be passed on to consumer animals in the area.

Little research work has been conducted to evaluate cooling tower drift effects on vegetation. It was, therefore, considered desirable to have an inventory of the ecophysiology of the vegetation which might be affected by water vapor and salt deposition as a result of cooling tower operations. Since all animal life is dependent either directly or indirectly upon vegetation as a source of food, decreased productivity or palatability of vegetation may be detrimental to animal populations. In addition, operation of the cooling towers may result in increased humidities and temperature changes in the immediate surrounding environment. Since the St. Vrain Nuclear Generating Station is in the Denver Air Pollution Corridor, increased humidity could interact with vegetation, resulting in increased leaf injury caused by the air pollutants. Numerous studies have indicated that a significantly-detrimental interaction exists between air pollutants and humidity which can cause severe damage to photosynthetically-active tissues.

OBJECTIVES

The objectives of this study were:

1. To determine leaf injury by pollutants, disease, and insects for certain species surrounding the Generating Station.
2. To determine concentrations of important elements in foliage of several species as related to distance and direction from the Generating Station.

LEAF INJURY

Leaves of cheatgrass (Bromus tectorum), kochia (Kochia scoparia), and cottonwood (Populus sargentii) were collected from a maximum of 32 locations on four radii at distances of 1/8, 1/4, 1/2 and 1 mile from the Generating Station during rapid spring growth from 1972 through 1979 (Figure 1). Sampling of kochia and cottonwood at these same locations was again repeated when vegetation was mature in August. Fifty leaves were taken from each location at each sampling period. Estimates were made of each leaf sampled for total leaf area, leaf area injured by chewing insects, and leaf area spotted caused by air pollutants, disease, nutrition, and sucking insects.

A literature search indicated that pinto bean plants were sensitive to air pollutants. As pinto beans are an important crop produced in the area around the St. Vrain Nuclear Generating Station, they were utilized during 1973, 1974, 1976, 1977, 1978 and 1979 in a controlled experiment to determine effects of air pollution and drift at varying distances and directions from the cooling towers.

Pinto beans were planted in polyethylene-lined #10 cans in the greenhouse. All plants received similar treatment in the greenhouse until mid July, when plants and containers were transported to the St. Vrain study site. Sixty-four containers with bean plants (four containers/location) were placed at two distances and eight directions from the cooling towers. Distances from the towers were 50 feet and 1/4 mile. The bean plants all received similar amounts of supplemental fertilizer, insecticide, and water. They were allowed to grow for approximately six weeks during each year at the study area. At that time, leaves from each plant in each container were sampled to determine

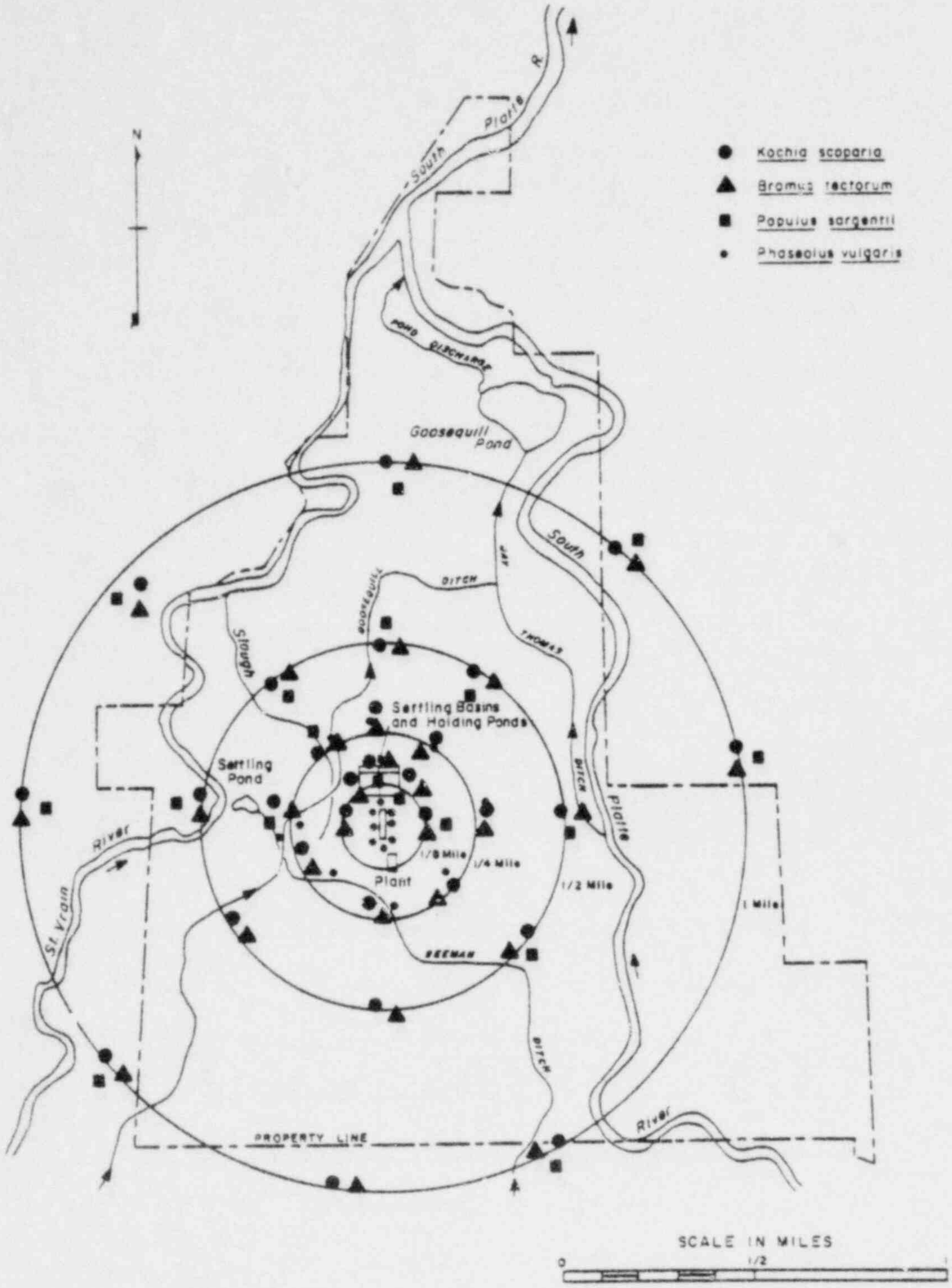


Figure 1. St. Vrain study area showing locations of collection sites.

leaf injury. Ten to 20 leaves from each location were collected each year. However, because of large numbers of grasshoppers feeding on the plants in 1979, only enough samples remained for chemical analyses.

Wet bulb and dry bulb temperatures at each location for pinto beans were measured in 1976, 1977, 1978, and 1979, each time bean plants were watered. Data were collected using a portable psychrometer. Utilizing these data, relative humidity and dew point temperature were calculated to aid in determining the sphere of influence around the cooling towers.

Cultural practices such as crop rotation, fertilization, irrigation, and use of insecticides that could influence leaf injury and chemical constituents of vegetation were beyond the control of the investigator. Therefore, quantitative data for agronomic species grown in the study area were not taken. The three naturally-occurring species utilized in this study were selected because of their wide distribution and abundance on the site. In addition, other studies have indicated that Bromus tectorum and Phaseolus vulgaris are sensitive to air pollutants.

ELEMENTAL CONCENTRATIONS IN FOLIAGE

Chemical analyses were conducted on foliage samples of kochia and cottonwood collected at maturity from each of the permanent sampling locations shown in Figure 1. Aboveground biomass samples of pinto bean plants in the controlled experiment were collected after six weeks of growth. All samples were dried at 60°C, ground to pass through a 40-mesh screen, and stored in glass jars. Chemical analyses indicated concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), iron (Fe), manganese (Mn), copper (Cu), sulfate (SO_4-S), mercury (Hg), lead (Pb), cadmium (Cd) and boron (B) in plant tissue. These analyses indicated whether concentrations of various nutritive and toxic elements were influenced by either distance or direction from the Generating Station through the years of the study. However, not all chemical determinations were conducted for each species during each year. A brief description of the analytical techniques utilized by personnel of the Front Range Laboratory in Fort Collins, Colorado, in analyzing these samples is given in Table 1.

DATA ANALYSIS

Data on leaf injury and chemical constituents of vegetation prior to electric power generation (1972-1976) were compared with data collected during the station start-up phase (1977-1979). Analysis of variance was utilized to determine if statistically significant differences for any chemical constituent of vegetation or leaf injury occurred as related to year, distance, or direction from the Station. When significant ($p < 0.05$) conservative F values were found, Tukey's test was utilized to separate significant ($p < 0.05$) mean differences.

RESULTS AND DISCUSSION

Blowers on the cooling towers were usually not in operation and water was only being circulated through the towers during 1973 through 1977. However, the blowers generally were in continuous operation in 1978 and 1979. Ambient environmental conditions (relative humidity and temperature) surrounding the cooling towers were found to not vary significantly (p 0.05) during the study in 1976 and 1977. In 1979, wet bulb and dry bulb temperature was found to increase significantly (p 0.05) with distance from the towers, whereas dew point temperature decreased

Table 1. Procedures and equipment utilized by the Front Range Lab, Inc. in analyzing plant samples.

Parameter	Procedure	Instrumentation	References
Calcium (Ca)	Nitric-Perchloric Acid Digestion, Atomic Absorption (A.A.) Quantification	Perkin-Elmer 5000 A.A. Spectrophotometer	Colorado State University Soil Testing Lab, Plant Analysis Procedure, August, 1971; Perkin-Elmer A.A. Methods Manual, 1979.
Magnesium (Mg)	Nitric-Perchloric Acid Digestion, Atomic Absorption (A.A.) Quantification	Perkin-Elmer 5000 A.A. Spectrophotometer	Colorado State University Soil Testing Lab, Plant Analysis Procedure, August, 1971; Perkin-Elmer A.A. Methods Manual, 1979.
Potassium (K)	Nitric-Perchloric Acid Digestion, Atomic Absorption (A.A.) Quantification	Perkin-Elmer 5000 A.A. Spectrophotometer	Colorado State University Soil Testing Lab, Plant Analysis Procedure, August, 1971; Perkin-Elmer A.A. Methods Manual, 1979.
Zinc (Zn)	Nitric-Perchloric Acid Digestion, Atomic Absorption (A.A.) Quantification	Perkin-Elmer 5000 A.A. Spectrophotometer	Colorado State University Soil Testing Lab, Plant Analysis Procedure, August, 1971; Perkin-Elmer A.A. Methods Manual, 1979.
Iron (Fe)	Nitric-Perchloric Acid Digestion, Atomic Absorption (A.A.) Quantification	Perkin-Elmer 5000 A.A. Spectrophotometer	Colorado State University Soil Testing Lab, Plant Analysis Procedure, August, 1971; Perkin-Elmer A.A. Methods Manual, 1979.
Copper (Cu)	Nitric-Perchloric Acid Digestion, Atomic Absorption (A.A.) Quantification	Perkin-Elmer 5000 A.A. Spectrophotometer	Colorado State University Soil Testing Lab, Plant Analysis Procedure, August, 1971; Perkin-Elmer A.A. Methods Manual, 1979.
Manganese (Mn)	Nitric-Perchloric Acid Digestion, Atomic Absorption (A.A.) Quantification	Perkin-Elmer 5000 A.A. Spectrophotometer	Colorado State University Soil Testing Lab, Plant Analysis Procedure, August, 1971; Perkin-Elmer A.A. Methods Manual, 1979.
Lead (Pb)	Nitric-Perchloric Acid Digestion, Atomic Absorption (A.A.) Quantification	Perkin-Elmer 5000 A.A. Spectrophotomet.	Colorado State University Soil Testing Lab, Plant Analysis Procedure, August, 1971; Perkin-Elmer A.A. Methods Manual, 1979.
Cadmium (Cd)	Nitric-Perchloric Acid Digestion, Atomic Absorption (A.A.) Quantification	Perkin-Elmer 5000 A.A. Spectrophotometer	Colorado State University Soil Testing Lab, Plant Analysis Procedure, August, 1971; Perkin-Elmer A.A. Methods Manual, 1979.
Mercury (Hg)	Aqua-Regia Digestion, Atomic Absorption (Cold Vapor Method)	Jarrell-Ash 810 A.A. Spectrophotometer	Colorado State University Soil Testing Lab, Plant Analysis Procedure, August, 1971; Jarrell Ash Methods Manual, 1971 (Fisher Scientific Co.)
Boron (B)	Dry Ashing, Curcumin Colorimetric Determination	Coleman Linear Spectrophotometer	Colorado State University Soil Testing Lab, Plant Analysis Procedure, August, 1971.
Sulfate (SO_4-S)	Dilute HCl Extraction, Turbidimetric Determination	Coleman Linear Spectrophotometer	Colorado State University Soil Testing Lab, Plant Analysis Procedure, August, 1971.

Table 1.--Continued

Parameter	Procedure	Instrumemtation	References
Phosphorus (P)	Vanadomolybdophosphoric Yellow HNO_3 Method	Coleman Linear Spectrophotometer	Colorado State University Soil Testing Lab, Plant Analysis Procedure, August, 1971.
Nitrogen (N)	Micro-Kjeidahl	Sargent-Welsh Recording Titrator	A.S.A., Monogr. No. 9. p. 1196, 1965.

significantly with distance (Table 2). Relative humidity was slightly greater and dew point temperatures were slightly lower near the towers as compared with data collected at 1/4-mile distance in 1976, 1978, and 1979, whereas the reverse was true in 1977. It therefore appears that the major sphere of influence around the cooling towers is within 1/4-mile distance of the towers.

Water samples were taken in 1979 from the cooling towers to compare with makeup water from the St. Vrain and South Platte Rivers, and irrigation water in Goosequill Ditch where blowdown water is received. The four locations were sampled once in both July and August. These samples were analyzed for total phosphorus (P), magnesium (Mg), sulfates (SO_4-S) and electrical conductivity (EC) by the Front Range Lab., Inc. Although sample size was small, these data indicated that total phosphorus, sulfate, and e[illegible] conductivity (i.e., salts) were at least twice as high in cooling tower water as in makeup water or diluted blowdown water (Table 3). We might therefore expect drift from the cooling towers to have a higher concentration in several elements and salts. This drift would be deposited on vegetation, other objects, and on soil in an area surrounding the towers. Drift at any one time would, however, be highly dependent upon prevailing weather at the time.

LEAF INJURY CAUSED BY POLLUTANTS, DISEASE AND INSECTS

Natural Vegetation

Statistical analyses of all leaf data for each year of the study have been completed. As expected, highly significant ($p<0.01$) differences existed for most leaf measurements among the eight years of data collection even when a conservative F-test was utilized. This indicates the

Table 2. Average environmental conditions during a six-week period in 1979 at varying distances and directions from the cooling towers of the Nuclear Generating Station.

Distance from Cooling Towers	Direction from Cooling Towers	Ambient Environment			
		Wet Bulb Temp (°F)	Dry Bulb Temp (°F)	Relative Humidity (%)	Dew Point Temp (°F)
50 feet		67b[1]	83b	47a	59b
1/4 mile		69a	87a	45a	61a
	N	67a[1]	85a	45a	60a
	NE	67a	84a	46a	59a
	E	68a	85a	46a	60a
	SE	68a	86a	45a	60a
	S	67a	86a	44a	59a
	SW	69a	85a	48a	61a
	W	68a	86a	46a	60a
	NW	68a	86a	45a	60a

[1]Numbers in a column followed by similar letters are not significantly different at the 0.05 level of probability.

Table 3. Chemical concentrations in water samples taken from four locations near the Nuclear Generating Station in July and August, 1979.

Location	Month	Total P (mg/l)	Mg (mg/l)	SO_4-S (mg/l)	EC (mmhos/cm)
St. Vrain River		1.2	68	513	1421
South Platte River		1.4	18	304	1137
Blowdown ditch		1.4	22	436	1452
Cooling towers[1]		2.8	52	1296	3789
	July	1.7	40	850	1950
	August	1.7	40	425	

[1]The Fort St. Vrain cooling towers are designed to operate so as to utilize water 3 to 5 times to conserve water. This will, therefore, concentrate chemicals within the cooling tower water.

high degree of yearly variation that influences leaf growth and injury. Distance and direction from the Generating Station were usually not significant ($p>0.05$) variables in affecting leaf injury, either before or after the Station began to generate electrical power in December 1976.

In general, leaf area of cottonwood increased from May or June through August. Kochia, however, had smaller leaf area per leaf in August than in May. No significant trend in leaf area per leaf for cheatgrass or cottonwood was found as related to distance from the station. In some years, leaves were larger near the Generating Station, whereas in other years they were larger at the 1/2- and 1-mile distance from the station. Leaves of kochia tended to be somewhat larger during the eight years of sampling at the 1/2- and 1-mile distance from the Generating Station.

Cheatgrass leaves were larger in a south through a northeasterly direction from the Generating Station. Leaves of both kochia and cottonwood were often larger in a southeasterly direction. This may be related to intensive farming and irrigation practices occurring southeast of the Generating Station during the years of the study.

The percentage of leaf area removed by chewing insects increased for both kochia and cottonwood between rapid growth and maturity during six of the eight years of study. This was very evident during 1979 when large populations of grasshoppers fed on kochia. Cheatgrass leaf area removed by insects was about the same near the Generating Station as at greater distances. In contrast, chewing insects usually removed more leaf area of kochia at the 1/8- to 1/2-mile distance from the Power Station. Leaf area missing for cottonwood as related to distance from the Generating Station showed no trend. Removal of cheatgrass leaf area by insects was greater in a south and southwesterly direction from the Generating Station in five of eight years of sampling. No consistent directional trend in leaf area removal among the years was found for kochia or cottonwood. Therefore, there was no consistent distance or directional influence from the Generating Station affecting insect leaf removal among the three species.

Brown tip leaf area and leaf spotting for kochia was greater by an order of magnitude in 1978 and 1979 than in previous years. This resulted primarily from storage problems in 1978 and insect feeding activity in 1979. Brown leaf tips of kochia were also often greater in a south through west direction. This same trend was also noted for cottonwood. This trend might be related to less intensive agricultural activity in a southwesterly direction from the station.

Leaf spotting may be the better indicator of leaf injury caused by pollutants or cooling tower drift. A significant ($p<0.05$) effect as related to distance from the Generating Station was detected for leaf spotting of cheatgrass and kochia. No significant differences for leaf spotting of cottonwood were found as related to distance from the station. Although there was a difference in leaf spotting of cheatgrass as related to distance, no consistent trend in the data were apparent. Leaf spotting was sometimes greatest at further distances from the station for the June collection of kochia, but spotting was greatest at 1/8 to 1/2 mile by the time of the August sampling period.

Leaf spotting of cheatgrass and kochia was not related to direction from the Generating Station. However, leaf spotting for cottonwood was related to direction from the station and was usually more pronounced in a north through east direction from the station. This would be downwind from the station as the prevailing wind during the growing season is from the southwest.

Data for various leaf characteristics were compared utilizing a conservative F-test for two time periods: before (1972-1976) the station generated electrical power and after (1977-1979) startup of limited power generation. Leaf area of cheatgrass was similar for the two time periods; whereas, leaf area of kochia declined and that of cottonwood increased significantly after the station began operation (Table 4). A greater percentage of leaf area was removed by insects using kochia after the station began operation, and the opposite trend was evident for cottonwood. Leaf spotting and brown tips were both greater for cottonwood before the station began power generation. However, percentage spotted leaf area for both cheatgrass and kochia were greatest after the station began operation (Table 4). These data clearly illustrate the varied species responses that were obtained in this study. No apparent trend was evident among species, and it appears that the differences resulted primarily from causes other than operation of the Nuclear Generating Station.

It appears that leaf injury of the three naturally occurring species during the past eight years has been happening somewhat at random about the Generating Station. Intermittent and limited Generating Station operations varying from shutdown up to a maximum of 70% have not as yet resulted in the type of data that would be suitable for response analysis in determining leaf injury. Microclimatic differences, site characteristics, and agricultural activity appear to be the major factors causing any significant distance, directional, and yearly effect observed to date for leaf injury.

Table 4. Average leaf characteristics for three naturally occurring species collected at maturity near the Nuclear Generating Station before (1972-1976) and after (1977-1979) beginning of operation of the station.

Before/After	Leaf Area (mm)	% Missing	% Spotted	% Brown Tip
		Bromus tectorum		
Before	109a[1]	0.8a	5.0b	14.8a
After	111a	1.4a	15.2a	20.2a
		Kochia scoparia		
Before	115a[1]	0.9b	3.3b	1.9a
After	70b	6.0a	7.8a	2.5a
		Populus sargenti		
Before	2837b[1]	1.4a	3.9a	0.2a
After	5555a	0.3b	1.6b	0.1b

[1]Means for a species in the same column followed by a similar letter are not significantly different at the 0.05 level of probability.

Pinto Bean Experiment

Analysis of data for various leaf characteristics of pinto beans in the controlled experiment indicated that neither distance nor direction from the cooling towers significantly ($p<0.05$) affected most leaf characteristics, except for leaf area. Leaf area of individual leaves were smaller (360 mm) near (50 feet) the cooling towers as compared with leaves that had grown at 1/4-mile distant (460 mm) from the towers. As expected, significant differences among years for several leaf characteristics of pinto bean plants were probably caused by differences in growing conditions, insect activity, and status of tower operation during the five years of study (Table 5).

ELEMENTAL CONCENTRATIONS IN VEGETATION

Kochia scoparia

Analyses of data for elemental concentrations in foliage samples of kochia collected each August during six years indicated that nitrogen (N), sulfate (SO_4-S), mercury (Hg), lead (Pb), and boron (B) all varied significantly ($p<0.05$) through time (Table 6). However, only sulfate varied significantly with distance from the station when a conservative F test was used in analyzing these data. Sulfate was often more concentrated in kochia foliage at a one mile distance than closer to the station. No other chemical constituent varied significantly with either distance or direction from the Generating Station. Sulfate concentrations increased in foliage through time resulting in a greater concentration in foliage after the Generating Station began operation (Table 6). Somewhat of a reversal of this trend was noted for nitrogen and mercury as higher concentrations were recorded before the station began operation.

Table 5. Average leaf characteristics for pinto bean plants (*Phaseolus vulgaris*) collected at maturity at varying distances from the Nuclear Generating Station for 1973 through 1978.

Year		Distance	
		50 feet	1/4 mile
	Leaf area (mm^2)		
1973		775b[1]	1129a
1974		921a	1086a
1976		253d	403bc
1977		478c	460b
1978		205d	320c
	Leaf area missing (%)		
1973		0.79a[1]	4.31a
1974		0.27a	0.78a
1976		0.74a	0.49a
1977		0.59a	0.15a
1978		0.81a	1.33a
	Leaf area spotted (%)		
1973		6.74a[1]	3.92a
1974		1.32b	1.25a
1976		2.39b	3.04a
1977		3.73b	3.34a
1978		1.45b	1.61a
	Brown tip leaf area (%)		
1973		1.88a[1]	1.77a
1974		0.74a	1.05a
1976		1.16a	1.07a
1977		1.24a	0.91a
1978		1.64a	0.79a

[1]Numbers in a column followed by similar letters are not significantly different at the 0.05 level of probability.

Table 6. Average concentration of various elements in foliage tissue of kochia (*Kochia scoparia*) during six years and as related to before (1973-1976)[1] and after (1977-1979) beginning of operation of the Nuclear Generating Station.

Year or Operational Status	N (%)	SO_4-S (%)	Hg (μg/g)	Pb (μg/g)	Cd (μg/g)	B (μg/g)
1973	---	---	0.23a	1.42b	0.38a	74.1bc
1975	2.81c[2]	0.40c	0.14b	0.70bc	0.31a	51.6d
1976	4.29a	0.37c	0.12bc	0.23c	0.29a	92.5ab
1977	3.62b	0.47bc	0.09bcd	0.12c	0.25a	102.2a
1978	2.72c	0.53b	0.12bc	0.82bc	0.62a	69.2cd
1979	1.26d	0.97a	0.05d	3.04a	0.51a	63.6cd
Before (1973-1976)	3.56a[2]	0.38b	0.16a	0.89a	0.32a	73.0a
After (1977-1979)	2.58b	0.64a	0.09b	1.26a	0.46a	78.9a

[1]Data were not collected in 1974 because an insufficient amount of leaf material remained for analysis.

[2]Numbers in a column followed by a similar letter are not significantly different at the 0.05 level of probability.

Populus sargentii

Elemental concentrations in foliage samples of cottonwood collected each August for 1974 through 1979 are shown in Table 7. Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe) and copper (Cu) all exhibited varying concentrations through the six years. Nitrogen, potassium, and boron were all higher in foliage before (1974-1976) the station began operation, whereas phosphorus, iron, and sulfate were more concentrated in samples after (1977-1979) the Generating Station began operating. Potassium and calcium were usually more concentrated in cottonwood foliage near (1/8-1/4 mile) the station, but magnesium, zinc, manganese (Mn), and boron were usually higher in foliage at a distance of one mile from the station. It then appears that station operation to date has had little direct effect on elemental concentrations as related to distance from the station.

Significant directional effects were detected for concentrations of nitrogen, magnesium and zinc. Nitrogen was usually higher in a northeast through southeast direction from the station. Magnesium was more concentrated in cottonwood located southwest through northwest of the Generating Station. Zinc concentrations in foliage were consistently lowest in a northerly direction from the station. It therefore appears that the limited station operation to date has not affected directional distribution of elements in cottonwood foliage, as prevailing winds are usually southerly or westerly during the growing season.

Phaseolus vulgaris

More elements were different in concentrations among the six years of study for pinto bean plants in the controlled experiment than for

Table 7. Average concentrations of various elements in foliage tissue of cottonwood (<u>Populus</u> <u>sargentii</u>) over a six year time period and as related to before (1974-1976) and after (1977-1979) beginning of limited operation of the Nuclear Generating Station.

Year or Operational Status	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (μg/g)	Fe (μg/g)	Mn (μg/g)	Cu (μg/g)	SO_4-S (%)	B (μg/g)
1974	2.39a[1]	0.07d	1.41b	2.51a	0.53ab	109.4a	81.8b	41.2a	7.4b	0.46a	113.5a
1975	2.15ab	0.25bc	1.26bc	1.57b	0.33c	83.9a	82.2b	40.1a	10.7b	0.49a	117.8a
1976	2.37a	0.32b	1.85a	1.64b	0.36c	75.4a	93.7b	41.4a	10.4b	0.51a	104.1a
1977	1.88bc	0.51a	1.43b	1.77b	0.48abc	86.7a	68.3b	32.5a	5.9b	0.70a	94.6a
1978	1.85c	0.18c	0.98c	2.41a	0.57a	102.5a	85.8b	44.0a	7.7b	0.78a	105.5a
1979	0.80d	0.17c	1.24bc	1.45b	0.39bc	81.4a	1139.4a	37.9a	19.3a	0.83a	74.6a
Before (1974-1976)	2.31a[1]	0.21b	1.50a	1.92a	0.41a	89.9a	85.8b	40.9a	9.5a	0.49b	111.8a
After (1977-1979)	1.56b	0.29a	1.22b	1.89a	0.48a	90.3a	417.8a	38.2a	10.8a	0.77a	91.9b

[1]Numbers in a column followed by a similar letter are not significantly different at the 0.05 level of probability.

either kochia or cottonwood. Nitrogen, phosphorus, potassium, calcium, magnesium, zinc, iron, manganese, copper, sulfate, mercury, lead, and cadmium (Cd) all varied significantly through time (Table 8). In fact, the only element that did not show any significant concentration changes during the study period was boron, as boron concentrations were highly variable. The only obvious trend in these data was the increase in sulfate concentrations from 1974 through 1979. Sulfates increased from 0.20 μg/g to 4.37 μg/g during this five year period. This same significant trend was also observed in the naturally occurring kochia and cottonwood species (Tables 6 and 7). This significant increase in sulfate concentrations in all species may be related to increasing sulfur dioxide air pollution in the Denver metropolitan area which is likely affecting vegetation near the Nuclear Generating Station.

Phosphorus, calcium, zinc, iron, and sulfate were all more concentrated in aboveground biomass of pinto bean plants after (1976-1979) the Generating Station began operation than before (1973-1976) (Table 8). Nitrogen and potassium concentrations in biomass were, however, higher before the station began operating. Various salts in the drift from the cooling towers were probably at least partially responsible for the increased concentrations of the five constituents. A preliminary study indicated that cooling tower water was at least twice as high in phosphorus, sulfate, and electrical conductivity as was the makeup water from the St. Vrain and South Platte Rivers (Table 2). Less nitrogen and potassium in the plants may either be a dilution effect or may be related to smaller leaf size of plants grown near the cooling towers.

Table 8. Average concentrations of various elements in aboveground biomass of pinto bean plants (*Phaseolus vulgaris*) during six years and as related to before (1973-1976) and after (1977-1979) beginning of operation of the Nuclear Generating Station.

Year or Operational Status	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (μg/g)	Fe (μg/g)	Mn (μg/g)	Cu (μg/g)	SO_4-S (%)	Hg (μg/g)	Pb (μg/g)	Cd (μg/g)	B (μg/g)
1973	2.96b[1]	0.40b	2.75b	1.49d	0.56b	55.3b	301d	52.0cd	10.2c	---	0.25a	1.4b	0.5c	59.0a
1974	3.08b	0.38b	2.39b	3.26b	0.65b	38.0c	410d	37.5d	8.4c	0.20c	0.09c	1.4b	0.7b	60.9a
1976	4.26a	0.36bc	3.61a	2.04cd	0.39c	49.7b	968b	75.3b	15.2b	0.50c	0.10bc	1.1b	0.2d	76.4a
1977	2.94b	0.78a	2.52b	1.60d	0.39c	58.2b	317d	35.3d	8.1c	0.58c	0.11bc	0.3b	0.2d	15.0a
1978	3.06b	0.30c	2.34d	4.18a	0.88a	120.2a	589c	65.0bc	10.6c	1.59b	0.10bc	1.1b	0.7b	65.2a
1979	1.30c	0.34bc	1.50c	2.56c	0.57b	122.4a	3004a	146.0a	36.4a	4.37a	0.21ab	12.5a	1.3a	152.5a
Before (1973-1976)	3.38a[1]	0.38b	2.94a	2.02b	0.53a	50.0b	525b	56.0a	11.3a	0.38b	0.17a	1.29a	0.4a	64.6a
After (1977-1979)	2.58b	0.53a	2.22b	2.61a	0.58a	92.5a	1051a	71.2a	16.2a	1.80a	0.13a	3.48a	0.6a	63.5a

[1]Numbers in a column followed by a similar letter are not significantly different at the 0.05 level of probability.

There was a weak trend in these data which indicated that concentrations of nitrogen, magnesium, iron, manganese, copper, and sulfate were greater in pinto bean plants grown near the cooling towers (50 ft) as compared with plants grown at 1/4 mile distance from the towers. This was expected as drift deposition at 50 feet from the towers was heavy at times. The amount of drift deposition had certainly declined by 1/4-mile away from the towers.

SUMMARY AND CONCLUSIONS

In general, leaf area injured decreased with time during the growing seasons during most of the years of study. This was anticipated as leaves are more susceptible to injury while they are growing and before they reach maturity. Some leaf injury measurements for the three naturally occurring species showed significant differences for distance from the St. Vrain Nuclear Generating Station. But, it appeared that leaf injury was not related to direction from the Generating Station. Therefore, it appears that most variations in leaf injury were caused by microclimate, site, insects, and species differences and were little influenced by the intermittent, limited operations of the Generating Station to date.

Leaf area of pinto beans in a controlled experiment were often smaller when grown near (50 feet) the cooling towers. However, increased leaf spotting near the towers was observed only in one of the five years of study. Cooling tower blowers were usually not in operation during earlier years and humidity near the towers was only slightly greater during 1978 and 1979 than at the 1/4-mile distance from the towers. These relationships might become more pronounced when the Generating Station reaches full power operation. The Nuclear Generating Station has had only intermittent, irregular, and limited operation to date (1977--137 days, 1978--201 days, and 1979--77 days).

Elemental concentrations in foliage samples of kochia and cottonwood were little influenced by distance or direction from the St. Vrain Nuclear Generating Station. Although significantly higher concentrations of some elements were found in foliage from some local sites, there was no consistent trend in these data among the elements and sites or as related to prevailing winds during the growing season. The most obvious trend in these data is the significant increase of sulfate in foliage of both species during the past few years. Sulfate concentrations have nearly doubled during the past six years. This is probably indicative of increased levels of air pollution in the Denver Air Pollution Corridor. Sulfate levels in vegetation may prove to be a good integrated index for monitoring ambient levels of air pollution.

Five chemical constituents (phosphorus, calcium, zinc, iron, and sulfate) in pinto bean plants from the controlled experiment increased in concentration after startup of the Generating Station. Since water samples from the cooling towers had levels of phosphorus, sulfate, and salts that were at least twice as high as makeup water from the two rivers, it is probable that drift deposition on foliage was at least partially responsible for this increase. Heavy metal concentrations in pinto bean plants of mercury (Hg), lead (Pb) and cadmium (Cd) were not different before nor after station startup. However, a significant increase in all three of these heavy metals was detected in 1979. A larger difference in temperature and humidity also was detected around the cooling towers in 1979.

MAMMALS, AMPHIBIANS AND REPTILES

by

Bruce A. Wunder

INTRODUCTION

My participation in and initiation of the Mammal, Amphibian and Reptile portion of the Fort St. Vrain Biological Inventory and Monitoring Program began in Spring 1972 to determine the effects of the Nuclear Generating Station operations on these vertebrates. At that time (March 1972) it was expected that the Station would be in full operation by Fall 1972 and that monitoring might extend for one year beyond.

The goal was to determine which species were present on the Station property and where they were found, as the species lists given in the initial impact statement were obviously based on outdated species distribution maps and little or no on-site evaluation. One month was spent trapping and observing in the various habitat types, reading reports on how the Station was to function, hypothesizing how the Generating Station might affect the environment and hence the animals. We decided to assay species presence for large mammals, reptiles, and breeding amphibians and to concentrate numerical population analyses on small mammals. Large mammal densities on and use of the Station property and surrounding areas seemed low enough that for a 1 to 1½ year study, species presence seemed sufficient. Furthermore since large mammals are so mobile and range over large areas, it would be difficult to confine influence on their numbers just to factors on the Public Service Company (PSC) property. Given the apparent densities of reptiles and amphibians, we settled on assaying species presence.

Short of a major radioactivity or reactor mishap, it appeared that the major aspects of the Station operation which might affect vertebrate populations were those associated with cooling-tower water. Water is evaporated taking with it salts and other materials which may be subsequently deposited on neighboring vegetation and then be consumed by foraging mammals. Additionally, heavy metals and sub-biocides could leach into soils along the irrigation ditches and in Goosequill Pond, subsequently to be concentrated in plants eaten by animals or taken up by amphibians in the water. Consequently, amphibians breeding in Goosequill Pond and along the ditches were assayed. For these reasons and because small mammals and amphibians provide a food base for mammalian and avian predators in the areas, we also studied heavy metal concentrations in the two groups to provide baseline comparison with similar data obtained during operation of the Nuclear Generating Station.

METHODS

Items Sampled

The goals of this section of the monitoring project were as follows:

1. Monitor species presence or absence of large mammals, reptiles and amphibians, particularly breeding populations.
2. Monitor population numbers and trends in small mammals. The reasons for emphasizing small mammal populations were as follows:
    a. There are good data validating population sampling techniques.
    b. The animals forage on plants and their seeds, which may be affected by "drift" and/or "blowdown" water from the Generating Station.

c. The animals do not move great distances and thus changes in population densities should be due to factors in the immediate environment.

3. Determine concentrations of copper, zinc, and lead in various tissues of prairie voles (Microtus ochrogaster) and Woodhouse's toads (Bufo woodhousei). These three heavy metals were reported in the water to be used for cooling and hence could potentially be concentrated during Station operation. All are toxic in high concentration to vertebrates. Prairie voles were common in dense vegetation along the irrigation ditches and fed on that vegetation. Woodhouse's toads were common breeders in most of the water areas.

The detailed methods of determining species presence and small mammal population parameters have been presented in progress reports on the Fort St. Vrain Nuclear Generating Station (December 1973 and June 1974). Likewise, details of sample preparation and heavy metal analysis (performed by the Colorado State University Analytical Chemistry Lab) were given in the December 1974 Fort St. Vrain Progress Report.

The present techniques for small mammal population analysis have remained the same since 1972.

Sampling Periods

One or two trips per month were made to the PSC property to assay species presence. And, three times per year, five-day sampling periods for small mammal densities were undertaken: (1) late May-early June (late Spring) to determine numbers following Spring breeding; (2)

early September (early Fall) to assay population levels following summer breeding; and (3) late November (late Fall) to determine population numbers entering the winter.

Sampling Site Placement

Sampling sites were located as indicated in Figure 1. These locations were chosen compromising two factors: equidistant points and compass directions from the Nuclear Generating Station. However, the symmetric selection was influenced by the need for large blocks of similar vegetation for trapping that would not be affected by day-to-day farming activity. In addition, because of some species specificities, as many vegetation types as possible were trapped. Where there were large enough areas of homogeneous vegetation, 10 X 10 station trapping grids were established. Where areas were not adequate, then North American Census of Small Mammal Lines were established as indicated in the December 1973 Progress Report.

CHANGES IN MONITORING PROCEDURE

During the course of the study, three major changes in monitoring procedure occurred:

1. Elimination of two sampling sites--Following the Summer of 1973, Grid 2 and North American Census Line 6 (Fig. 1) were abandoned as sampling sites. The Spring of 1973 was wet with considerable flooding and these two sites (in the South Platte River floodplain) were completely under water during the June sampling period and had large areas of surface ponds into Summer and Fall.

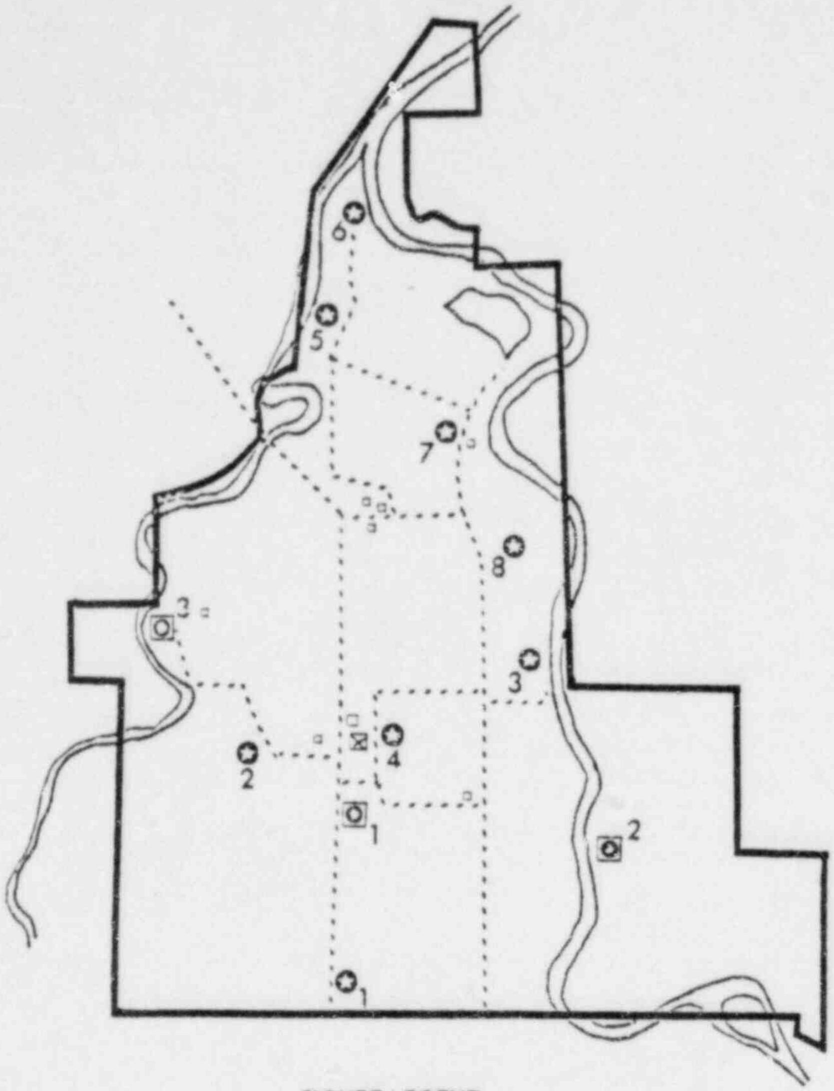


FIGURE LEGEND

Transect 1 - Cropland - pasture
2 - Vegetation along irrigation ditch
3 - River bottom
4 - Vegetation along irrigation ditch
5 - River bottom
6 - River bottom
7 - Vegetation near farm pond
8 - Cropland - pasture
Grid 1 - Cropland (Old field)
2 - River bottom
3 - Pasture

GRID

NACSM

Figure 1. Fort St. Vrain Nuclear Generating Station study area--permanent trapping areas and habitat descriptions.

2. Elimination of March (early Spring) Sampling Period--We had initially planned four trapping periods each year with one scheduled for early Spring to assay population levels following the winter and before Spring breeding. These were scheduled for early March. However, in March 1973 weather was so inclement that many animals died in the live traps during sampling. Because many deaths at this time would affect the Spring breeding populations adversely, the sampling period was dropped.
3. Heavy Metal Analysis--Following our conclusion that concentration of materials in "blowdown" water may be amplified and increased in concentration in small mammals and amphibians and have adverse environmental effects, we proposed to monitor levels of copper, zinc, and lead in these animals. These studies were initiated in 1974 and ended in 1977; however, we were able to analyze animals collected and frozen from 1972-1976. Monitoring ceased in 1977 primarily for financial reasons but also because good baseline data were available for comparisons.

RESULTS AND DISCUSSION

Mammals: Species Presence

Table 1 lists the mammals which we have confirmed to be utilizing the Nuclear Generating Station environs from 1972-1979. All of these species were still determined to be present on the PSC property during 1979 except those species listed in Table 2. For reasons discussed in the December 1979 Progress Report, most of those species may still be found on the property with the exception of the thirteen-lined ground

Table 1. Mammals present in the vicinity of the Fort St. Vrain Nuclear Generating Station.

Common Name	Scientific Name	Presence[1]	Abundance[2]
1. Shrew	*Sorex* sp.	1. C	R
2. White-tailed jackrabbit	*Lepus townsendii*	2. V	P
3. Black-tailed jackrabbit	*Lepus californicus*	3. V	P
4. Cottontail rabbit	*Sylvilagus* sp.	4. V	A-P
5. Thirteen-lined ground squirrel	*Spermophilus tridecemlineatus*	5. C	P
6. Spotted ground squirrel	*Spermophilus spilosoma*	6. C	P
7. Rock squirrel	*Spermophilus variegatus*	7. V	R
8. Black-tailed prairie dog	*Cynomys ludovicianus*	8. V	A(locally)
9. Fox squirrel	*Sciurus niger*	9. V	A
10. Beaver	*Castor canadensis*	10. T	P
11. Pocket gopher	*Geomys bursarius*	11. C	P(locally)
12. Harvest mouse	*Reithrodontomys sp.*	12. C	R
13. Deer mouse	*Peromyscus maniculatus*	13. C	A
14. Northern grasshopper mouse	*Onychomys leucogaster*	14. C	R
15. Prairie vole	*Microtus ochrogaster*	15. C	A-R
16. Meadow vole	*Microtus pennsylvanicus*	16. C	R
17. Muskrat	*Ondatra zibethicus*	17. V-T	P
18. House mouse	*Mus musculus*	18. C	A-R
19. Norway rat	*Rattus norvegicus*	19. C	R
20. Meadow jumping mouse	*Zapus hudsonicus*	20. C	R
21. Coyote	*Canis latrans*	21. V-T	R
22. Red fox	*Vulpes vulpes*	22. V	R
23. Raccoon	*Procyon lotor*	23. T-S	P
24. Long-tailed weasel	*Mustela frenata*	24. V	R
25. Striped skunk	*Mephitis mephitis*	25. T-D	P
26. Domestic cat	*Felis domesticus*	26. V	P
27. Domestic dog	*Canis familiaris*	27. V-T	P
28. Mule deer	*Odocoileus hemionus*	28. T-S-D	P
29. White-tailed deer	*Odocoileus virginianus*	29. V-T-S	R-P
30. Badger	*Taxodea taxus*	30. T-S	P-R

[1] C = Captured
D = Found Dead
S = Scat
T = Track
V = Visual Observation

[2] R = Rare
P = Present (moderately common)
A = Abundant

Table 2. Mammal species previously noted near the Fort St. Vrain Nuclear Generating Station that were not censused in the first ten months of 1979.

Common Name	Scientific Name
1. Shrew	*Sorex* sp.
2. Black-tailed jackrabbit	*Lepus californicus*
3. Thirteen-lined ground squirrel	*Spermophilus tridecemlineatus*
4. Spotted ground squirrel	*Spermophilus spilosoma*
5. Rock squirrel	*Spermophilus variegatus*
6. Northern grasshopper mouse	*Onychomys leucogaster*
7. Norway rat	*Rattus norvegicus*
8. Meadow jumping mouse	*Zapus hudsonius*
9. Long-tailed weasel	*Mustela frenata*[1/]

[1/] May have been present, as tracks were recorded, but species identification was not possible.

squirrels and spotted ground squirrels. Both squirrels were common in the vicinity of Grid 3 and Transect 8 in the early years of the study but have not been seen since 1976. The reason for the disappearance is not known. Since both are diurnally active and fairly conspicuous, I must assume that our not seeing them is justification to conclude they are no longer present. Also, since no other species seem to be greatly affected and the prior relative numbers or presence-absence of these squirrels were greatly influenced by agricultural practices, I must conclude that they have been driven out by changes in agricultural practices and not by any direct function of the Nuclear Generating Station.

Mammals: Populations

Deer mice and house mice continue to be the most common small mammals on the PSC property. Their numbers have stabilized since late 1976 (Figure 2), thus these values provide a good baseline for future measurements. One major population change since the initiation of the study was the reduction of the prairie vole numbers at the trapping sites. In the early years (1972-1974), prairie voles were always the second most numerous species; but following their almost virtual disappearance during late 1975 and again in 1977, they have been low in density. This species is known to show periodic population fluctuations and to need relatively moist habitat. Thus, it appears that the dry years on Grid 3 and the manipulation of Transect 7 (where many of these animals were caught) may have reduced numbers to levels from which the species has not been able to recover. At present we have no reason to link this reduction to the intermittent and irregular operation of the Nuclear Generating Station.

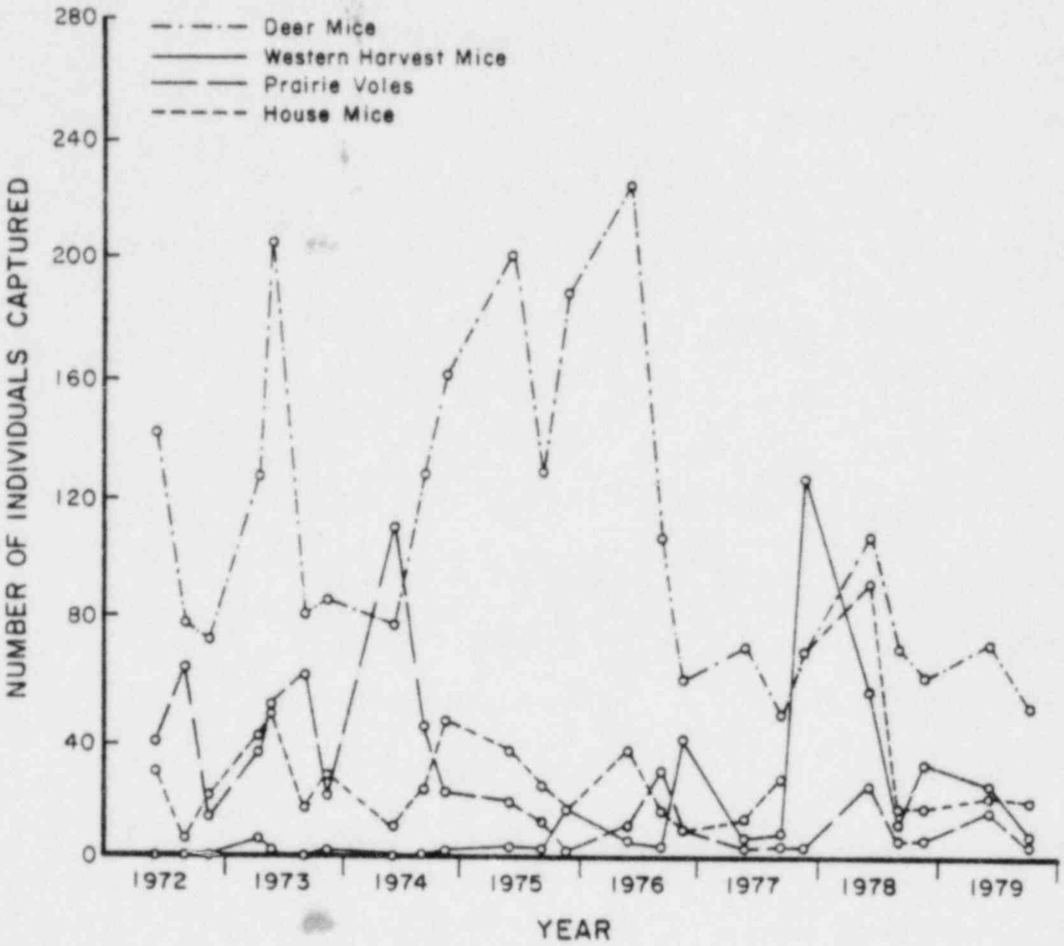


Figure 2. Total number of small mammal individuals captured at the Fort St. Vrain Nuclear Generating Station: late Spring 1972 - early Autumn 1979.

Table 3. Amphibians and reptiles present in the vicinity of the Fort St. Vrain Nuclear Generating Station.

Common Name	Scientific Name	Presence[1]
1. Spadefoot toad	*Scaphiopus bombifrons*	1. V-C
2. Great Plains toad	*Bufo cognatus*	2. C
3. Woodhouse's toad	*Bufo woodhousei*	3. C
4. Western chorus frog	*Pseudacris triseriata*	4. C
5. Bullfrog	*Rana catesbiana*	5. C
6. Leopard frog	*Rana pipiens*	6. V
7. Tiger salamander	*Ambystoma tigrinum*	7. V
8. Snapping turtle	*Chelydra serpentina*	8. D
9. Painted turtle	*Chrysemys picta*	9. V-D
10. Spiny soft-shelled turtle	*Trionyx spiniferus*	10. V
11. Racer	*Coluber constrictor*	11. V
12. Common garter snake	*Thamnophis sirtalis*	12. C
13. Plains garter snake	*Thamnophis radix*	13. C
14. Bull snake	*Pituophis melanoleucas*	14. C
15. Western rattlesnake	*Crotalus viridis*	15. V

[1]C = captured
D = found dead
S = scat
T = track
V = visual observation

Amphibian and Reptile: Species Presence

Table 3 lists the species of amphibians and reptiles that have been observed on the PSC property. Virtually all the amphibians and reptiles previously inventoried on the PSC property were inventoried during 1979. The lesser earless lizard (Holbrookia maculata), with only one previous sighting, and the western rattlesnake (Crotalus viridis), which probably still occur in low numbers, were the only reptiles not recorded. Spiny soft-shelled (Trionyx spiniferus) and snapping turtles (Chelydra serpentine) were not seen but have never been abundant on the rivers since the floods of 1973. And the tiger salamander (Ambystoma tigrinum), not recorded in 1979, has only been seen in the Nuclear Generating Station settling ponds which were not censused in 1979. Thus, it appears that Station operation has had no apparent effect on amphibian or reptilian presence in the area.

Heavy Metal Analysis

We were especially interested in answering two questions concerning heavy metal concentrations in mammals on the PSC property: (1) are there differences in tissue concentration of specific metals for animals from different sites? and (2) are there differences between years in these concentrations? To answer the first question we compared (using 2-tailed T-tests) levels of copper, zinc, and lead in liver and kidney of animals from Grid 3 and Transect 7. These sites were quite far apart and are affected differently by water discharge patterns from the Nuclear Generating Station. No significant differences in any metal concentrations in either liver or kidney could be demonstrated (Tables 4 through 6).

Table 4. Copper (Cu) concentrations in *Microtus ochrogaster* (µg/g).

Month	Group		N	Tissue	$\bar{x}$	S.D.	Tissue	$\bar{x}$	S.D.	Tissue	$\bar{x}$	S.D.
June	All Sites	1972-74	11	Liver	16.5	3.6	Kidney	19.4	2.5	Long Bones	-	-
	All Sites	1975	9	"	15.7	1.9	"	16.3	1.9	"	0.2	0.1
	Grid 03	1972-74	5	"	14.4	2.1	"	19.0	2.9	"	-	-
	Grid 03	1975	2	"	17.5	3.5	"	17.5	0.7	"	0.2	0.1
	Tran 07	1972-74	5	"	17.0	3.5	"	16.7	2.4	"	-	-
	Tran 07	1975	4	"	15.8	1.3	"	16.2	1.3	"	0.2	0.1
Sept.	All Sites	1972-74	6	Liver	17.3	3.4	Kidney	17.3	1.9	Long Bones	-	-
	All Sites	1975	7	"	16.1	2.2	"	16.3	1.1	"	0.3	0.4
	Grid 03	1972-74	3	"	16.7	3.1	"	16.7	2.5	"	-	-
	Grid 03	1975	5	"	15.0	1.0	"	16.2	1.3	"	0.1	0.1
	Tran 07	1972-74	2	"	15.5	.7	"	18.0	1.4	"	-	-
	Tran 07	1975	0	"	-	-	"	-	-	"	-	-
Nov.-Dec.	All Sites	1972-74	4	Liver	13.4	4.5	Kidney	17.0	1.8	Long Bones	0.3	0.1
	All Sites	1975	6	"	15.3	4.2	"	17.5	1.8	"	0.1	0.1
	Grid 03	1972-74	2	"	17.0	2.8	"	18.5	0.7	"	0.2	0.0
	Grid 03	1975	1	"	17.0	0.0	"	19.0	0.0	"	0.1	0.0
	Tran 07	1972-74	0	"	-	-	"	-	-	"	-	-
	Tran 07	1975	2	"	13.5	2.1	"	19.0	0.0	"	0.2	0.1
Nov.	All Sites	1974	3	Liver	12.9	5.4	Kidney	16.7	2.1	Long Bones	0.3	0.1

Table 5. Zinc (Zn) concentrations in Microtus ochrogaster (μg/g).

Month	Group		N	Tissue	$\bar{x}$	S.D.	Tissue	$\bar{x}$	S.D.
June	All Sites	1972-74	11	Liver	86.7	26.3	Kidney	84.3	19.6
	All Sites	1975	9	"	102.0	9.0	"	76.2	7.5
	Grid 03	1972-74	5	"	83.2	14.2	"	90.4	28.0
	Grid 03	1975	2	"	98.0	2.8	"	75.5	13.4
	Tran 07	1972-74	5	"	83.4	34.9	"	80.6	8.6
	Tran 07	1975	4	"	102.0	12.4	"	73.0	7.3
Sept.	All Sites	1972-74	6	Liver	105.0	13.8	Kidney	87.2	6.2
	All Sites	1975	7	"	104.7	12.2	"	96.8	24.5
	Grid 03	1972-74	3	"	96.7	11.7	"	83.0	2.7
	Grid 03	1975	5	"	100.6	6.1	"	87.2	4.4
	Tran 07	1972-74	2	"	110.0	14.1	"	88.5	5.0
	Tran 07	1975	0	"	-	-	"	-	-
Nov.-Dec.	All Sites	1972-74	4	Liver	87.0	21.5	Kidney	86.3	2.2
	All Sites	1975	6	"	96.0	12.8	"	89.3	24.2
	Grid 03	1972-74	2	"	97.0	18.4	"	85.5	3.5
	Grid 03	1975	1	"	91.0	0.0	"	52.0	0.0
	Tran 07	1972-74	0	"	-	-	"	-	-
	Tran 07	1975	2	"	106.0	19.8	"	112.0	21.2
Nov.	All Sites	1974	3	Liver	88.0	26.2	Kidney	87.3	0.58

Table 6. Lead (Pb) concentrations in Microtus ochrogaster (μg/g).

Month	Group		N	Tissue	$\bar{x}$	S.D.	Tissue	$\bar{x}$	S.D.	Tissue	$\bar{x}$	S.D.
June	All Sites	1972-74	11	Liver	0.3	0.2	Kidney	1.5	1.8	Pelt	0.2	0.2
	All Sites	1975	9	"	0.3	0.1	"	1.1	0.9	"	0.4	0.3
	Grid 03	1972-74	5	"	0.2	0.2	"	2.0	2.7	"	0.2	0.1
	Grid 03	1975	2	"	0.3	0.1	"	1.6	1.3	"	0.6	0.2
	Tran 07	1972-74	5	"	0.3	0.2	"	1.0	0.5	"	0.2	0.2
	Tran 07	1975	4	"	0.2	0.1	"	0.7	0.6	"	0.2	0.1
Sept.	All Sites	1972-74	6	Liver	0.3	0.1	Kidney	2.5	1.1	Pelt	0.1	0.1
	All Sites	1975	7	"	0.2	0.1	"	1.5	2.8	"	0.4	0.3
	Grid 03	1972-74	3	"	0.2	0.2	"	3.2	1.2	"	0.2	0.1
	Grid 03	1975	5	"	0.2	0.1	"	0.6	0.4	"	0.4	0.3
	Tran 07	1972-74	2	"	0.3	0.1	"	2.1	0.1	"	0.1	0.0
	Tran 07	1975	0	"	-	-	"	-	-	"	-	-
Nov.-Dec.	All Sites	1972-74	4	Liver	0.6	0.3	Kidney	4.3	2.5	Pelt	0.4	0.2
	All Sites	1975	6	"	0.6	0.3	"	2.8	3.3	"	0.5	0.4
	Grid 03	1972-74	2	"	0.7	0.1	"	4.6	3.0	"	0.4	0.0
	Grid 03	1975	1	"	0.6	0.0	"	1.2	0.0	"	0.5	0.0
	Tran 07	1972-74	0	"	-	-	"	-	-	"	-	-
	Tran 07	1975	2	"	1.3	0.1	"	1.3	1.0	"	-	-
Nov.	All Sites	1974	3	Liver	0.5	0.3	Kidney	4.9	2.7	Pelt	0.3	0.3

Few seasonal or yearly differences in heavy metal concentrations were observed (Tables 4 through 6). The only significant seasonal differences were the higher concentrations of lead in liver that occurred in November 1974 and November 1975 when compared to the June 1975 and September 1975 samples respectively; the June 1975 zinc concentrations in kidney tissue that were lower than those observed in November 1974 or September 1975; and, the June 1975 lead concentrations in kidney tissue that were lower than those observed in kidneys from November 1974. Lead concentrations were higher in November than earlier in the year. The few significant yearly differences were the high June 1975 kidney copper concentrations for all trapping areas and for Transect 7 when compared to the composite 1972-1974 results, the high Grid 3 lead concentrations in kidneys during September 1975 as compared to the composite 1972-74 results, and the low concentrations of lead in September 1975 pelts when compared to those of 1972-74 animals.

Adequate numbers of measurements have been made in Microtus tissues, given the inherent seasonal and yearly variability of such measurements, so that reasonable comparisons to baseline conditions can be determined.

In order to determine how baseline levels of heavy metals from animals on the PSC property compared to other animals studied, we compared concentrations of both zinc and lead in prairie vole kidneys collected from 1972-76 to the few values in the literature. The only data we found suitable for comparison were for gray squirrels trapped in the Gulf Hammock Wildlife Management Area of Florida (a relatively undisturbed area) and Jacksonville, Florida, with some degree of industrial pollution (McKinnon, et al., 1976, J. Wildl. Disease, 12:367-371). Kidneys from voles caught near the St. Vrain Nuclear Generating Station had higher concentrations of zinc and lead than did the kidneys from squirrels collected in rural Florida but less than the kidneys from squirrels exposed to light to medium levels of industrial pollution in urban Jacksonville (Table 7, Figures 3 and 4). At this point, it is not evident why zinc and lead are found in higher concentrations in kidneys of voles from the PSC property than in those of squirrels from rural Florida other than species differences. However, the levels of zinc and lead in kidneys of voles from St. Vrain are considerably lower than levels of kidneys of squirrels from urban Jacksonville. If the St. Vrain Nuclear Generating Station becomes a significant producer of airborne or aquatic heavy metal contaminants, which enter or are deposited on plants, the levels of heavy metals in vole kidneys should rise toward the levels observed in the kidneys of urban squirrels.

Amphibians were usually collected from Goosequill Pond or the ditch draining into it so comparisons were only made between years and species. The differences in mean concentrations of liver zinc in laboratory frogs (*Rana pipiens*) supplied by a commercial dealer, when compared with either Woodhouse's toads (*Bufo woodhouseii*) or spadefoot toads (*Scaphiopus bombifrons*) from PSC property, were significant as were the mean copper concentrations in the liver of spadefoot toads when compared with Woodhouse's toads or the laboratory *R. pipiens* (Table 8). The yearly differences in the means of metal concentrations of liver copper and zinc in Woodhouse's toads also were tested for significance (Table 9). The copper and zinc content of livers from Woodhouse's toads captured in 1975 were significantly lower than the contents found in 1973 and 1974 which are not different from one another. We do not know the reason for these lower levels but suspect they are the result of rainfall and

Table 7. Kidney concentrations of zinc and lead in gray squirrels captured in Florida[1] and in prairie voles captured at the Fort St. Vrain Nuclear Generating Station, Colorado.

Groups	Number Animals	Zinc[3] Mean±S.E.	Lead[3] Mean±S.E.
Jacksonville (squirrels)[2]			
<1 year	75	27.72±1.21	1.32±0.17
1 year	69	29.68±1.80	1.28±0.24
2 years	20	30.54±2.49	1.18±0.31
3 years	10	25.99±3.14	0.47±0.16
4 years	6	23.04±2.69	0.86±0.33
Gulf Hammock (squirrels)			
1 year	5	14.32±1.64	0.20±0.02
2 years	7	18.61±1.43	0.26±0.04
St. Vrain (voles)			
All animals	70	22.36±0.56	0.56±0.15
Grid 3	33	22.79±0.96	0.64±0.12
Transect 7	16	21.81±0.93	0.41±0.11

[1]From McKinnon, et al., 1976.

[2]Equals animals of different age classes.

[3]Parts per million, wet weight.

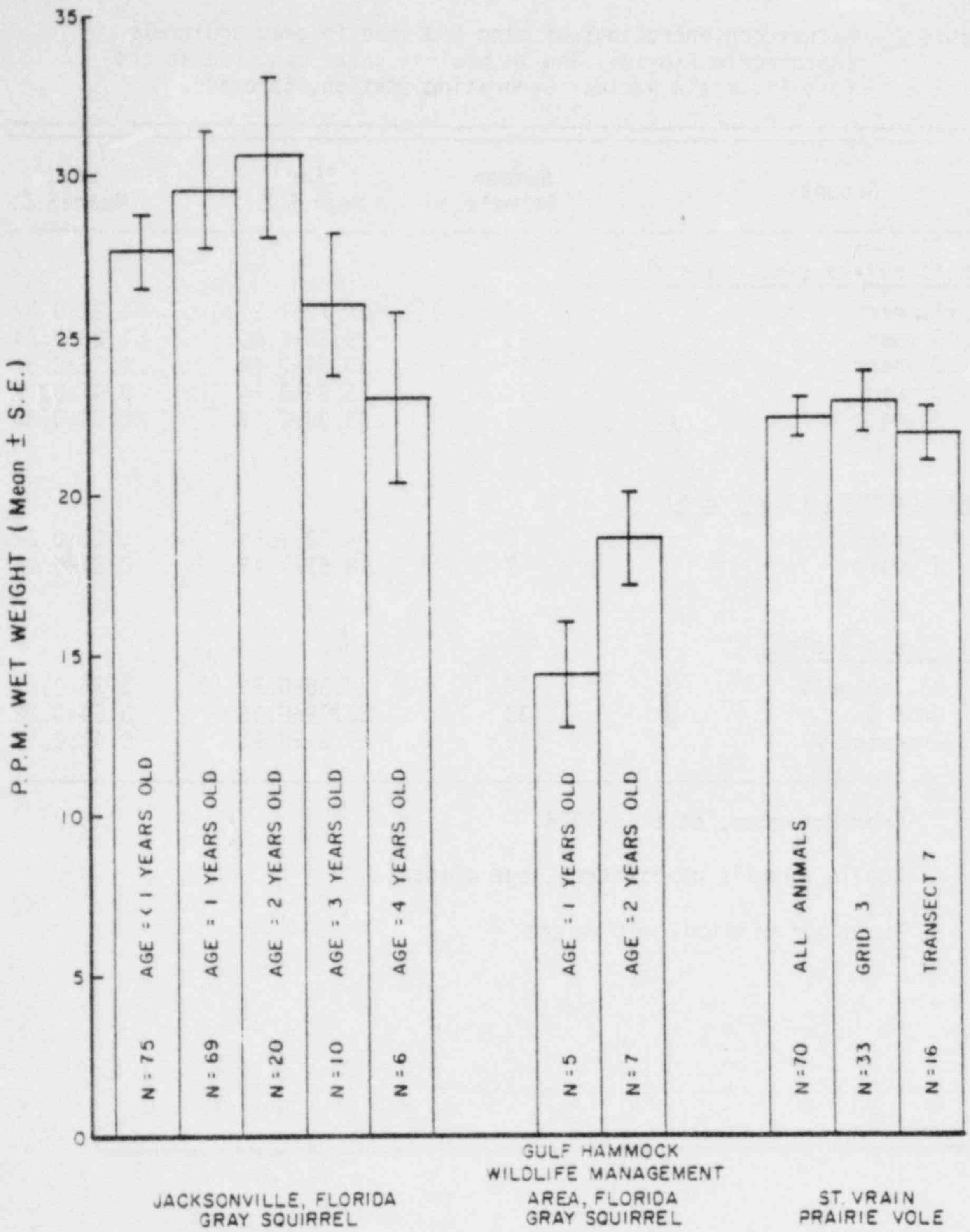


Figure 3. Zinc concentrations in kidneys from wild rodents captured in Florida (McKinnon, et al., 1976) and on the St. Vrain Nuclear Generating Station.

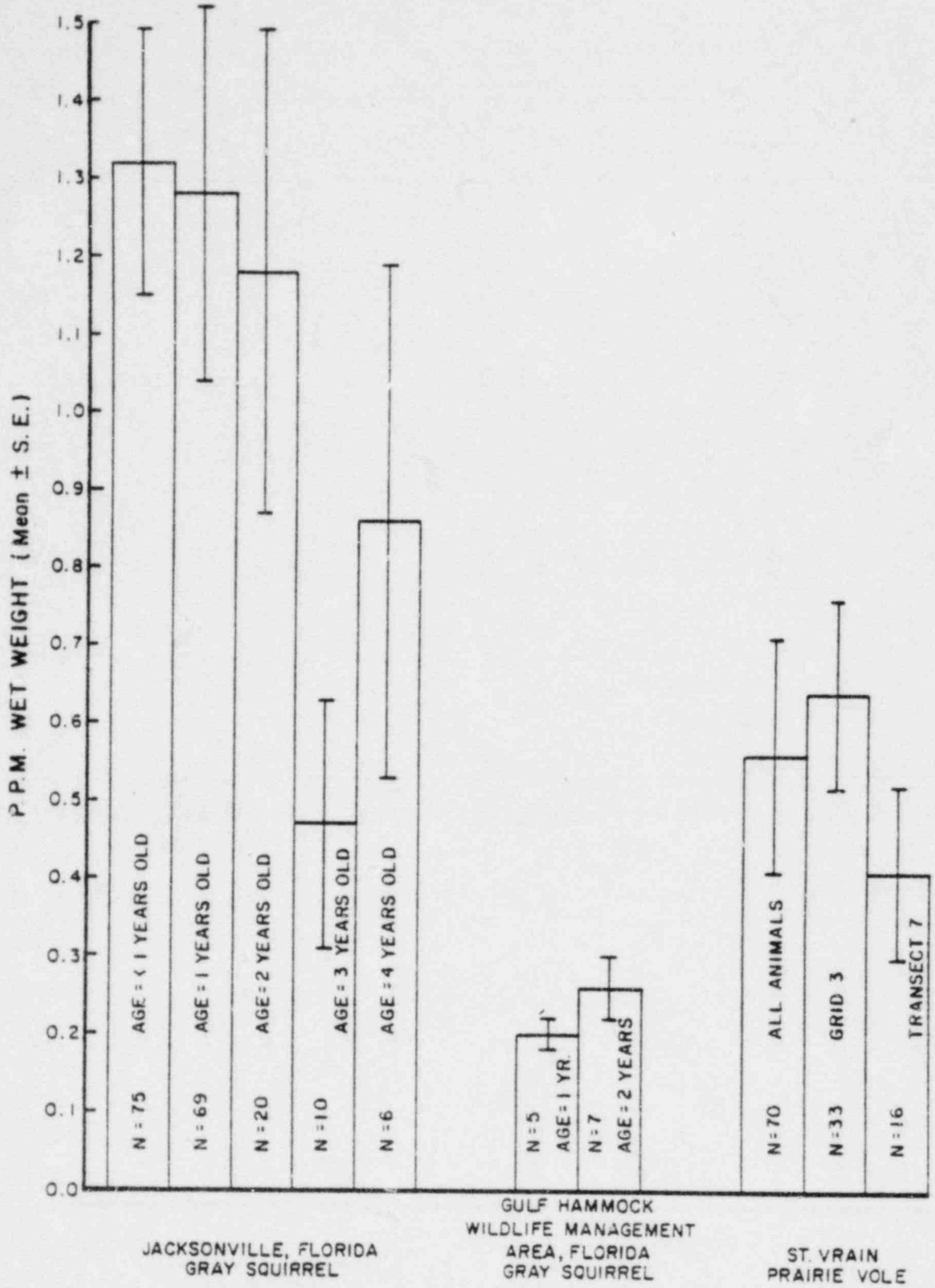


Figure 4. Lead concentrations in kidneys from wild rodents captured in Florida (McKinnon, et al., 1976) and on the St. Vrain Nuclear Generating Station.

Table 8. Metal concentrations in amphibia (μg/g).

Animal	Group	Analysis	Tissue	N	$\bar{X}$	S.D.
BB[1]	---	Cu	Liver	10	153	92.5
SB[2]	1973	Cu	"	10	45.3	41.3
BW[3]	All years	Cu	"	33	238.1	206.1
BW	1972	Cu	"	3	233.3	118.46
BW	1973	Cu	"	11	328.2	304.9
BW	1974	Cu	"	10	245.0	130.8
BW	1975	Cu	"	10	119	65.5
BB	---	Zn	"	9	217.8	132.6
SB	1973	Zn	"	10	117.3	24.6
BW	All Years	Zn	"	33	121.9	40.8
BW	1972	Zn	"	3	13.3	15.3
BW	1973	Zn	"	10	142	37.1
BW	1974	Zn	"	9	137.8	47.5
BW	1975	Zn	"	10	100.4	29.0
BB	---	Zn	Whole Body	10	129.0	22.8
BW	All years	Zn	Whole Body	10	133.4	27.7

[1]BB are samples of tissue from commercial frogs (Rana pipiens) used to work out analysis techniques.

[2]SB are samples of tissue from Scaphiopus bombifrons, the spadefoot toad, from the Fort Saint Vrain Farm Pond. Samples were taken in 1973.

[3]BW are samples of tissue from Bufo woodhousei, Woodhouse's toad from the Fort Saint Vrain Farm Pond. Samples were taken in 1972, 1973, 1974 and 1975.

Table 9. Heavy metal concentrations in Bufo Woodhousei (µg/g).

Group	Metal	Tissue	N	$\bar{X}$	S.D.	Tissue	N	$\bar{X}$	S.D.
1972	Cu	liver	3	233.3	118.5	--	--	--	--
1973	Cu	liver	10	351.0	311.3	--	--	--	--
1974	Cu	liver	10	245.0	130.7	--	--	--	--
1975	Cu	liver	10	119.6	65.5	kidney	10	13.8	4.7
1972-75	Cu	liver	33	229.0	204.6	kidney	10	13.8	4.7
1976	Cu	liver	8	66.8	89.9	kidney	8	5.2	1.5
1972	Zn	liver	3	93.3	15.3	--	--	--	--
1973	Zn	liver	10	142.0	37.1	--	--	--	--
1974	Zn	liver	10	132.0	48.0	--	--	--	--
1975	Zn	liver	10	100.4	29.0	kidney	10	93.8	16.6
1972-75	Zn	liver	33	122.0	40.8	kidney	10	93.8	16.6
1976	Zn	liver	8	83.6	7.4	kidney	8	82.4	13.0

collecting patterns. In 1973 and 1974, rainfall was scattered in the Spring and pools of water were readily available to toads for breeding. Thus, we simply collected during May when we could make time for such collections. In 1975 Spring rainfall was sparse and we could not collect toads easily. Therefore, we concentrated our collecting efforts following what little rain there was. Thus, the animals were probably inhabiting more bodies of water in 1975 with lower levels of metal concentrations than in 1973 and 1974. It is encouraging, for baseline information, to note that when rains are scattered and the available ponds receive fresh water infrequently, there is no difference in year-to-year liver zinc and copper content in Woodhouse's toad. We also note that there are real species differences in liver copper content (compare 1973 Spadefood toads with Woodhouse's toads, Table 8). Scaphiopus is a more opportunistic breeder than Bufo and may come out to breed only following rains when ponds have low metal concentrations. Thus, it is interesting to note that Scaphiopus liver copper content is lower than Bufo. However, liver zinc contents do not differ; thus, suggesting that the two species concentrate these heavy metals differently.

TRENDS, ENVIRONMENTAL QUALITY AND INFLUENCE OF THE STATION

As indicated in the Results and Discussion section, there have been a few changes in the vertebrate component of the environment surrounding the Fort St. Vrain Nuclear Generating Station. Most of the changes seen in the past 7½ years can be ascribed to or associated with climate or agricultural practices and none by direct link to effects of the Nuclear Generating Station.

Over the 7½ year inventory and monitoring period there have been no obvious changes in species presence nor habitat use patterns by reptiles or by large mammals, except for beaver. Initially beaver were present in low numbers and minor activity. However, with a continuous and monitored outflow of water from Goosequill Pond their activity became localized in the pond effluent stream flow area.

Small mammal populations have shown more fluctuations. It has appeared that most of these fluctuations were associated with various agricultural practices, particularly those related to irrigation. When Grid 1 was allowed to go to the old field condition, ground squirrel numbers were reduced and prairie voles increased. The burning of the field reduced the voles and allowed deer mice to increase. The bulldozing and burning of weeds east of the fence and along the irrigation ditch on Transect 4 in the Spring of 1974 resulted in the reduction of the populations of deer and house mice. The channelization of the Goosequill Ditch along Transect 7 several times was coincident with a decline in voles and a rise in jumping mice. Flooding of the south ends of Grid 3 and Transect 5 by irrigation water runoff from neighboring fields preceeded declines in the numbers of voles captured in those areas.

Indeed, prairie voles (Microtus ochrogaster) were initially present on our sampling areas in fair numbers but since 1975 have been caught only in low densities. Likewise, deer mice (Peromyscus maniculatus) numbers have decreased through the years from their initial high densities but have been stable since 1976. There have been periodic irruptions of harvest mice and jumping mice but in both cases these seem to be related to weather and agricultural practices. Prairie dog (Cynomys ludovicianus) towns have periodically been poisoned and hence greatly reduced temporarily in numbers, but have always recovered. And lastly, ground squirrels are the only species which seem to have disappeared from the environment.

Such fluctuations have given rise to discussion about whether sampling areas should be protected from all activities. The area was historically agricultural before the Nuclear Generating Station was built. The channelization of irrigation ditches, burning of weeds, poisoning prairie dog towns, etc., are all traditional agricultural practices and are part of the "environment." To leave areas unattended by man does not mean they will not change. Natural succession along unburned irrigation ditches and in old fields would, in itself, bring about changes in species composition. Allowing prairie dog towns to increase without the natural predators that were present 100 years ago (e.g., black-footed ferrets) would also be somewhat "artificial." Thus, since the goal for the area seemed to be to maintain agriculture as previously pursued and not to establish a "natural" wildlife park without human intervention, the continuance of normal agricultural practices and the fluctuations they cause seemed the more "natural" course to follow.

The species presence of breeding amphibians and their apparent relative densities have varied from year to year depending upon temperature and moisture conditions. The only obvious trends have been: (1) the appearance of leopard frogs (Rana pipiens) in 1977. Given several years of no sightings and now several years with sightings becoming more frequent, I conclude they are a new addition and not a species missed in the inventory phase. However, I cannot correlate their appearance with any obvious environmental change as all other amphibian species are still present and were breeding in good numbers in Spring 1979. (2) Spiny soft-shelled (Trionyx spiniferus) and snapping turtles (Chelydra serpentina)do not now seem as abundant in the rivers as in the early years of the study. But, again, this downward trend in numbers does not seem to be correlated with any obvious changes in the environment, especially due to the operation of the Generating Station.

MONITORING PROGRAM

Effectiveness

It is difficult to conclude how effective an environmental monitoring program is. If effective means that the program measures well those factors that have been affected by operation of the Nuclear Generating Station, then it is difficult to conclude that the program (or any monitoring program) has been effective. The major problem here is in not being absolutely certain, a priori, what environmental influences a given modification (e.g., establishing a Nuclear Generating Station) will have. Indeed, if anyone could definitively answer such questions, we would not need monitoring programs. However, if effective means--does the program measure those parameters it is designed to measure--then I can conclude that monitoring has been effective in measuring species presence and certain population parameters. Since the ultimate effect of a modification on these animals should affect these parameters, then we have an index to whether the populations have been adversely or beneficially affected.

The major disadvantage of the monitoring program is that it simply notes when and whether species are showing population declines and/or local extinction. We do not have good measures of causations, except for the heavy metal analyses, but rather they must be sought as we see numbers changing. However, this is a problem common to vertebrate monitoring. By sampling more often (monthly or bimonthly) we could follow population trends better, determine if numbers were changing because of mortality or natality factors, and have a closer coupling of number changes to weather, agricultural practices and variations in operation of the Nuclear Generating Station. However, such sampling would be extremely expensive and probably economically unwarranted.

TERRESTRIAL INVERTEBRATES

by

J. Wayne Brewer

and

Judy Bodenham

INTRODUCTION

Operation of the Fort St. Vrain Nuclear Generating Station could create environmental changes that would alter populations or biological cycles of terrestrial invertebrates in the area. According to previous reports (1, 2) the minor increases in radiation levels expected near the Station probably would not affect most invertebrates. However, hot water discharged from cooling towers into man-made or natural drainage systems could affect them since studies have shown many species of invertebrates to be sensitive to even minor changes in temperature (3, 7, 8). An inventory of invertebrate species was conducted near the Station and six groups representing different ecological habitats were selected for monitoring from 1972 through 1979. This report presents a summary and analysis of the data collected on those groups.

METHODS

A description of the study area was presented in an earlier report (4). The location of pit fall trap rows 2, 3 and 4 is shown in Figure 1 (row 1 was abandoned early in the study). Details of the procedures used have been presented previously (4), however, the following changes have since occurred: In January, 1974 the Malaise trap was discontinued for diurnal invertebrates when it was destroyed by a storm. It was felt that the data obtained did not justify replacement cost. In January, 1975 the sampling period was changed from weekly to monthly intervals. It seemed reasonable that the large data base available made it possible to monitor populations adequately with reduced sampling periods. In January, 1976, Ms. Bodenham assumed responsibility for identification of the Formicidae when the services of Dr. Snelling were no longer available. Beginning January, 1979 the black light trap was not established during the winter because reduced activity at that time made collection unnecessary.

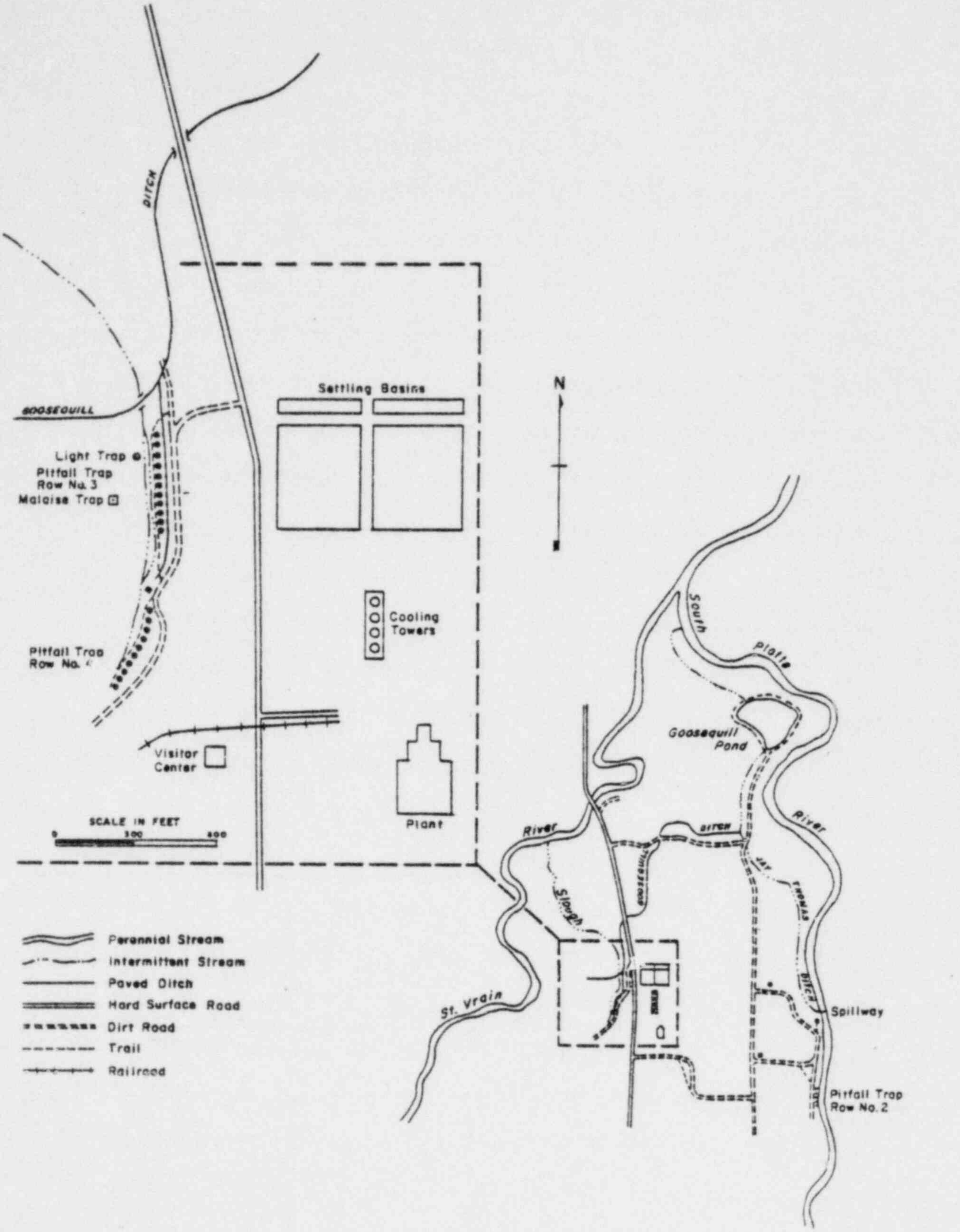


Figure 1. Fort St. Vrain Nuclear Generating Station and environs, showing invertebrate collection sites.

RESULTS AND ANALYSIS

Collembola

A list of the species of Collembola collected from three rows of pit fall traps near the Fort St. Vrain Nuclear Generating Station site and serviced from 1972 until 1979 is presented in Table 1. The distribution of Collembola was quite uniform in that all species were collected at all three of the sampling sites located at varying distances from the Generating Station. Population levels of the different species varied considerably during the study but that seemed to be primarily a function of natural population fluctuations. Species diversity of Collembola in the area was analyzed using Sorenson's quotient of similarity (5). The procedure for calculating this similarity index has been previously reported (4). The similarity index for two areas having identical species composition would be 1.000. The index for two areas in which only 50% of the species were found in both situations would be 0.500. We compared species collected each year to all years to determine if species composition of the area changed over the course of the study. As shown in Table 2, the similarity quotient for all yearly comparisons was high, ranging from 0.928 (1973 versus 1975) to 1.000 (several couplets). This indicated that the species composition of Collembola did not vary substantially from 1972 to 1979. Since the Nuclear Generating Station was partially operational at various times beginning about 1976, these results suggest that the operation periods did not adversely affect species composition in the areas surrounding the Station. We also compared total collections from all years from the three different sampling sites as shown in

Table 1. Species of Collembola collected from pit fall traps at the Fort St. Vrain Nuclear Generating Station Site, Platteville, Colorado, 1972-1979.

Collembola

Entomobryidae

Entomobrya nivalis (L.)

Entomobrya unostrigata Stach

Entomobryoides guthriei (Mills)

Lepidocyrtus cyaneus Tullberg

Tomocerus vulgaris (Tullberg)

Hypogastruridae

Hypogastrura armata (Nicolet)

Hypogastrura matura (Folsom)

Isotomidae

Isotomurus palustris (Muller)

Proisotoma minuta (Tullberg)

Pseudachorutes subcrassoides (Mills)

Pseudosinella rolfsi Mills

Sminthuridae

Bourletiella arvalis (Fitch)

Sminthurinus elegans (Fitch)

Sminthurides pumulis (Krausberger)

Xenylla sp.

Table 2. Matrix of Sorenson's quotient of similarity comparing species composition of Collembola collected in the environs of the Fort St. Vrain Nuclear Generating Station by year from 1972-1979.

	1972	1973	1974	1975	1976	1977	1978	1979
1972	-	1.000	.965	.928	.965	1.000	.965	.965
1973		-	.965	.928	.965	1.000	.965	.965
1974			-	.962	1.000	.965	1.000	1.000
1975				-	.962	.928	.962	.962
1976					-	.965	1.000	1.000
1977						-	.965	.965
1978							-	1.000
1979								-

Table 3. Matrix of Sorenson's quotient of similarity comparing species composition of Collembola collected in the environs of the Fort St. Vrain Nuclear Generating Station by pit fall trap row.

	Row 2	Row 3	Row 4
Row 2	-	.965	.965
Row 3		-	1.000
Row 4			-

Table 3. The results indicate that the species composition of those areas was similar over the seven years of the study with quotients of similarity ranging from 1.000 to 0.965.

Annual variations in populations of Collembola collected from pit fall traps are presented in Figure 2. Mean monthly collections of Collembola were over 60,000 individuals in 1973 but declined to a low of slightly more than 9,000 in 1975. Thereafter, populations generally increased and remained at approximately the 1973 levels for 1977 and 1978. A comparison of numbers of Collembola from the three rows of pit fall traps is presented in Figure 3. It is evident the number of individuals collected varied considerably from the three areas sampled during the study. Collections from Row two, the sample site located furthest from the plant, were low compared to Rows three and four, which were much closer to the Generating Station. General population trends, however, were similar from all three areas, with the exception that populations around Row three did not recover from the 1975 low as quickly as populations from Rows two and four.

As with species composition, it appeared that population levels of Collembola in the general environs of the Nuclear Generating Station have not been affected adversely by operation of the Station. Present population levels and species composition are now comparable to those occurring in the area at the beginning of the study.

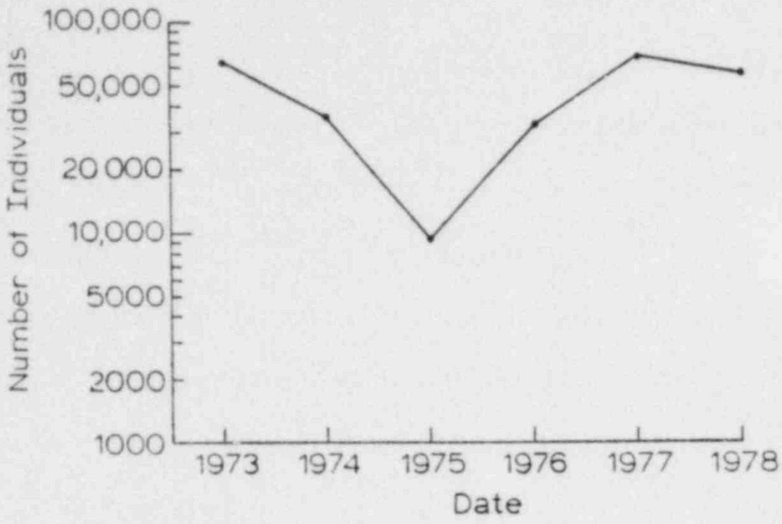


Figure 2. Total number of Collembola collected from pit fall traps near the Fort St. Vrain Nuclear Generating Station, Platteville, Colorado, 1973-1979.

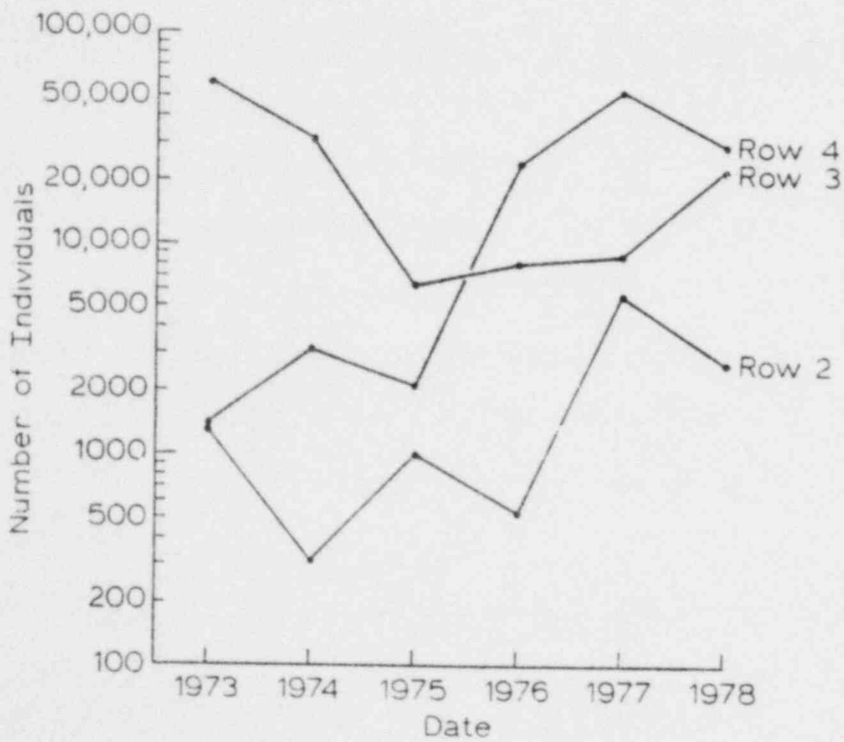


Figure 3. Number of Collembola collected from pit fall traps near the Fort St. Vrain Nuclear Generating Station, Platteville, Colorado, 1973-1979.

Formicidae

A list of the species of Formicidae collected in the vicinity of the Nuclear Generating Station during this period is presented in Table 4. Species distribution varied for the three areas but most species were common to all areas.

Annual variations in population levels of Formicidae collected from all three rows of traps is presented in Figure 4. Populations were low in 1973 and 1974 but began a general increase in 1975 that continued, with minor exceptions, to a peak in 1979. A comparison of collections from the individual sample areas is presented in Figure 5. As with the Collembola there was variation in the number of individuals collected from the different areas. Population levels were highest from Row two, the area most distant from the Station. In general, trends in population shifts were similar in collections from the three areas. An exception was in the collections for 1979 where numbers decreased slightly from Row 3, and drastically for Row 4 but increased greatly for Row 2. Since Rows 3 and 4 are much closer to the Generating Station than Row 2, and thus should be more affected by any environmental changes produced by its operation, it is possible that the population declines observed from those areas were related to increased activity of the Station in 1977 and 1978. Population changes in biological systems are rarely immediate. It is possible that the above changes are lagging influences of earlier environmental effects caused by operation of the Station. Such changes could be caused by various interrelated environmental factors such as an increase in temperature or humidity, a modification of vegetation composition, an altered food chain, or a modified trophic level response which in turn create invertebrate stresses.

Table 4. Species of Formicidae collected from pit fall traps at the Fort St. Vrain Nuclear Generating Station site, Platteville, Colorado, 1972-1979.

Formicidae

Formicinae

Lasius latipes (Walsh)

Camponotus nearcticus Emery

Camponotus sayi Emery

Camponotus vicinus Mayr

Formica bradleyi Wheeler

Formica fusca Linne

Formica lasioides Emery

Formica limata Wheeler

Formica cinerea lepida Wheeler

Formica neoclara Emery

Formica neogagates Emery

Formica perpilosa Wheeler

Formica subnuba Emery

Lasius niger neoniger Emery

Lasius pallitarsis (Provancher)

Polyergus breviceps Emery

Formica obscuripes Forel

Formica pallidefulva nitidiventris Emery

Lasius murphyi Forel

Lasius interjectus Mayr

Table 4. (Cont.)

Dolichoderinae

Dorymyrmex pyramicus (Roger)

Tapinoma sessile (Say)

Myrmicinae

Myrmica brevinodis Emery

Myrmica brevispinosa Wheeler

Myrmica sabuleti americana Weber

Pheidole pilifera coloradensis Emery

Pheidole bicarinata Mayr

Pogonomyrmex occidentalis (Cresson)

Solenopsis molesta validiuscula Emery

Stenamma brevicorne Mayr

Ponerinae

Ponera trigona opacior Forel

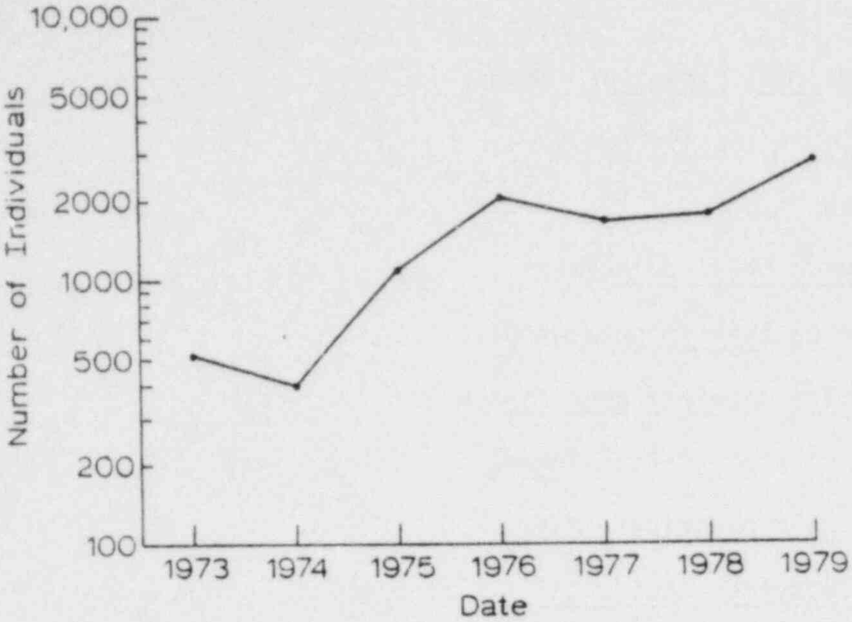


Figure 4. Total number of Formicidae collected from pit fall traps near the Fort St. Vrain Nuclear Generating Station, Platteville, Colorado, 1973-1979.

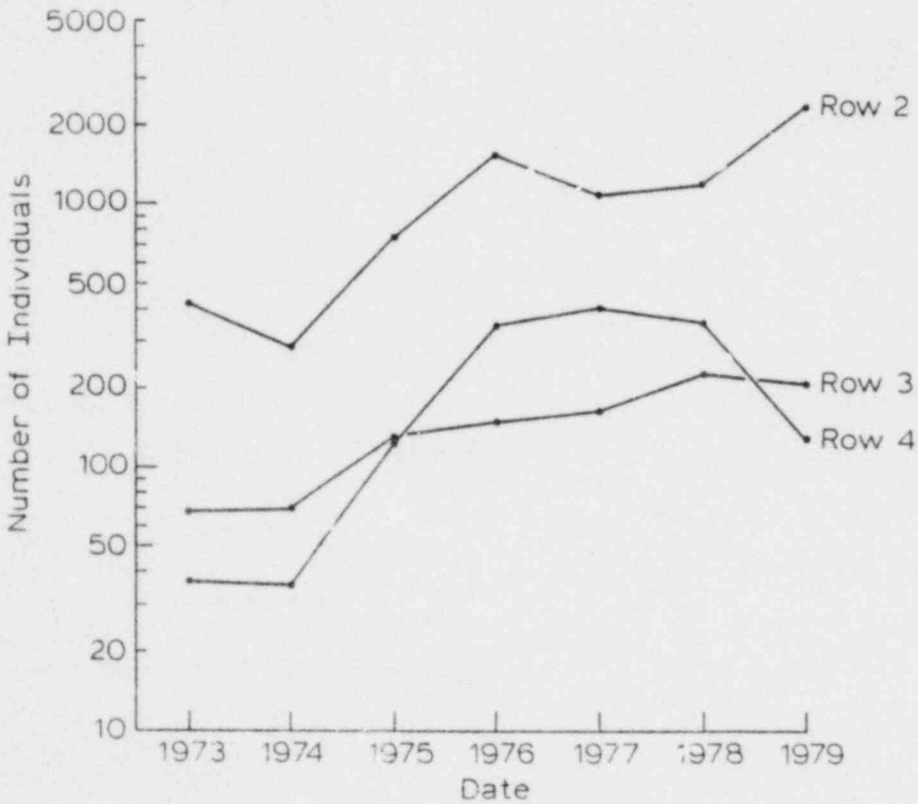


Figure 5. Number of Formicidae collected from pit fall traps near the Fort St. Vrain Nuclear Generating Station, Platteville, Colorado, 1973-1979.

IMAGE EVALUATION TEST TARGET (MT-3)

6″

<u>Silpha ramosa</u>

Biological studies showed that both adult and immature carrion beetles feed on dead animal carcasses, mainly small rodents (4). Consequently, this insect was considered important to the study because of its high level in the food chain and the possibility of biological magnification of changes caused by operation of the Station. Population levels of adult and immature forms of *S. ramosa* collected during the study are shown in Figure 6. The number of adults remained relatively constant with peak levels occurring in 1975 followed by a slow decline through 1978 and a resurgence in 1979. Population levels of the immature forms followed a similar pattern but with levels fluctuating more than those of the adults. The data from 1979 indicated that populations were increasing and that the declines seen earlier were probably a result of natural variation rather than an influence of operation of the Generating Station.

Data on collections of *S. ramosa* adults from the three areas sampled by pit fall traps are presented in Figure 7 and similar data on the immatures are shown in Figure 8. Both forms were collected in high numbers throughout the study from rows three and four but infrequently from row two. Since populations were consistently highest from row three (Figures 7 and 8), and that is the row most likely influenced by hot water discharge (4), it seems unlikely that *S. ramosa* populations are being adversely affected by operation of the Station. Thus, data on general population levels and those collected from specific areas indicated that populations of this species have not been reduced by operation of the Station.

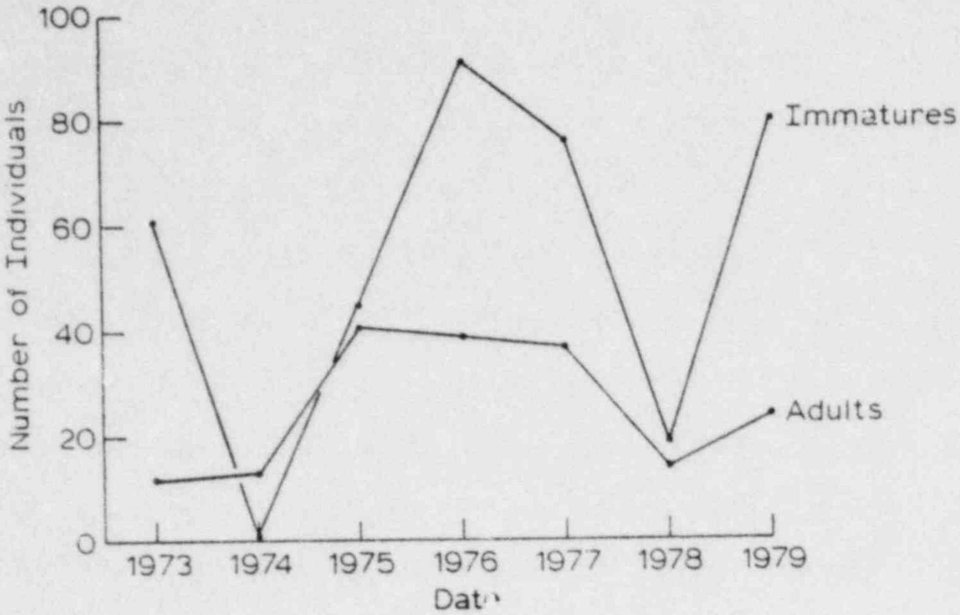


Figure 6. Mean number of Silpha ramosa collected per month from pit fall traps near the Fort St. Vrain Nuclear Generating Station, Platteville, Colorado, 1973-1979.

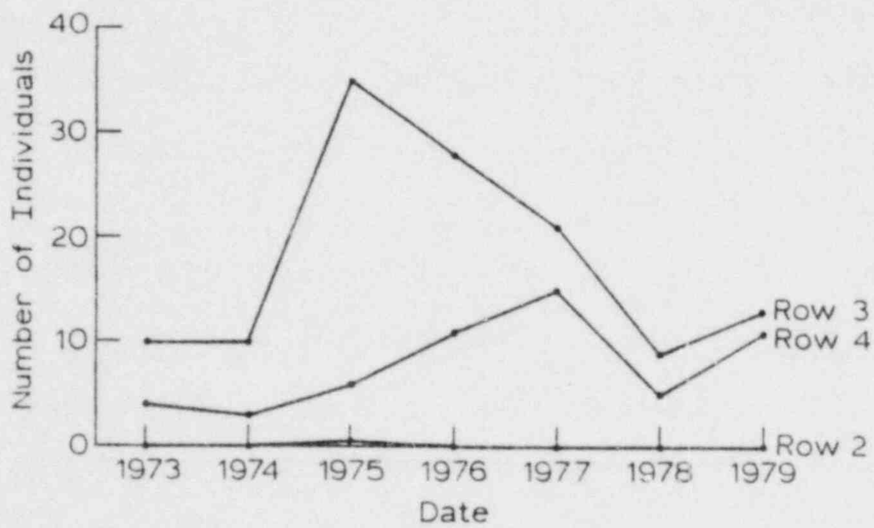


Figure 7. Mean number of Silpha ramosa collected per month from pit fall traps near the Fort St. Vrain Nuclear Generating Station, Platteville, Colorado, 1973-1979. (Adult form.)

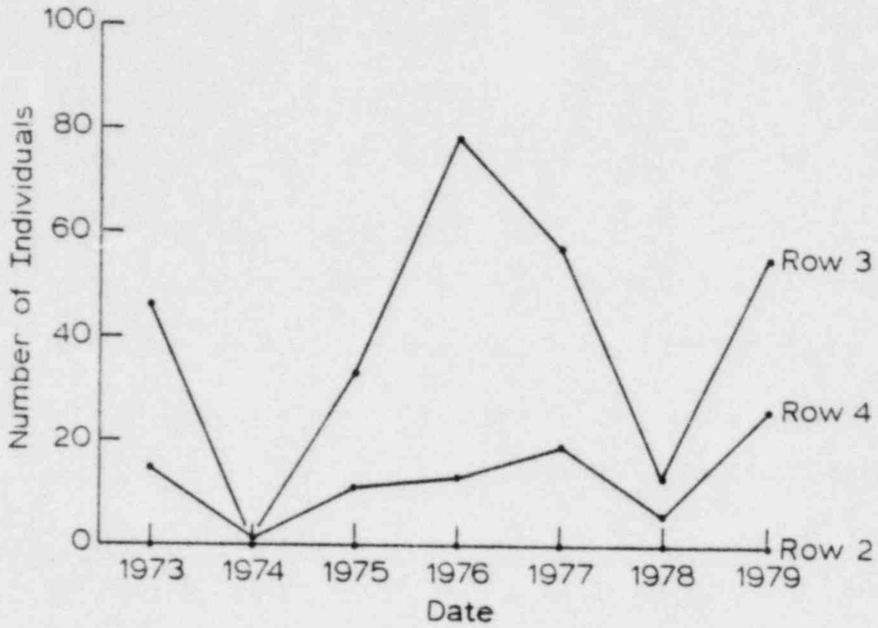


Figure 8. Mean number of Silpha ramosa collected per month from pit fall traps near the Fort St. Vrain Nuclear Generating Station, Platteville, Colorado 1973-1979. (Immature form.)

Araneida

The number of Araneida (spiders) collected during the study is presented in Figure 9. Population levels varied considerably in the area beginning with relatively low levels in 1973 and reaching a peak in 1975 followed by a consistent decline through 1976, 1977, 1978 and 1979. Thus, it is evident that population levels in the vicinity of the Generating Station have been reduced since 1975. It is not possible to determine the reason for the decline from our studies but it seems correlated with increased activity of the Generating Station. We must note, however, that even after several years of declining populations the levels are still comparable to those at the beginning of the study.

A comparison of collections from the three sample areas is presented in Figure 10. Collections from Row two, which is located at the greatest distance from the Station, followed the general trend of total collections discussed above. However, collections from Rows three and four varied and the population declines were less severe. Collections from Row four showed numbers increased from 1977 to 1978 with a moderate decline in 1979. Population levels from area three declined from 1977 until 1978, then increased slightly in 1979.

Consequently, although the general populations of Araneida are declining in the vicinity of the Station, the data from individual sample areas suggest the cause is probably not due to the operation of the Station, since collections from the areas most immediate to it do not follow the general trend.

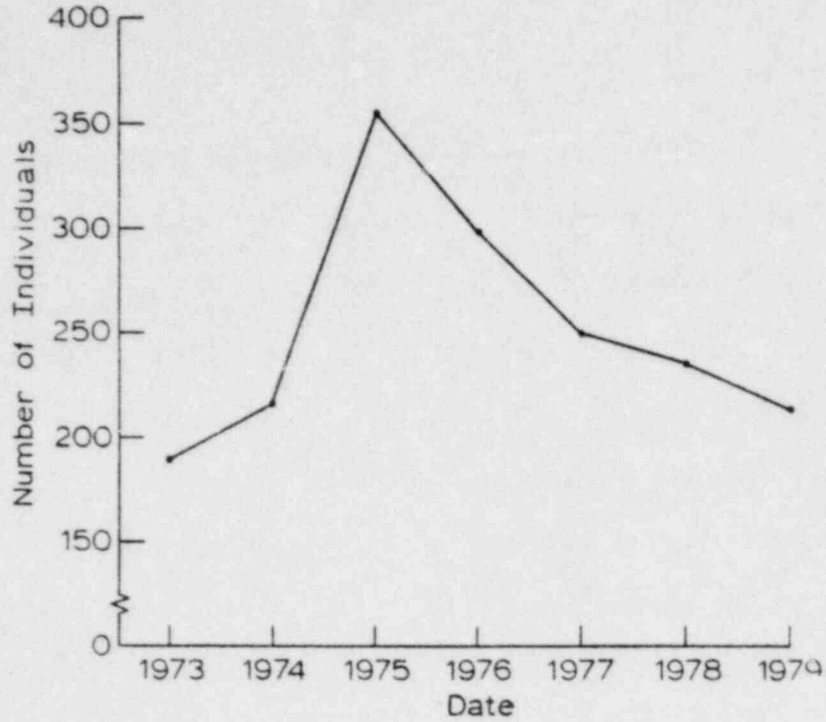


Figure 9. Mean number of Araneida collected per month from pit fall traps near the Fort St. Vrain Nuclear Generating Station, Platteville, Colorado, 1973-1979.

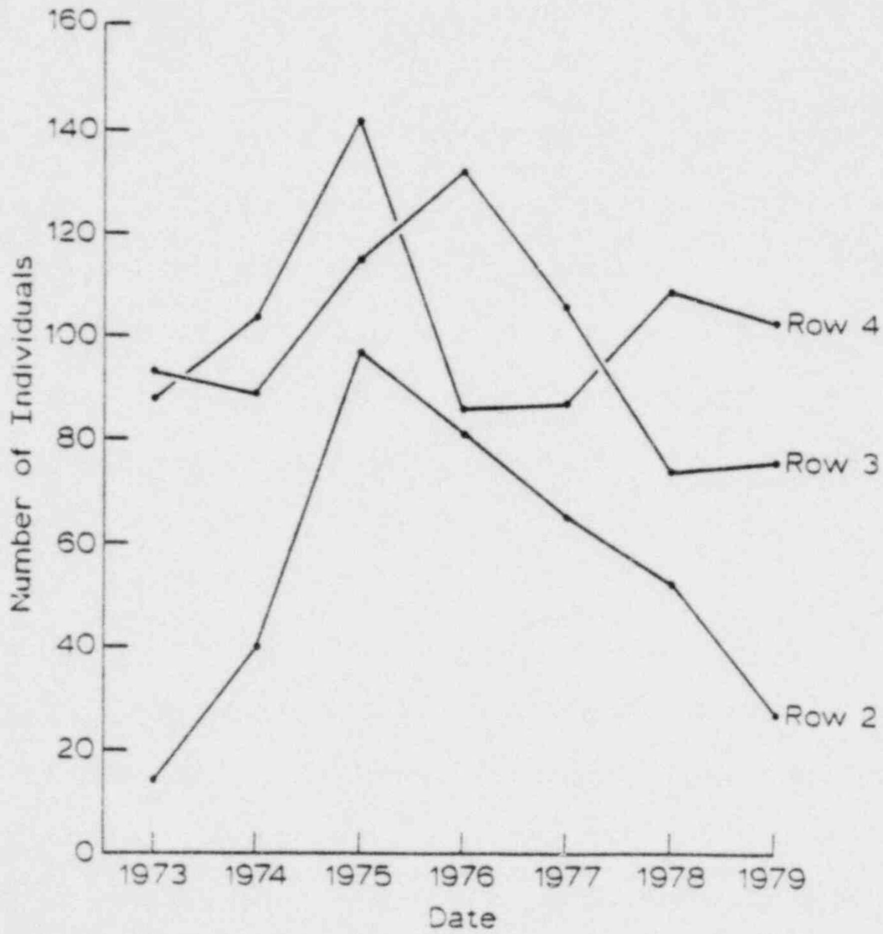


Figure 10. A comparison of collections of mean number of Araneida from the three sample areas near Fort St. Vrain Nuclear Generating Station, Platteville, Colorado, 1973-1979.

Tricoptera

Tricoptera, or caddisflies, are nocturnal, aerial invertebrates that were collected in large numbers in a black light trap during the study. The maximum number of individuals collected per month for the years 1973 through 1979 is presented in Figure 11. Population levels were high in 1973, declined in 1974 and 1975, increased slightly in 1976 and 1977 and remained stable in 1978 and 1979.

Population levels of Tricoptera vary and it appears likely that the observed changes in numbers were a result of natural fluctuations. For example, the low levels in 1975 may be a result of the lower than normal moisture levels that occurred that year. However, the fact remains that the population has declined since the beginning of the study and although increased numbers have been collected in recent years, levels are still below those at the beginning of the study. Since the immature stages of this organism are aquatic, they could be affected by changes in water temperature caused by the hot water discharge by the Station. For example, Fey (7) demonstrated that increased temperature of a river caused by a power station eliminated the quiescent stage of one species of Tricoptera and advanced emergence time three to four months. Earlier, Nebeker (8) showed that premature emergence could eliminate species if air temperatures were lethal, as would be the case for Tricoptera during winter months. It cannot be demonstrated that the decline in numbers of Tricoptera was due to the operation of the Station, and in fact, numbers have increased somewhat from 1975 until 1979, a period when time of Station operation generally increased. Population levels have not approached those at the beginning of the study; however, and it is possible that the reduced numbers are a result of changes caused by the Station.

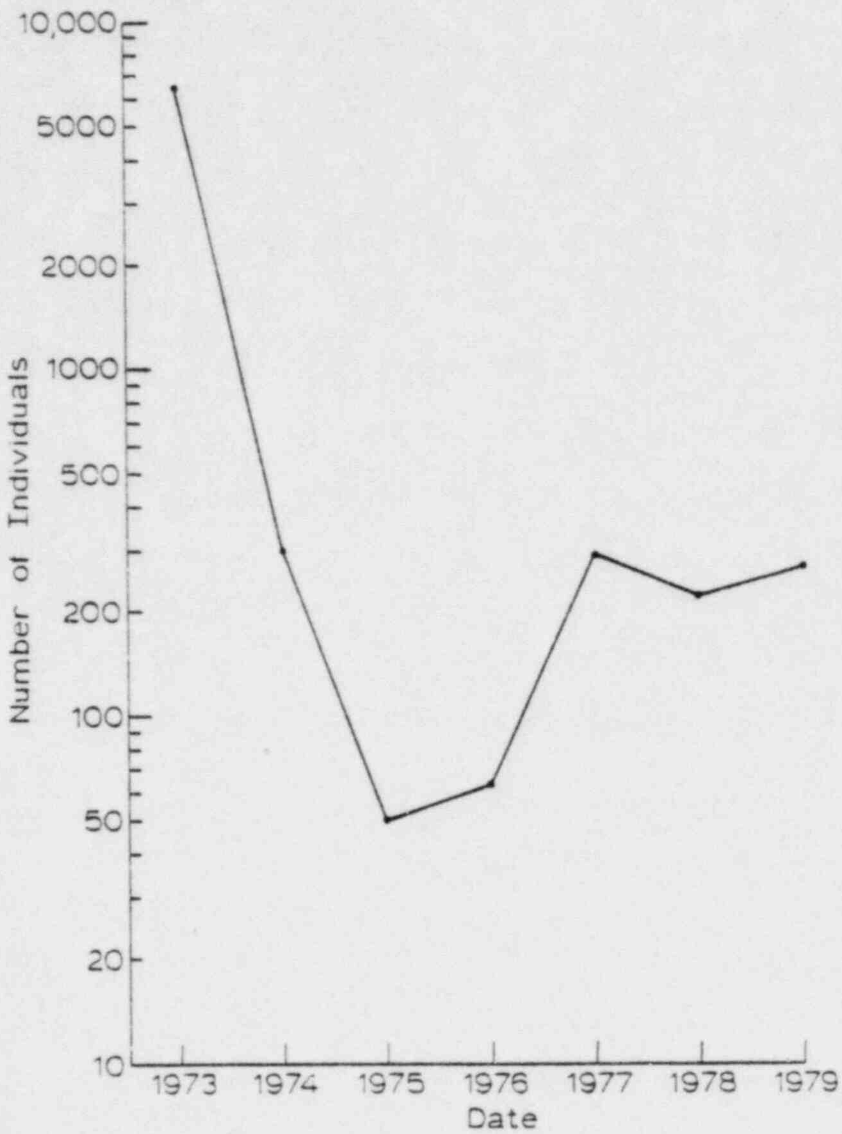


Figure 11. Maximum number of Tricoptera collected per month from a black light trap located near the Fort St. Vrain Nuclear Generating Station, Platteville, Colorado, 1973-1979.

Heteroceridae

The heterocerids, or mud-loving beetles, live in the mud shores of the slough near the Generating Station. The maximum number of beetles collected in the black light trap per month for the years 1973 through 1979 is presented in Figure 12. Population levels of this beetle declined from a high in 1973 to a low in 1975, similar to the trend in Tricoptera populations previously discussed. However, beginning in 1976, population levels increased about to the 1973 levels. In 1978 and 1979 population levels were somewhat lower than in previous years, but higher than the low of 1975. Thus, it appears that the fluctuations in population levels of heterocerids is not correlated with operation of the Station but rather is the result of natural factors. For example, it is likely that a major factor causing the low populations recorded in 1975 was the low moisture level that occurred during that year, as discussed for the Tricoptera.

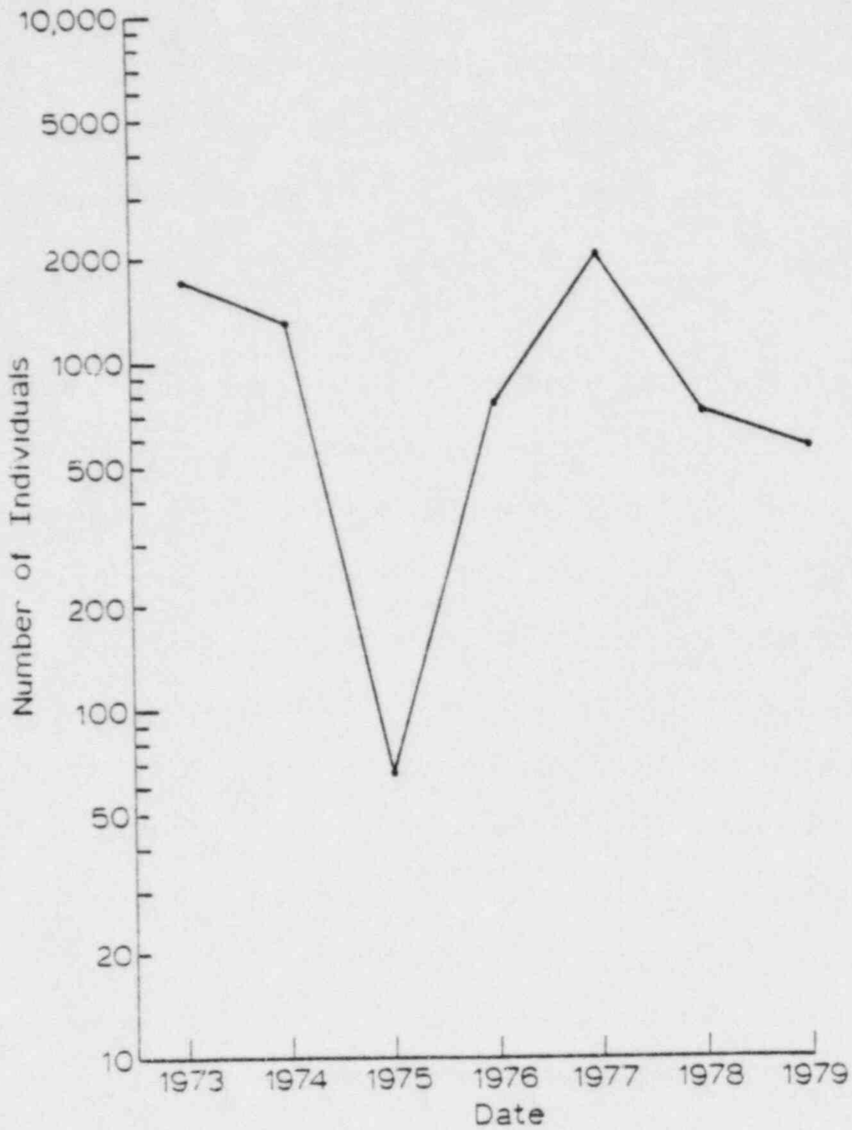


Figure 12. Maximum number of Heteroceridae collected per month from a black light trap located near the Fort St. Vrain Nuclear Generating Station, Platteville, Colorado, 1973-1979.

SUMMARY

Population levels of terrestrial invertebrates collected in the environs of the Fort St. Vrain Nuclear Generating Station varied considerably during the study period of 1972 through 1979. However, the variation in population levels of the six groups monitored during that time seemed to be a result of natural fluctuations rather than operation of the Station. There are, however, two possible exceptions where adverse influences to invertebrate populations might have resulted from operation of the Station. First, a general population increase of Formicidae occurred during the latter stages of the study when collections from all areas were considered. However, a comparison of the individual sampling areas near the Station revealed a decline in numbers of individuals. The population decline was minor from row three, the site considered most likely to be influenced by heated discharge water, but greater from row four where the effect should be less serious. If the reduction in numbers of Formicidae was due to the operation of the Station, the opposite situation would be expected. We believe that the population decline in the area near the Station could have resulted from natural factors and not Station operation but it is not possible to rule out the latter possibility.

The second possible exception was in collections of Tricoptera where population levels declined compared to those at the beginning of the study. The Tricoptera is the group most likely to be affected by heated discharge water because the immature forms live directly in the water of the slough, and possibly, that of the concrete-lined drainage ditch. Thus, the population reduction of Tricoptera might be a direct result of the operation of the Generating Station. Some evidence to the contrary is that populations of heterocerid beetles followed the "mid-study" decline similar to that of Tricoptera but have since recovered to levels approximating those early in the study. Since these beetles live in the mud shores of the slough the effects of the heated discharge water would be less dramatic than for Tricoptera, but the similarity in population trends suggests that the fluctuations might be natural ones. Also, population changes in Tricoptera are known to fluctuate widely in natural situations and it seems probable the changes seen during this study were natural ones.

In general, we believe that the limited operation of the Fort St. Vrain Nuclear Generating Station to date has not caused changes in species composition nor population levels of terrestrial invertebrates considered in this study. In our opinion, construction of the Generating Station, and the loss of former suitable terrestrial invertebrate habitat in the area, have had more serious effects on the terrestrial invertebrate populations than the operation of the plant. Certainly, construction of a ten-story building with acres of parking lots and associated facilities is a drastic change from a former prairie environment.

The benefits of the monitoring program have been excellent. The monitoring provided a rare opportunity to follow changes in populations of terrestrial invertebrate species over an extended period of time.

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