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Macroscopic Benthos Populations in A South Dakota Power Plant Cooling Reservoir

Gordon B. Sloane

MACROSCOPIC BENTHOS POPULATIONS IN A SOUTH DAKOTA POWER PLANT COOLING RESERVOIR

BY

GORDON B. SLOANE

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MACROSCOPIC BENTHOS POPULATIONS IN A SOUTH

DAKOTA POWER PLANT COOLING RESERVOIR

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser

Head, Wildlife and
Fisheries Sciences
Department

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MACROSCOPIC BENTHOS POPULATIONS IN A SOUTH DAKOTA POWER PLANT COOLING RESERVOIR

Abstract

Gordon B. Sloane

The standing crop, distribution, seasonal variation, and entrainment of benthos were studied at the Big Stone Power Plant cooling reservoir. Benthos samples were collected from January 1979 through March 1980 utilizing a stratified random sampling design in 3 areas related to the thermal discharge site and cooling water intake site.

Maximum surface and bottom water temperatures in the discharge area were 42.0 C and 33.5 C respectively. The intake area had a maximum surface and bottom temperature of 32.0 C and 30.0 C respectively. Reservoir temperatures ranged from 0.0 C to 42.0 C during the study. Dissolved oxygen ranged from 0.2 to 15.6 ppm.

Chironomids were numerically and gravimetrically the most abundant organisms taken in the cooling reservoir. Numerically they constituted 94% of all organisms sampled. They were found in greatest numbers in the intake area of the cooling reservoir. Chironomids comprised 95% of the total dry weight. Oligochaetes were numerically the second most abundant organisms. They constituted 4% of total numbers and 1% of total dry weight. The mean standing crop of benthos in the cooling reservoir ($0.6 g/m^2$) was lower than the average for most North American lakes. Numerically the standing crop ($1,460/m^2$) was closer to the average North American lakes. Benthos populations were less abundant in the

discharge area of the cooling reservoir.

The rip-rap area of the cooling reservoir was sampled with artifical substrate baskets. Numerically chironomids comprised 65% of all organisms colonizing the baskets. Gravimetrically *Physa* spp. comprised 71% of the total mean biomass. This resulted from including the shells in the dry weight. Annual mean standing crop for the rip-rap area was 258mg/m^2.

Calculated 24-hour estimates of benthic organisms entrained ranged from a high of 1,010,625 in June 1979 to none in December 1979. Chironomids were the most commonly entrained organisms.

INTRODUCTION

The objectives of this study were to determine the following characteristics of the macroscopic benthos population in a power plant cooling reservoir: (1) estimation of the standing crop and seasonal variation; (2) evaluation of the potential effects of heated discharge water on abundance; (3) determination of the entrainment loss; and (4) estimation of the standing crop of the rip-rap area in the cooling reservoir.

If current predictions hold true, the electric-power industry will be producing 2 million megawatts of electricity by the year 2000 (Clark 1969). To satisfy this increased demand more than 600 new power plants will be constructed in the United States (Anonymous 1978). It is estimated that 20% of these new power plants will utilize artifical cooling ponds, lakes, or reservoirs for power plant cooling (Meredith 1973). These cooling ponds, lakes, and reservoirs can serve a multi-purpose function with proper power plant siting. They can yield other economic and social benefits in addition to fulfilling their primary role of dissipating waste heat from power plants (Metz 1977).

Benthic macroinvertebrates are essential components of the food web and their availability is reflected in the well-being of higher forms (EPA 1973). Trophic interrelationships and population dynamics of benthic fauna in lentic waters is poorly understood (Wetzel 1975). Benthos investigation in South Dakota has been limited to the Missouri River reservoirs (Schmulback and Sandholm 1962; Cowell and Hudson 1968), Lake Kampeska (Hartung 1968) and Lake Poinsett (Smith 1971). Knowledge gained about the ecology and population dynamics of macroinvertebrates from this study will add to the information on South Dakota benthos.

STUDY AREA

The Big Stone Power Plant and cooling reservoir, located in Grant County, South Dakota is owned jointly by Montana-Dakota Utilities Company, Norhtwestern Public Service Company, and Otter Tail Power Company. The cooling reservoir was completed in 1972 and includes granite rip-rapping of a baffle dike and encompassing levee. Big Stone Lake, on the South Dakota-Minnesota border provides water to the cooling reservoir. The coal-fired Big Stone Power Plant became operational in May 1975 and generates 440 MW of electric energy. It has the capability of circulating water from the cooling reservoir through its main condenser at a rate of 509.7 m^3/min (Wheeler 1979).

The cooling reservoir is 1600 m long, averages 800 m in width, and has a shoreline development of 1.9. The reservoir has a surface area of 145 ha, maximum depth of 10.0 m, and mean depth of 4.9 m at a water level of 341.1 m above mean sea level (msl) (Fig. 1). The water level fluctuated from a low of 340.1 m to a high of 342.0 m above msl during the study. The reservoir bottom is composed of compacted clay. An 8 cm layer of silt covers the clay bottom. A 40 by 70 m scour protection area consisting of granite rocks surrounds the point of discharge in the cooling reservoir. The bottom of this area was covered by a black crystalline-like substance. The cooling reservoir is slightly higher than the surrounding land and is frequently subjected to severe wind and wave action.

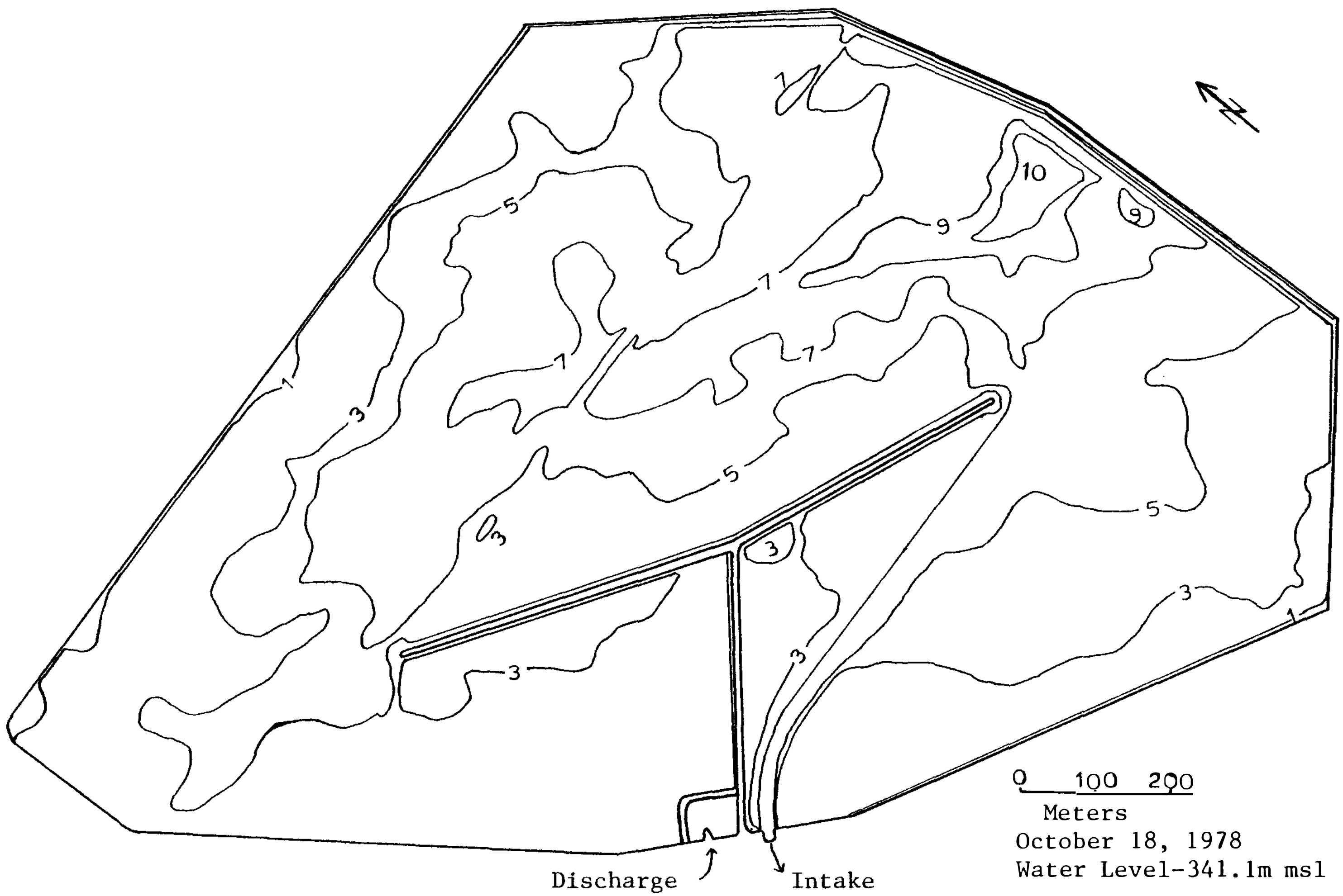

Fig. 1. Big Stone Power Plant cooling reservoir, South Dakota, with depth contours shown at a level of 341.1 m above mean sea level.

MATERIALS AND METHODS

Physicochemical Evaluation

Surface and bottom dissolved oxygen and temperature plus water transparency were measured during macroinvertebrate collections. Reservoir level data were obtained from records maintained by Big Stone Power Plant personnel.

Water transparency was measured with a 20.0 cm Secchi disk. A Lowrance Model LRG 1510B depth recorder was used to estimate reservoir depths. Recorded depths were transposed in 2.0 m intervals onto a shoreline map of the cooling reservoir. Shoreline development was calculated from a formula provided in Lind (1979). Dissolved oxygen and temperature determinations were made with a YSI (Yellow Springs Instrument Company) Model 54 Temperature and Dissolved Oxygen meter.

In-reservoir Sampling

A stratified random sampling scheme was used for this study. The baffle dike divides the reservoir into 3 regions; intake (Area I), mixing (Area II), and discharge (Area III) (Fig. 2). Utilizing a random grid technique within each area a total of 10 sampling stations were established in the reservoir (Fig. 2). Water depths ranged from 1.0 m at Stations 1, 7, and 10 to 10.0 m at Station 4. Sampling was conducted every other week from April 1979 through March 1980. Benthic macroinvertebrates were sampled with a Ponar dredge (sampling area = 225 cm^2). Three replicate hauls constituting a single sample, were taken at each of the 10 stations, making a total of 240 samples (720 dredge hauls) taken throughout the study period.

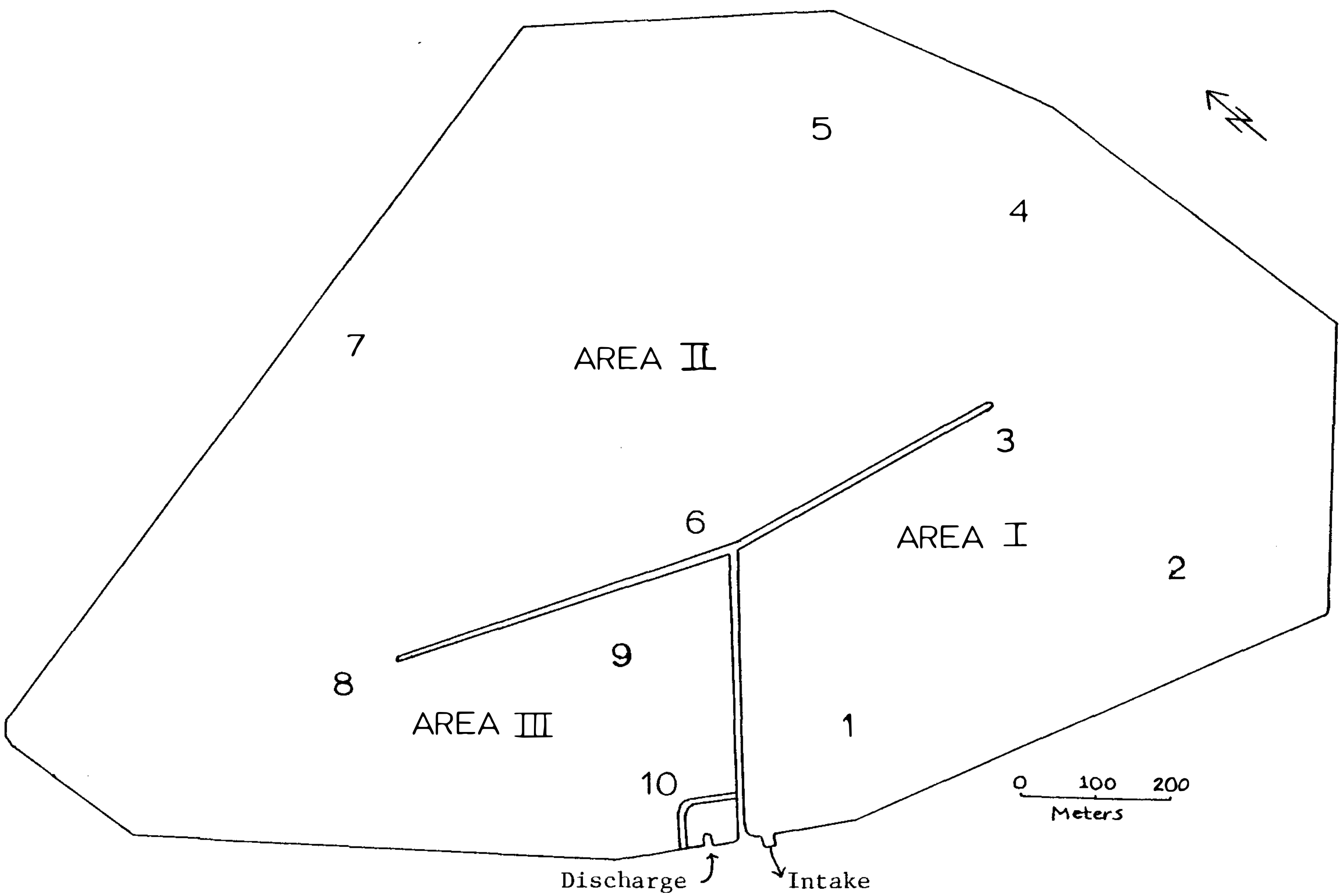

Fig. 2. Big Stone Power Plant cooling reservoir, South Dakota, with in-reservoir sampling stations shown.

Benthic macroinvertebrates are defined as bottom animals large enough to be seen by the unaided eye and retained by a U. S. Standard No. 30 sieve (0.595 mm openings) (EPA 1973; APHA 1978). Dredge hauls were partially sieved through a 0.5 mm mesh screened bucket immediately after collection in order to reduce sediment volume. Remaining organisms and large substrate material were washed into a 1 l widemouth jar containing 70% ethanol and rose bengal. Rose bengal, at a concentration of 100 mg/l, was used to increase organism visability during sorting (Mason and Yevich 1967).

Organisms were separated into taxonomic groups and counted. Representative specimens were preserved in 70% ethanol for identification. Permanent slides of specimens were made using CMC mounting media.

Organisms were identified to the lowest identifiable taxon. Keys by Beck (1968) and Mason (1968) were used for larval chironomid identification. Keys by Usinger (1956), Ward and Whipple (1959), Hudson (1971), Oliver (1971), Wiggins (1977) and Pennak (1978) were also used for some chironomids and for other groups of organisms.

Dry weight was determined to the nearest 0.1 mg using an analytical balance. Organisms were separated from the preservative and allowed to air dry for 15 minutes. They were then placed in previously weighed crucibles and oven dried at 105 C for 24 hours. Crucibles were removed from the oven and cooled to room temperature in a desiccator and reweighed (Lind 1979).

Entrainment Sampling

Samples of entrained benthic macroinvertebrates were collected at the Power Plant cooling water intake from February 1979 through January

1980. An attempt was made to obtain a 24-hour sample every other week from the surface and 4.0 m levels.

Samples were collected using Kenco Model 139 submersible pumps. The pumps were fitted with flexible hose having a 5.1 cm diameter. Water was pumped at a rate of 330 l/min from the intake bay in front of the trash racks through a 1.0 m by 3.0 m plankton sampling net with a mesh size of 333 microns. This flow yielded a 479,520 l sample for a 24-hour collection period. Samples were removed after 24 hours and preserved in 70% ethanol with rose bengal. Samples were returned to the laboratory and processed like the in-reservoir samples.

Rip-rap Sampling

Three sampling stations were randomly selected along the shoreline of each area within the cooling reservoir (Fig. 3). Monthly sampling was conducted from April 1979 through December 1979.

A rock-filled basket sampler measuring 30.0 cm by 12.0 cm by 12.0 cm was constructed from 2.5 cm by 5.0 cm mesh galvanized fencing fabric. The basket held approximately 20, 3 to 6 cm diameter granite rocks. At each shore station baskets were securely attached within the rip-rap 15.0 to 20.0 cm above the bottom.

The collection procedure consisted of placing the basket in a 0.5 mm mesh screened bucket while still submerged and then pulling both out of the water. Each rock was cleaned with a stiff-bristled brush to remove attached organisms. The samples were concentrated with a U. S. Standard No. 30 sieve and preserved in 70% ethanol with rose bengal (Mason et al 1970). The estimated total surface area of the baskets

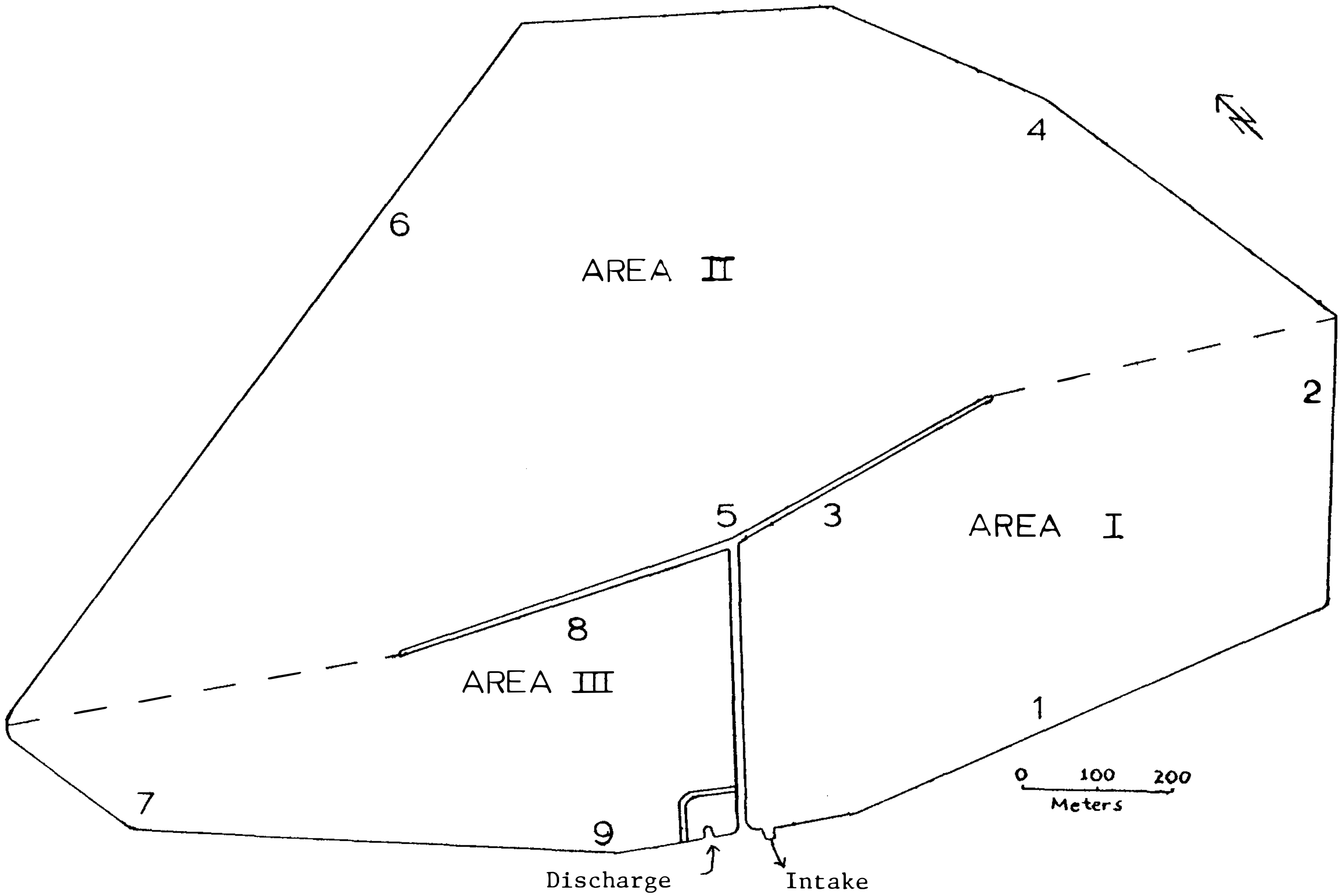

Fig. 3. Big Stone Power Plant cooling reservoir, South Dakota, with rip-rap sampling stations shown.

was 0.2 m^2. Samples were returned to the laboratory and processed like the in-reservoir samples.

Statistical Analysis

All data were analyzed using Analysis of Variance and Student-Neuman-Keuls multiple contrast procedure at the 0.05 level of confidence (Steele and Torrie 1960).

RESULTS AND DISCUSSION

Physicochemical Evaluation

Thermal stratification was observed in all areas during the study. Stratification was established by June and continued through September 1979 (Figs. 4, 5 and 6). Stratification was minimal in Area I (intake) but increased steadily in Area II (mixing). Area III (discharge) was stratified thermally throughout the entire study. In all 3 areas the stratification was artifically produced by the heated discharge water. The less dense, warmer water would layer above the cooler water and form a thermal plume. The plume configuration varied with wind and plant operating conditions. Maximum surface and bottom temperatures at the intake (Station 1) were 32.0 C and 30.0 C respectively. Discharge (Station 10) surface and bottom maximum temperatures were 42.0 C and 33.5 C respectively. The maximum difference in intake and discharge temperatures occurred in January 1980 when surface temperatures at the discharge exceeded those at the intake by 21.5 C. Bottom temperatures were 16.0 C at the discharge and 6.0 C at the intake during the same period. During the colder months 95% of the heated discharge water was diverted to the intake rather than recirculated through the entire reservoir.

Comparisons between mean winter (December through April) surface and bottom temperatures showed the heated effluent affecting the surface and bottom temperatures at Stations 8, 9 and 10. Mean summer (May through November) surface and bottom temperatures showed the heated effluent affecting surface temperatures at Stations 8, 9 and 10. However,

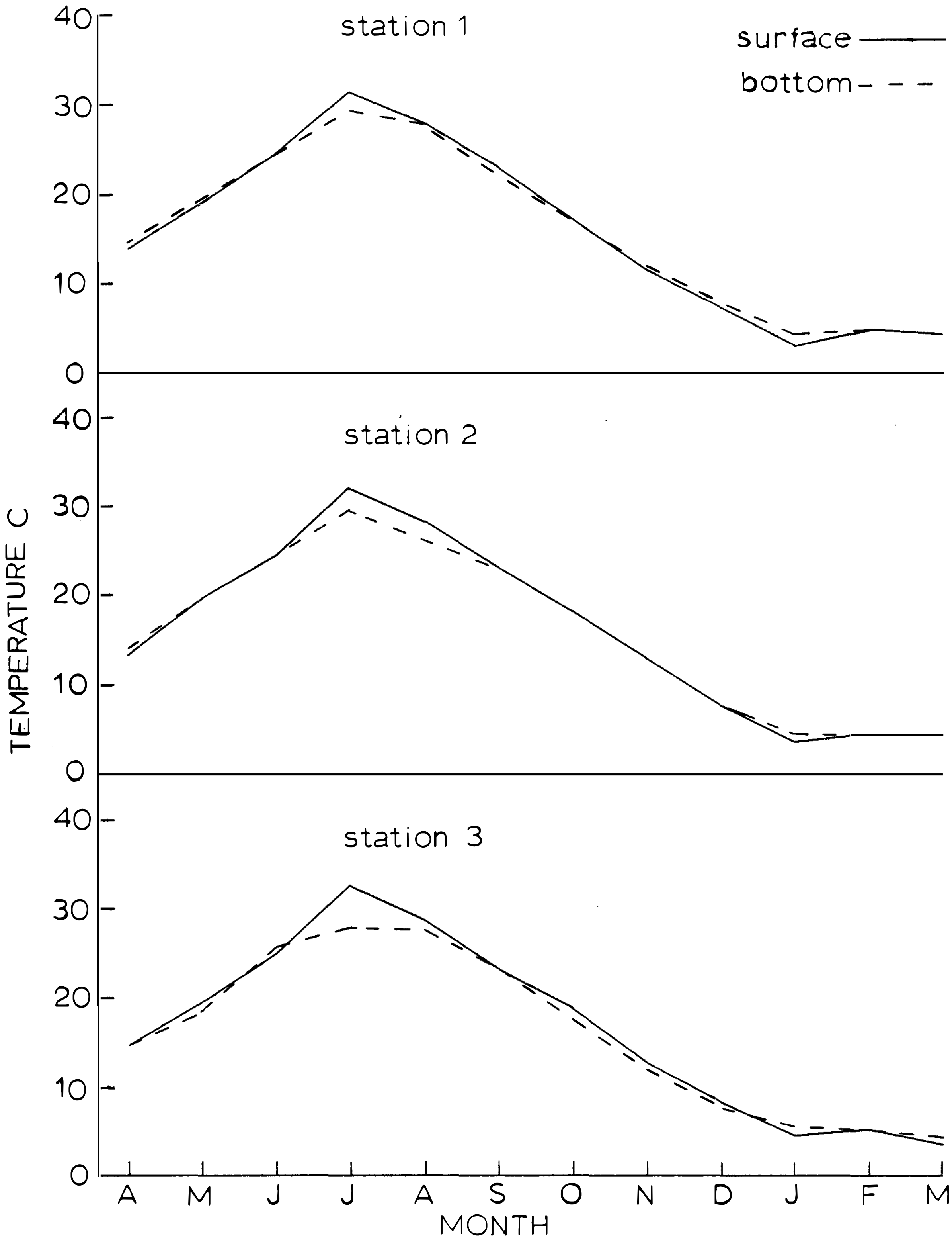

Fig. 4. Mean monthly surface and bottom temperatures from Area I, Big Stone Power Plant cooling reservoir (April 1979 through March 1980).

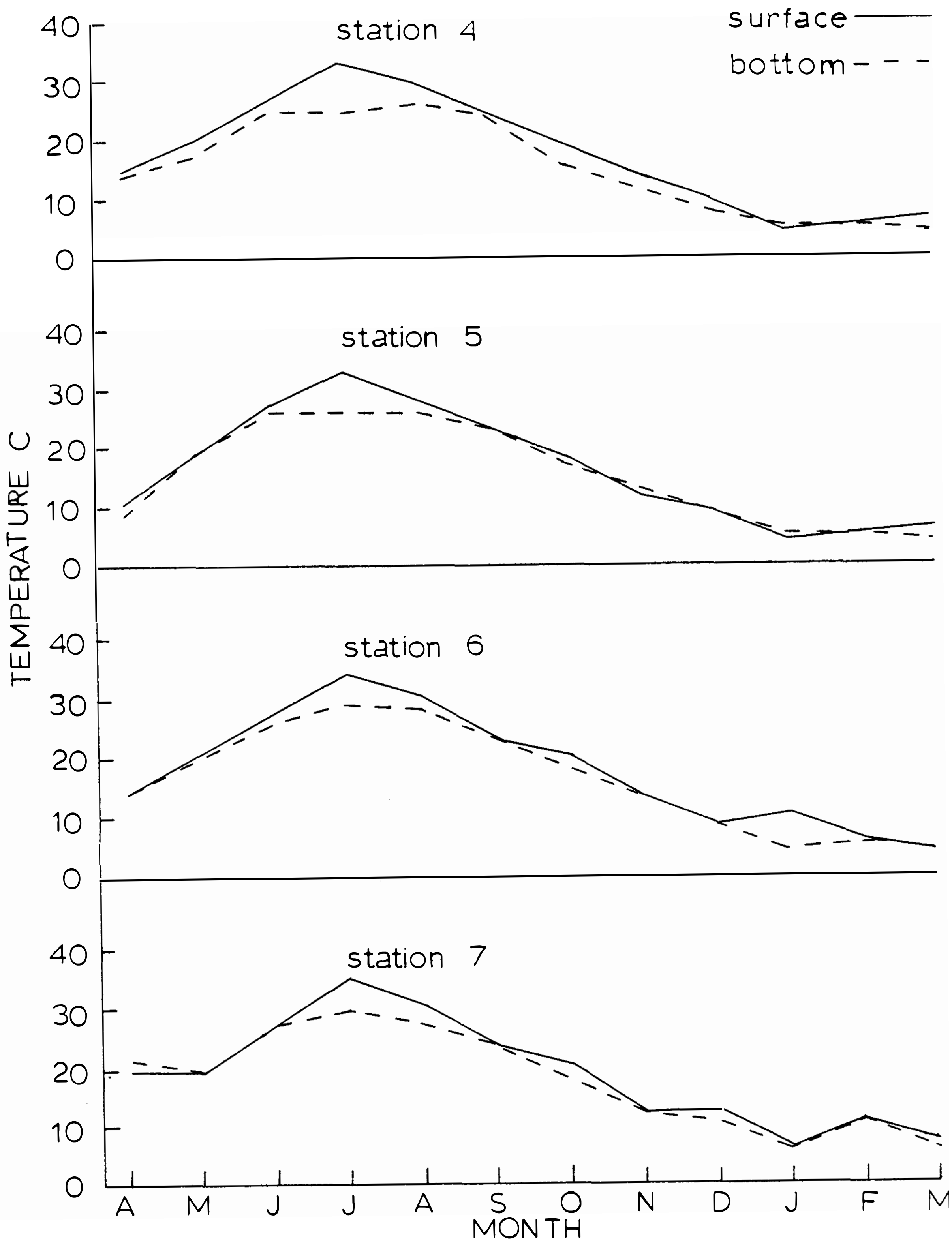

Fig. 5. Mean monthly surface and bottom temperatures from Area II, Big Stone Power Plant cooling reservoir, South Dakota (April 1979 through March 1980).

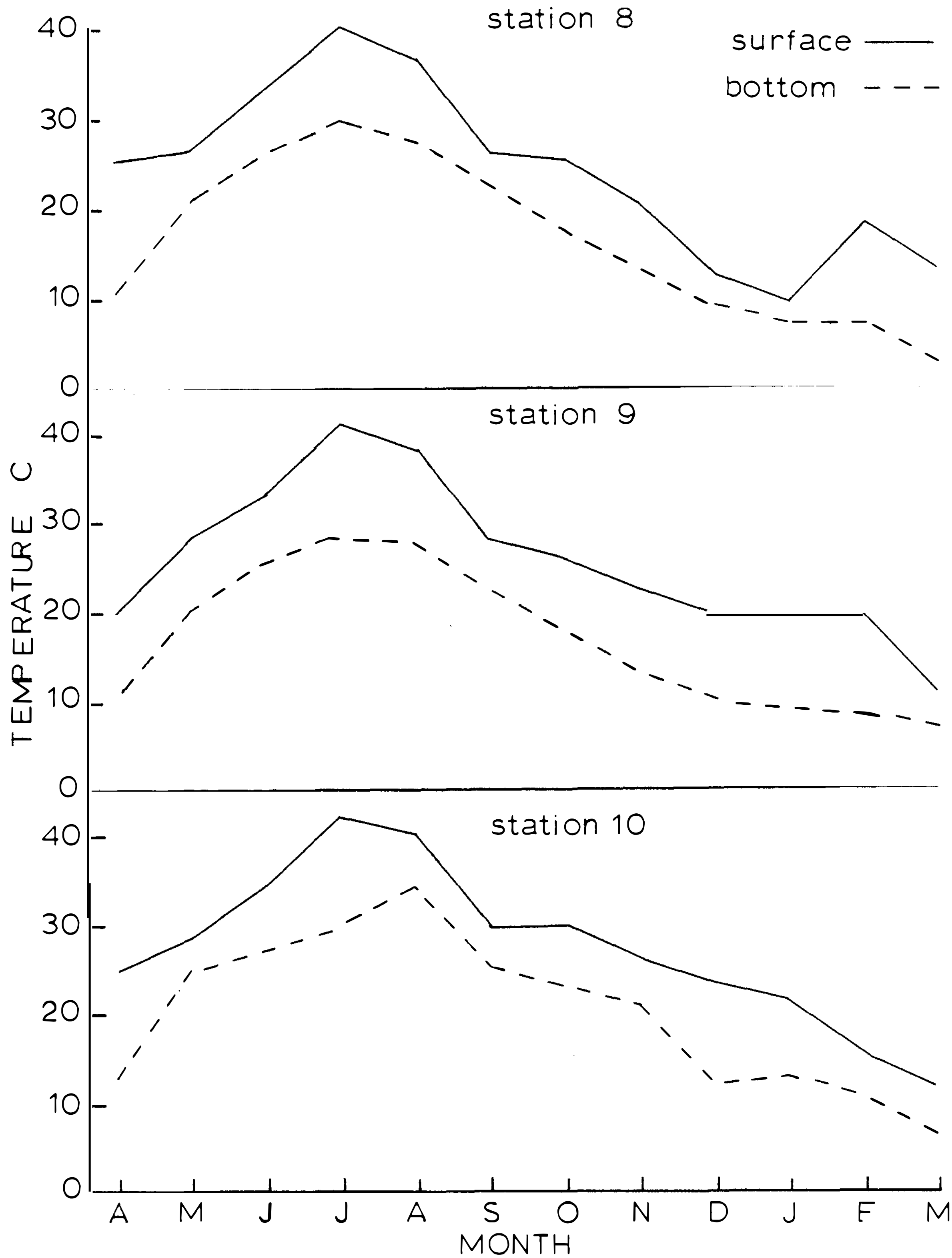

Fig. 6. Mean monthly surface and bottom temperatures from Area III, Big Stone Power Plant cooling reservoir, South Dakota (April 1979 through March 1980).

the heated effluent affected bottom temperatures only at Station 10 (Table 1).

during this study (Figs. 7, 8 and 9). Surface oxygen concentrations ranged from 15.6 ppm in April 1979 and January 1980 (Station 7) to 2.8 ppm in October 1979 (Stations 5 and 8). Bottom oxygen concentrations ranged from 15.5 ppm in April 1979 (Station 7) to 0.2 ppm in August 1979 (Station 4).

Bottom oxygen concentrations were higher than surface concentrations at Station 10 during April and November 1979 and January 1980. This may have been due to the inability of the warmer surface water to retain concentrations of dissolved gasses as high as the cooler, deeper water.

Secchi disc transparency ranged from 0.5 m at Station 10 to 4.0 m at Stations 4 and 5. Station 10 was the most turbid station due to discharge currents and wave action stirring bottom sediments. Station 8 was the second most turbid station. Although deeper than Station 10 it was located at the west end of the baffle dike and stronger water currents were observed there. Seasonal patterns in reservoir water clarity were observed; it was clearest in early summer and most turbid in late fall and early winter (Fig. 10). A more detailed physicochemical report of the reservoir can be obtained from Wheeler (1979).

In-reservoir Sampling

Dipterans were qualitatively and quantitatively the most abundant organisms in the cooling reservoir (Table 2). In many studies dealing with macrobenthos, chironomids were the most abundant organisms reported

Table 1. Winter (December through April) and summer (May through November) surface and bottom temperatures (C) and water depth (m), Stations 1 through 10, Big Stone Power Plant cooling reservoir, South Dakota (April 1979 through March 1980).

Period			Stations 1	2	3	4	5
Winter	Surface	mean	6.9	6.7	7.3	8.0	6.9
		range	0.5-17.0	0.5-17.0	0.5-17.8	0.5-19.0	1.0-12.0
	Bottom	mean	7.2	7.1	7.3	7.0	6.4
		range	2.0-18.5	3.0-18.5	3.0-17.0	1.5-18.0	1.9-11.5
	Water depth*	mean	1.8	3.3	5.2	9.1	5.4
		range	1.0-2.0	2.5-4.0	4.0-6.0	7.0-10.0	5.0-7.0
Summer	Surface	mean	22.1	22.6	22.8	22.8	23.4
		range	9.5-32.0	12.0-32.0	12.0-32.0	13.0-34.0	11.0-34.0
	Bottom	mean	22.0	22.2	21.8	20.9	21.7
		range	10.0-30.0	13.0-29.0	10.5-29.0	11.0-28.0	12.0-28.0
	Water depth	mean	2.8	4.1	5.9	9.9	7.0
		range	2.5-3.0	3.0-5.0	5.0-7.0	9.0-10.0	6.5-8.0

* Varied over time due to evaporation.

Table 1 (cont.).

Period			Stations 6	7	8	9	10
Winter	Surface	mean	7.2	11.0	13.9	16.5	18.5
		range	1.8-14.0	2.5-20.0	6.5-25.3	5.5-23.0	5.5-28.0
	Bottom	mean	6.2	9.7	8.3	8.7	10.8
		range	2.1-10.0	2.5-21.5	5.5-10.5	5.0-13.0	6.0-16.0
	Water depth*	mean	3.2	1.7	2.6	2.6	1.7
		range	2.5-4.5	1.0-2.0	2.0-3.0	2.0-3.0	1.0-2.0
Summer	Surface	mean	24.6	24.1	29.7	31.3	32.8
		range	12.0-36.5	11.0-35.0	18.0-41.0	18.3-42.0	18.3-42.0
	Bottom	mean	22.7	22.7	22.6	22.1	26.2
		range	13.0-31.0	12.0-31.0	13.0-31.0	13.0-29.0	18.3-33.5
	Water depth	mean	3.7	2.9	3.5	3.8	2.5
		range	3.0-4.0	2.0-3.5	3.0-4.5	3.0-5.0	2.0-3.0

* Varied over time due to evaporation.

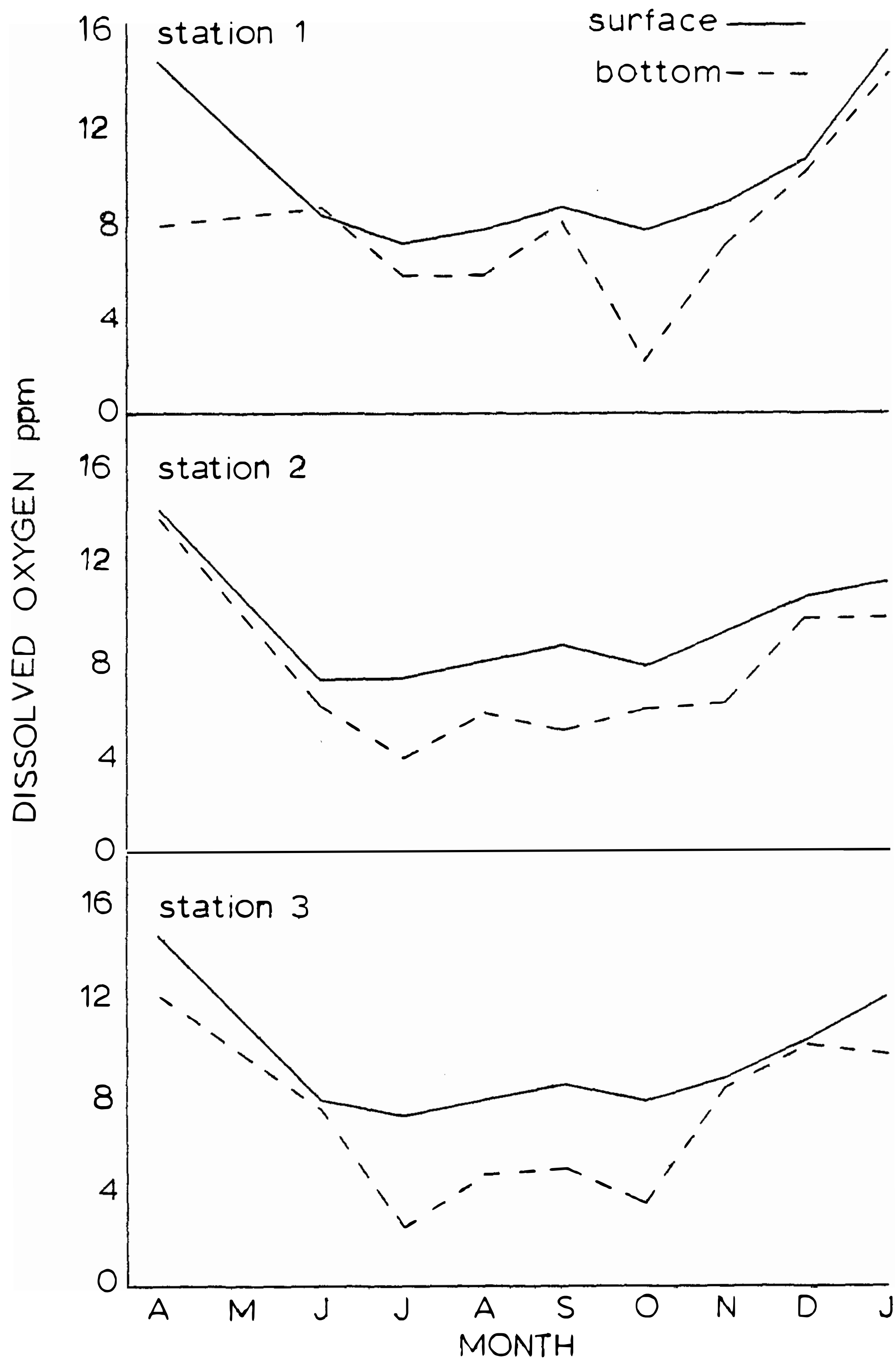

Fig. 7. Mean monthly surface and bottom dissolved oxygen from Area I, Big Stone Power Plant cooling reservoir, South Dakota (April 1979 through January 1980).

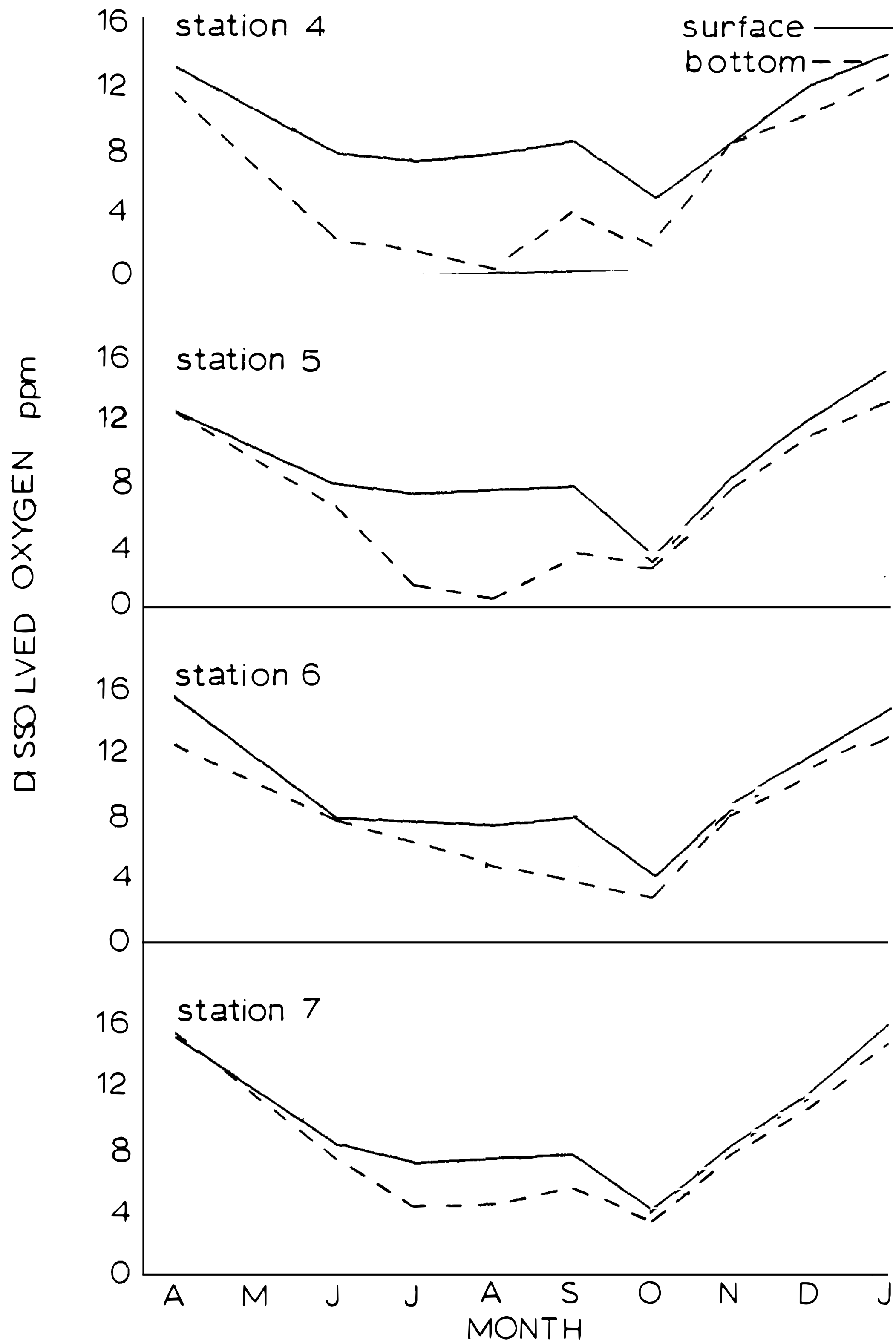

Fig. 8. Mean monthly surface and bottom dissolved oxygen from Area II, Big Stone Power Plant cooling reservoir, South Dakota (April 1979 through January 1980).

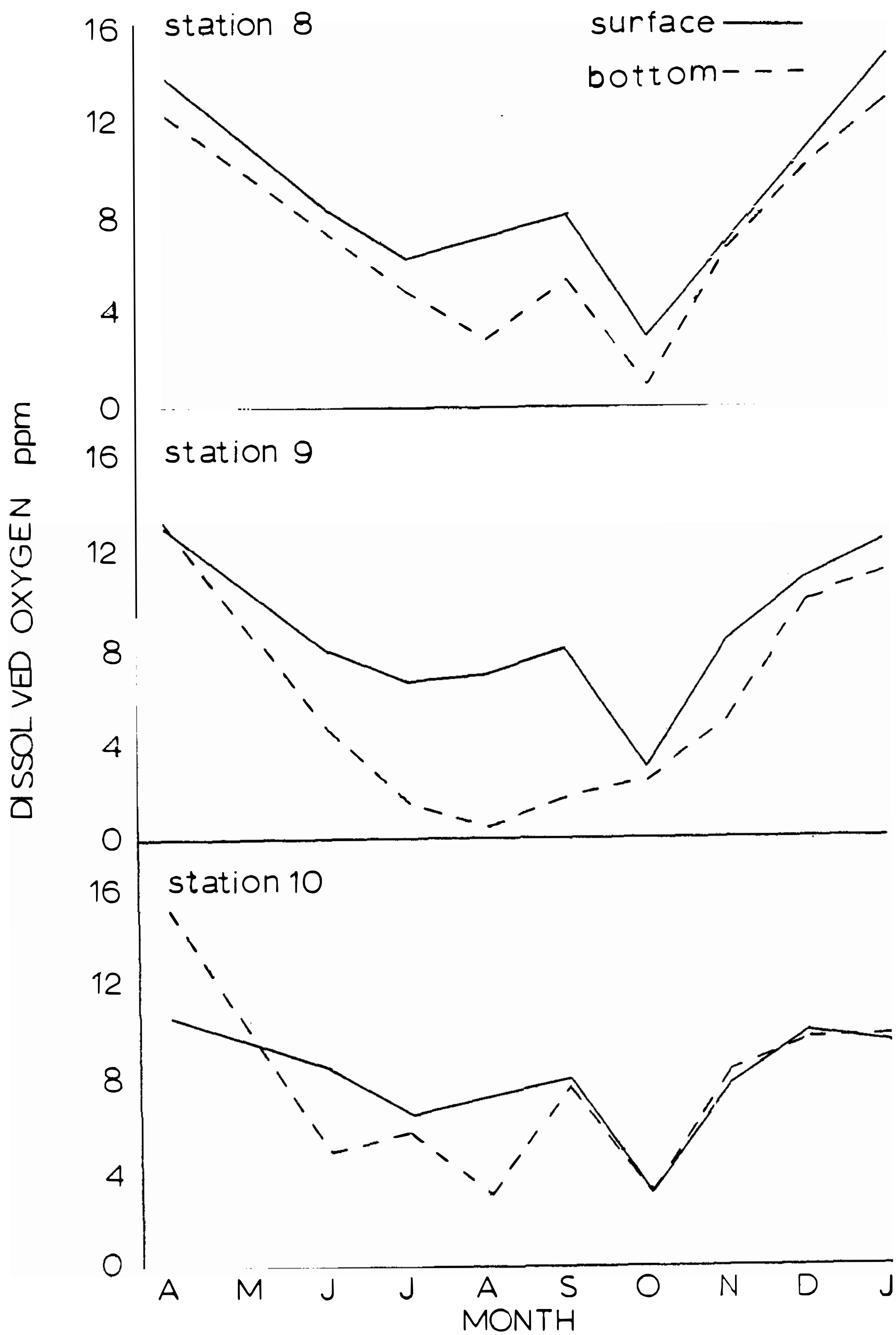

Fig. 9. Mean monthly surface and bottom dissolved oxygen from Area III, Big Stone Power Plant cooling reservoir, South Dakota (April 1979 through January 1980).

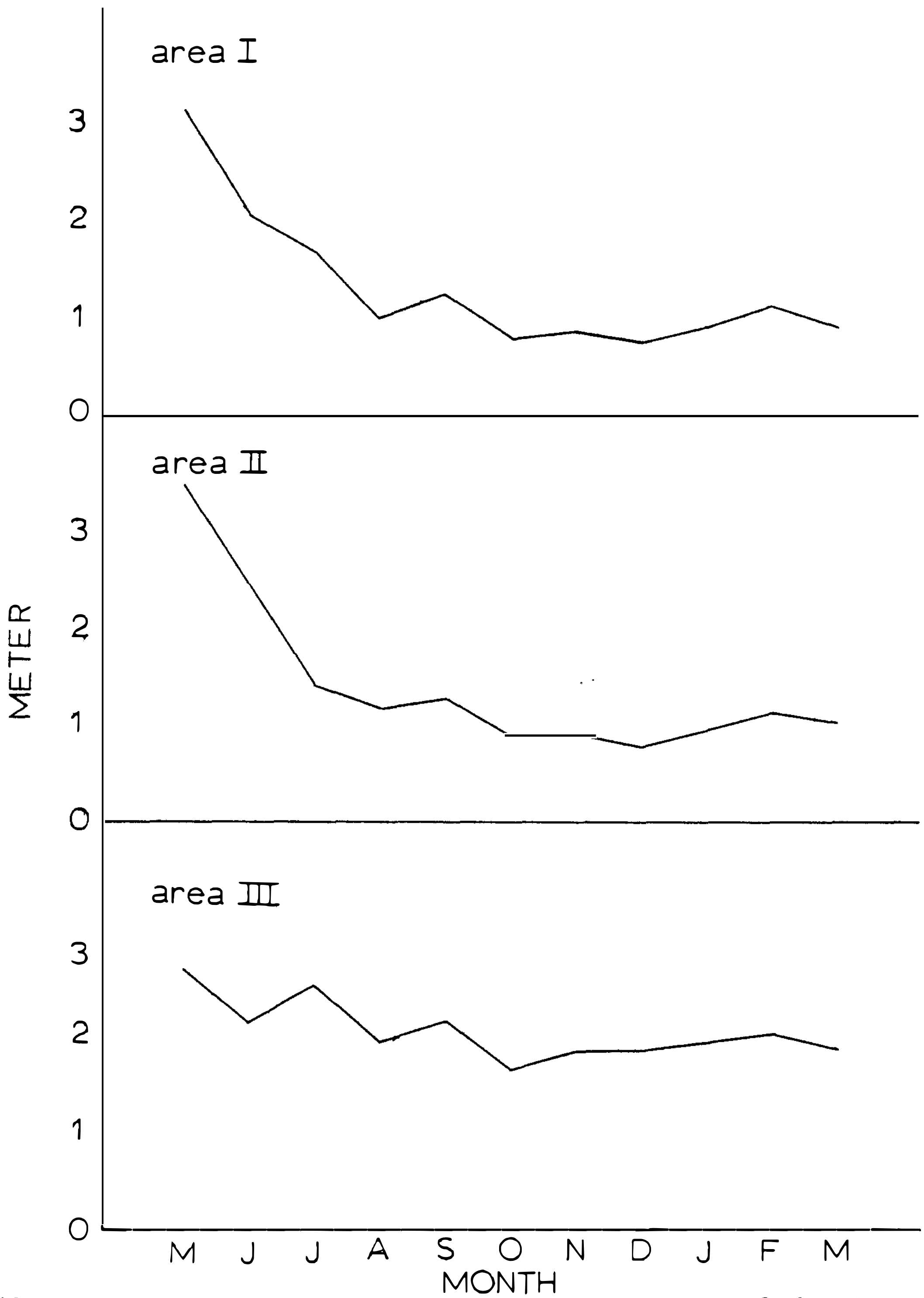

Fig. 10. Mean monthly secchi readings from the three areas of the Big Stone Power Plant cooling reservoir, South Dakota (May 1979 through March 1980).

Table 2. Mean monthly abundance and biomass (mg) of organisms per square meter at Big Stone Power Plant cooling reservoir, South Dakota (April 1979 through March 1980). Numbers represent combined samples of 10 stations on 2 representative sampling dates during the month indicated. T = less than 1.0.

	April	May	June	July	August	September	October
Caenis							
Number	1	7	4	43	1	1	1
Dry weight	T	5	1	12	T	T	T
Chaoborus							
Number	0	1	0	1	0	19	19
Dry weight	0	T	0	T	0	3	3
Chironominae							
Number	667	1519	6107	273	9	475	1144
Dry weight	653	439	2229	218	9	53	548
Chironominae Pupae							
Number	14	126	55	3	0	1	0
Dry weight	34	118	48	1	0	1	0
Oligochaetae							
Number	61	59	199	119	14	13	33
Dry weight	4	11	38	8	1	1	2
Tanypodinae							
Number	227	726	1221	611	34	17	74
Dry weight	8	81	114	43	1	T	2
Total							
Number	973	2439	7623	1068	58	526	1277
Dry weight	705	655	2583	323	11	58	558

Table 2 (cont.)

	November	December	January	February	March	Total	Mean
Caenis							
Number	1	0	4	0	14	76	6
Dry weight	T	0	1	0	24	43	4
Chaoborus							
Number	25	8	11	6	13	101	9
Dry weight	3	1	2	1	2	14	1
Chironominae							
Number	634	234	337	330	285	12015	1001
Dry weight	610	329	539	706	483	6814	568
Chironominae Pupae							
Number	1	0	0	0	1	202	17
Dry weight	1	0	0	0	T	203	17
Oligochaetae							
Number	55	43	31	46	10	682	57
Dry weight	4	3	7	3	1	59	5
Tanypodinae							
Number	217	223	243	251	388	4232	353
Dry weight	5	5	5	7	6	277	23
Other							
Number	5	4	2	3	5	88	7
Dry weight	4	1	4	3	9	209	18
Total							
Number	937	512	628	637	717	17396	1450
Dry weight	627	338	558	719	524	7620	635

(Clampitt et al. 1960; Oliver 1962; Schmulbach and Sandholm 1962; Cole and Underhill 1965; Mrachek and Bachman 1967; Hartung 1968; Smith 1971; Peterka 1972; Schoumacher and Woodrum 1975; Lawson 1977; and Sigmon 1979). Numerically chironomids constituted approximately 94% of all organisms (Table 3) which is comparable to the 93% reported in Lake Francis Case (Cowell and Hudson 1968). Gravimetrically chironomids constituted 95% of the total mean weight of all organisms. This was higher than the 83% reported by Smith (1971) for Lake Poinsett, South Dakota or the 73% reported by Hartung (1968) for Lake Kampeska, South Dakota. Table 4 is a species list of the benthic macroinvertebrates collected from the cooling reservoir.

Chironominae

Chironominae larvae were the dominant benthic macroinvertebrates collected in the cooling reservoir. The mean annual standing crop was estimated at 570 mg/m^2 with an average numerical abundance of $1001/m^2$ (Table 2). Midges were collected at every station and were particularly abundant at Stations 9 and 10 where they constituted 87% and 86% respectively of all benthos collected at these stations (Table 3). Densities ranged from a high in June 1979 ($6107/m^2$) to a low in August 1979 ($9/m^2$) (Table 3). The decline in abundance in July and August may have been a result of a major emergence; numerous pupal exuviae were observed on the water surface at this time. This appeared to be the only major emergence of Chironominae during the year. A single emergence of the Chironominae species *Chironomus plumosus* was observed by Cole and Underhill (1965) in Lake Itaska, Minnesota and Hartung (1968) in Lake Kampeska, South Dakota. Highest densities of Chironominae were collected at Station 10 ($15981/m^2$)

Table 3. Mean monthly abundance and biomass determinations of the principal macrobenthic organisms collected from Big Stone Power Plant cooling reservoir, South Dakota (April 1979 through March 1980). All values are percentages based upon the mean number and dry weight per square meter of substrate. T = less than 1.0.

	Caenis	*Chaoborus*	Chironominae	Chironominae Pupae	Oligochaetae	Tanypodinae	Other
Station 1							
Number	1	T	78	2	2	15	1
Dry weight	3	T	88	T	T	2	6
Station							
Number	2	T	49	1	6	40	1
Dry weight	3	T	79	1	1	10	6
Station 3							
Number	T	2	62	1	2	33	1
Dry weight	T	T	95	2	T	2	T
Station 4							
Number	T	2	85	1	T	12	-
Dry weight	T	T	97	2	T	1	-
Station 5							
Number	T	2	65	1	2	29	1
Dry weight	T	1	90	3	1	4	1

Table 3 (cont.).

	Caenis	_Chaoborus_	Chironominae	Chironominae Pupae	Oligochaetae	Tanypodinae	Other
Station 6							
Number	T	T	37	T	15	47	1
Dry weight	T	T	78	1	5	10	5
Station 7							
Number	–	T	60	3	2	35	T
Dry weight	–	T	83	9	T	8	T
Station 8							
Number	T	T	66	T	10	22	1
Dry weight	T	T	81	1	2	6	10
Station 9							
Number	T	1	87	1	T	10	T
Dry weight	T	T	95	3	T	1	T
Station 10							
Number	–	–	87	1	1	12	T
Dry weight	–	–	92	3	T	3	2
Total							
Number	T	1	68	1	4	26	1
Dry weight	1	T	88	3	1	5	3

Table 4. Species list of benthic macroinvertebrates collected at Big Stone Power Plant cooling reservoir, South Dakota (January 1979 through March 1980).

ANNELIDA		
Oligochaeta		
	Limnodrilus spp.	
	Tubifex spp.	
ARTHROPODA		
Insecta		
COLEOPTERA		
Dytiscidae:	*Agabus* spp. *	
Haliplidae:	*Peltodytes* spp. *	
DIPTERA		
Chironomidae:		
	Chironominae:	*Chironomus* spp.
		Cryptochironomus spp.
		Glyptotendipes spp.
		Parachironomus spp.
		Polypedilum spp.
		Rheotanytarsus spp.
	Tanypodinae:	*Coelotanypus* spp.
		Procladius spp.
		Tanypus spp.
Culicidae:	*Chaoborus* spp.	
Heleidae:	*Palpomyia* spp.	
EPHEMEROPTERA		
Baetidae:	*Baetis* spp. *	
Caenidae:	*Caenis* spp.	
Ephemeridae:	*Hexagenia* spp.	
HEMIPTERA		
Corixidae:	*Sigara* spp.*	
ODONATA		
Coenagriidae:	*Ischnura* spp.	
TRICHOPTERA		
Hydropsychidae:	*Hydropsyche* spp. *	
Hydroptilidae:	*Hydroptila* spp. *	
Leptoceridae:	*Oecetis* spp.	
Polycentropodidae:	*Polycentropus* spp.	
MOLLUSCA		
Gastropoda		
Physidae:	*Physa* spp.	

*organism collected infrequently

during June 1979 (Appendix Table 3). No organisms were found at Stations 4, 5 and 6 during August 1979 and Station 10 during September 1979 (Appendix Tables 5 and 6).

Tanypodinae

Larvae of the subfamily Tanypodinae were the second most abundant organisms in the cooling reservoir. The mean annual standing crop was estimated at 23 mg/m^2 with an average numerical abundance of $353/m^2$ (Table 2). Tanypodinae larvae were present at every station and were most numerous at Stations 2 and 6 (Table 3). Stations 2 and 6 were the stations where Chironominae larvae were least abundant. Many genera of Tanypodinae are considered predaceous and the high numbers observed at Stations 2 and 6 may indicate a predator-prey relationship. Hartung (1968) noted this same occurence with the predaceous genus *Coelotanypus* spp. in Lake Kampeska, South Dakota and suggested that it was caused by substrate differences. No substrate differences were detected between Stations 2 and 6 and the rest of the stations. A more detailed investigation should be conducted before a predator-prey relationship is confirmed in the Big Stone Power Plant cooling reservoir. The smallest number of Tanypodinae were taken at Station 9 (Table 3).

Oligochaetae

Oligochaetes were the next most common taxon of organisms collected in the cooling reservoir. Numerically they constituted 4% of all benthos and occurred in greatest numbers throughout the year at Station 6 (Table 3). High and low mean monthly densities were recorded in June and December 1979 respectively (Table 2). It is speculated that the estimated mean annual standing crop of 5 mg/m^2 (numeric mean $57/m^2$) may not reflect the true standing crop of oligochaetes in the cooling reservoir. Many oligochaete fragments were found while sorting samples. These fragments were believed to have been caused by the abrasive action of the washbucket in separating substrate sediments from the dredge hauls. Oligochaete fragments were not counted as part of the total standing crop.

Chironominae Pupae

Chironominae pupae were the only other organisms collected that represented more than 1% numerically of all benthic macroinvertebrates (Table 3). Although not collected consistently, they were recovered at all stations. They were most abundant at Station 8 and least abundant at Station 6 (Table 3).

Less Abundant Taxa

Caenis naiads were not collected consistently during the study and were never found at Stations 7 and 10. They were most abundant in the July samples at Stations 1 and 2 (Table 2; Appendix Table 4).

Chaoborus spp. comprised less than 1% of the total numbers of organisms sampled in the cooling reservoir. Station 10 was the only station where *Chaoborus* spp. were not found.

The occurence of *Palpomyia, Hexagenia, Ischnura, Oecetis,* and *Physa* species in the cooling reservoir samples were sporadic. These groups together represented less than 1% of the total number of organisms collected. The 3% of total dry weight was contributed primarily by the shells of *Physa.*

Sampling Station Differences

Station 1 exhibited the greatest mean number of organisms (2470/m^2) and contained 17% of all organisms (Table 5). However, the dry weight of organisms at Station 1 made up only 14% (923mg/m^2) of the total (Table 6). Conversely, Station 4 which was located in the deepest part of the cooling reservoir contained 11% of the total number and 26% of the total dry weight. These results were caused by variations in the instar composition of the chironomid larvae. At Station 1 only the smaller chironomid instars were collected whereas at Station 4 the majority of chironomids were larger instars.

Oligochaetes were found at all stations but were most abundant at Station 6 where they made up 6% of the total dry weight and 15% of total numbers (Table 3). Station 6 contributed 38% and 42% of all oligochaetes on a numerical and dry weight basis, respectively (Table 5 and 6).

Caenis naiads were not found at Stations 7 and 10 but constituted 41% and 40% of the total numbers at Stations 2 and 1, respectively (Tables 5 and 6). However, Station 1 consistently produced larger organisms and contained 65% (23mg/m^2) of the total *Caenis* biomass as opposed to 26% of the total biomass at Station 2 (Table 6).

Station 4 had 32% and 31% of the total numbers and dry weight of all the *Chaoborus* spp. collected. Station 10 (discharge) was the only station where *Chaoborus* spp. were not collected (Tables 3 and 6). This may have been due to the proximity of Station 10 to the thermal effluent discharge. Recent studies have reported that thermal effluents can cause decreased densities of benthic macroinvertebrates (Benda and Proffitt 1974; Lenat

Table 5. Annual mean number of organisms per square meter at sampling stations in Big Stone Power Plant cooling reservoir, South Dakota (April 1979 through March 1980). Numbers in parentheses are percentages of total abundance found at each station which the indicated taxon comprises.

	Caenis	Chaoborus	Chironominae	Chironominae Pupae	Oligochaetae	Tanypodinae	Other	Total
Station 1	25 (40)	1 (1)	1937 (19)	44 (27)	52 (9)	394 (11)	17 (23)	2470 (17)
Station 2	26 (41)	4 (4)	600 (6)	11 (7)	73 (13)	495 (14)	13 (18)	1221 (8)
Station 3	2 (3)	14 (17)	586 (6)	10 (6)	19 (3)	306 (9)	9 (12)	946 (7)
Station 4	2 (3)	27 (32)	1354 (14)	23 (14)	5 (1)	184 (5)	1 (2)	1595 (11)
Station 5	4 (6)	24 (29)	660 (7)	6 (4)	16 (3)	297 (8)	5 (7)	1011 (7)
Station 6	1 (2)	5 (6)	514 (5)	4 (2)	215 (38)	654 (18)	8 (11)	1402 (10)
Station 7	- (-)	2 (2)	1073 (11)	45 (27)	34 (6)	624 (18)	2 (3)	1780 (12)
Station 8	3 (4)	3 (4)	872 (9)	3 (2)	135 (24)	288 (8)	14 (20)	1319 (9)
Station 9	1 (1)	5 (6)	917 (9)	13 (8)	4 (1)	110 (3)	1 (1)	1049 (7)
Station 10	- (-)	- (-)	1501 (15)	8 (5)	9 (2)	213 (6)	3 (4)	1734 (12)

Table 6. Annual mean biomass (mg) of organisms per square meter at sampling stations in Big Stone Power Plant cooling reservoir, South Dakota (April 1979 through March 1980). Numbers in parentheses are percentages of total biomass found at each station which the indicated taxon comprises. T = less than 1.0.

	Caenis	*Chaoborus*	Chironominae	Chironominae Pupae	Oligochaetae	Tanypodinae	Other	Total
Station 1	23 (65)	T (2)	816 (14)	4 (2)	4 (8)	19 (8)	57 (33)	923 (14)
Station 2	9 (26)	1 (4)	294 (5)	5 (3)	6 (11)	38 (16)	22 (13)	373 (6)
Station 3	1 (1)	2 (16)	636 (11)	- (-)	2 (3)	14 (6)	2 (1)	656 (10)
Station 4	1 (1)	4 (31)	1629 (28)	39 (25)	1 (1)	9 (4)	1 (1)	1683 (26)
Station 5	1 (1)	4 (29)	499 (9)	19 (12)	5 (10)	22 (9)	6 (3)	555 (9)
Station 6	T (1)	1 (7)	309 (5)	6 (4)	21 (42)	40 (17)	20 (12)	396 (6)
Station 7	- (-)	T (3)	492 (8)	54 (34)	3 (5)	45 (19)	2 (1)	597 (9)
Station 8	1 (2)	T (3)	403 (7)	5 (3)	10 (19)	28 (12)	50 (29)	497 (8)
Station 9	T (1)	1 (6)	387 (7)	14 (9)	T (1)	3 (1)	1 (1)	406 (6)
Station 10	- (-)	- (-)	414 (7)	11 (7)	1 (1)	16 (7)	9 (6)	452 (7)

1976). However, Butler (1975), Esterly (1975) and Sigmon (1979) concluded that thermal effluent effects were minimal on the benthic community.

The standing crops of benthos at the various areas and stations were significantly different ($F = 18.9$; 9 df) throughout the study period. During June 1979 Area III (Stations 8, 9 and 10) was higher in abundance and biomass than either Area I (Stations 1, 2 and 3) or Area II (Stations 4, 5, 6 and 7) (Table 7). In all other monthly means, except September 1979, Area III was lower in abundance and biomass (Table 4).

A potential source of the standing crop differences appears to come from Stations 1 and 10. Station 10 exhibited the greatest mean number of organisms ($17760/m^2$) for June 1979. Station 1 had a mean number of organisms for June 1979 of $13124/m^2$ (Appendix Table 3).

Because the reservoir substrate is fairly uniform (clay and silt) and depth does not vary widely (Fig. 1 and Table 1) temperature gradients likely caused differences in density and biomass between stations. It was expected that Station 10 (discharge) would have been significantly lower in total numbers due to the effects of the thermal effluent (Benda and Proffitt 1974; Lenat 1976). However, a Student-Newman-Keuls test indicated that Station 1 (intake) was the only station significantly different (higher) in total numbers of organisms. The high density of organisms at Station 1 may have been affected by dense growths of submergent vegetation (*Potomogeton pectinatus*) at this station during the summer. Areas with abundant vegetation tend to have greater standing crops of benthos (Rosine 1955; Schneider 1965). This information and the mean daily entrainment of about 600,000 organisms (Table 8) may indicate

Table 7. Mean monthly abundance and biomass (mg) per square meter of macroinvertebrates in the intake (Area I), mixing (Area II), and discharge (Area III) sections of Big Stone Power Plant cooling reservoir, South Dakota (April 1979 through March 1980).

	Area I		Area II		Area III	
	numbers	biomass	numbers	biomass	numbers	biomass
April 1979	985	1092	1260	765	583	203
May 1979	3277	580	2825	1547	1083	258
June 1979	6495	2193	5936	1935	10997	3533
July 1979	1439	364	1173	378	711	211
August 1979	97	16	53	6	24	11
September 1979	346	57	558	85	662	27
October 1979	1542	731	1416	650	824	263
November 1979	1082	522	1117	863	556	423
December 1979	674	498	565	375	260	129
January 1980	852	570	696	856	315	149
February 1980	778	525	844	1348	208	66
March 1980	978	482	930	869	179	111

Table 8. Calculated 24-hour estimates of benthic macroinvertebrate entrainment at the Big Stone Power Plant cooling reservoir, South Dakota (February 1979 through January 1980). Dry weight is represented in grams. T = less than 1.0.

	Caenis	Chaoborus	Chironominae	Chironominae Pupae	Corixinae	Polycentropodinae	Total
February 07-08							
Number	-	21,000	875	-	-	-	21,875
Dry weight	-	29	1	-	-	-	30
February 27-28							
Number	-	263	438	438	-	-	1,139
Dry weight	-	1	1	1	-	-	3
April 19-20							
Number	14,438	875	875	-	-	438	16,626
Dry weight	17	T	T	-	-	T	17
May 02-03							
Number	-	-	-	15,750	-	-	15,750
Dry weight	-	-	-	6	-	-	6
May 23-24							
Number	1,750	11,375	60,375	51,625	437	-	125,562
Dry weight	T	1	4	83	22	-	110
June 19-20							
Number	2,625	875	797,125	203,000	6,125	875	1,010,625
Dry weight	T	T	112	83	156	1	352
June 29-30							
Number	875	-	7,875	161,000	875	-	170,625
Dry weight	T	-	2	14	22	-	38

Table 8 (cont.).

	Caenis	Chaoborus	Chironominae	Chironominae Pupae	Corixinae	Polycentropodinae	Total
July 24-25							
Number	32,375	-	48,125	28,000	2,625	-	111,125
Dry weight	2	-	5	11	67	-	85
August 15-16							
Number	-	-	1,750	-	-	-	1,750
Dry weight	-	-	1	-	-	-	1
August 23-24							
Number	875	-	-	-	-	-	875
Dry weight	T	-	-	-	-	-	T
October 04-05							
Number	-	21,875	42,875	1,750	-	875	67,375
Dry weight	-	2	4	1	-	T	7
October 18-19							
Number	-	56,000	20,125	-	875	-	77,000
Dry weight	-	4	12	-	22	-	38
November 01-02							
Number	-	40,250	5,250	-	-	-	45,500
Dry weight	-	5	2	-	-	-	7
November 15-16							
Number	-	10,500	-	-	-	-	10,500
Dry weight	-	1	-	-	-	-	1
December 18-19							
Number	-	-	-	-	-	-	-
Dry weight	-	-	-	-	-	-	-

Table 8 (cont.).

	Caenis	Chaoborus	Chironominae	Chironominae Pupae	Corixinae	Polycentropodinae	Total
January 15-16							
Number	-	438	-	-	-	-	438
Dry weight	-	T	-	-	-	-	T
January 23-24							
Number	-	875	-	-	-	-	875
Dry weight	-	T	-	-	-	-	T
Total							
Number	52,938	164,326	985,688	461,563	19,937	2,188	1,677,640
Dry weight	19	44	143	199	289	1	694
Mean							
Number	3,114	9,666	57,982	27,151	643	129	98,685
Dry weight	1	1	8	12	17	T	41

why Station 10 had such a large standing crop for the month of June 1979. It was also observed that the majority of organisms collected at Station 10 during June 1979 were either dead or pale in color. During this same period blood-red larvae of the genus *Chironomus* were collected at all stations except Station 10. These observations along with the number of entrained organisms raises doubts as to the accuracy of the standing crop estimation at Station 10.

Area III (discharge) was consistently lower in total numbers and dry weight than either Areas I or II (Table 7). Disregarding the months of June and September 1979 all other months showed Area III to be lower than Areas I or II. This suggests that some factor or factors were depressing the standing crop of benthic organisms in Area III. Of the 3 sampling stations in Area III (8, 9 and 10) Station 10 had the lowest abundance of organisms during 9 sampling months and the lowest biomass in 7 months. Since this station is closest to the discharge site the thermal effluent may have played a major role in standing crop suppression. Another factor contributing to the depressed standing crop at Station 10 was the unique substrate. In all dredge samples taken at that station a black crystalline-like material filled the sampler. Usinger (1956) stated that many chironomid larvae build tubes in soft mucky substrates and feed on organic detritus. Observations using SCUBA equipment revealed tubes on the substrate of all stations except Station 10. The crystalline-like material at Station 10 may have been an unsuitable substrate for benthic macroinvertebrates.

Comparison With Other Lakes

The mean annual standing crop of benthos in the cooling reservoir during the study was approximately 0.6 g/m^2 with an average numerical abundance of 1460/m^2 (Table 2). The family Chironomidae comprised 94% of all organisms collected. Many lake studies in the North Central United States report chironomids as the dominant organisms (Mrachek and Bachman 1967; Hartung 1968; and Smith 1971). Lake Keowee, South Carolina, which receives a thermal effluent has a benthos population composed predominantly of larval Chironomidae (Sigmon 1979).

The average numerical standing crop of benthos in the Big Stone Power Plant cooling reservoir was below the average (2896/m^2) reported for other lakes in North America (Table 9). However, it was similar to the numerical standing crops reported in lakes Poinsett and Kampeska, South Dakota. Boomer Lake, Oklahoma, Decker Lake, Texas and Lake Keowee, South Carolina all receive thermal effluents and had numerical standing crops of 1850/m^2, 1186/m^2, and 1000/m^2, respectively. With an annual mean dry weight standing crop of 0.6 g/m^2 the cooling reservoir was below the average (3.1 g/m^2) standing crop reported for other lakes in North America (Table 10). However, the study conducted on Boomer Lake, Oklahoma reported a dry weight standing crop of 0.8 g/m^2 which is comparable to the standing crop of the cooling reservoir. Lake Kampeska, South Dakota with a numerical standing crop of 1178/m^2, had the lowest dry weight standing crop (0.2 g/m^2); Lake Poinsett, with a numerical abundance of 1402/m^2, had a dry weight standing crop of 1.3 g/m^2. The low value of 0.6 g/m^2 for the cooling reservoir may have been due to the young age of the reservoir. The lowness may also be a reflection of

Table 9. Numbers of benthos in selected lakes throughout North America.

Lake	No./m^2	Source
Middle Quiver, Illinois	11,929	Paloumpis and Starrett (1960)
Chautauqua, Illinois	9,537	Paloumpis and Starrett (1960)
Ludington, Michigan	7,096	Lawson (1977)
Big Eau Pleine, Wisconsin	6,989	Kaster (1976)
Moncove, West Virgina	5,550	Schoumacher and Woodrum (1975)
Matanzas, Illinois	5,328	Paloumpis and Starrett (1960)
West Okoboji, Iowa (shallow)	3,040	Clampitt et al. (1960)
Sugarloaf, Michigan	2,928	Anderson and Hooper (1956)
Munro, Michigan	2,146	Eggleton (1934)
West Okoboji, Iowa (deep)	2,135	Bardach et al. (1951)
Ashtabula, North Dakota	2,126	Peterka (1972)
Douglas, Michigan	2,001	Eggleton (1934)
Boomer, Oklahoma	1,850	Craven (1967)
Lancaster, Michigan	1,755	Eggleton (1934)
Itaska, Minnesota	1,550	Cole and Underhill (1965)
Lizard, Iowa	1,540	Tebo (1955)
Huron, Michigan	1,461	Teter (1960)
Cooling Reservoir, South Dakota	1,460	Present study
Poinsett, South Dakota	1,402	Smith (1971)
Michigan, Michigan	1,242	Eggleton (1934)
Decker, Texas	1,186	Butler (1975)
Kampeska, South Dakota	1,178	Hartung (1968)
Keowee, South Carolina	1,000	Sigmon (1979)
Lac La Ronge, Saskatchewan	742	Oliver (1962)
Lewis and Clark, South Dakota	430	Schmulbach and Sandholm (1962)
Vincent, Michigan	335	Eggleton (1934)
Carl Blackwell, Oklahoma	256	Norton (1966)

Table 10. Dry weight of benthos in selected lakes throughout North America.

Lake	gm/m^2	Source
Middle Quiver, Illinois	11.8	Paloumpis and Starrett (1960)
Big Eau Pleine, Wisconsin	9.8	Kaster (1976)
Mendota, Wisconsin	7.7	Juday (1921)
Ashtabula, North Dakota	7.2	Peterka (1972)
Echo, Saskatchewan	5.8	Rawson and Moore (1944)
Linsley, Connecticut	5.2	Deevey (1941)
Itaska, Minnesota	4.5	Cole and Underhill (1965)
Soap, Washington	4.4	Lauer (1959)
Lenore, Washington	4.3	Lauer (1959)
West Okoboji, Iowa (deep)	4.0	Bardach et al. (1951)
Winnipeg, Manitoba	3.1	Slack (1967)
Chautauqua, Illinois	2.6	Paloumpis and Starrett (1960)
Mantanzas, Illinois	1.5	Paloumpis and Starrett (1960)
Lizard, Iowa	1.4	Tebo (1955)
Poinsett, South Dakota	1.3	Smith (1971)
Lac La Ronge, Saskatchewan	0.9	Oliver (1962)
Clear, Iowa	0.9	Mrachek and Bachman (1967)
Boomer, Oklahoma	0.8	Craven (1967)
West Okoboji, Iowa (shallow)	0.8	Clampitt et al. (1960)
Cooling Reservoir, South Dakota	0.6	Present study
Falcon, Manitoba	0.4	Slack (1967)
Twin, Manitoba	0.4	Slack (1967)
Athapapuskow, Manitoba	0.3	Slack (1967)
Lewis and Clark, South Dakota	0.2	Schmulbach and Sandholm (1962)
Reed, Manitoba	0.2	Slack (1967)
Kampeska, South Dakota	0.2	Hartung (1968)

the way the organisms were preserved. Holme (1964) and Stanford (1973) stated that organisms may lose by leaching as much as 25% of their biomass when preserved in alcohol. If this were the case, the standing crop of the cooling reservoir would approach 0.8 g/m^2. This would be comparable with the work done by Craven (1967) on Boomer Lake, Oklahoma (0.8 g/m^2).

The true productivity of a lake is not always reflected in the standing crop of benthos observed. Bottom fauna form a major link in the food chain leading to fish populations. Hayne and Ball (1956) in their study of benthic productivity as influenced by fish predation reported that the average production of bottom fauna fish-food during a growing season amounted to about 17 times the standing crop, when fishes were present. Wahl (1980) estimated that the total standing crop of the 4 major forage fish species in the Big Stone Power Plant cooling reservoir was 28.1 kg/ha. The population estimate for these forage fishes was approximately 17,000. With that density of fish population the standing crop of macrobenthic organisms could have been modified. The interaction of forage fish populations to benthic productivity of a body of water should be accounted for when reporting benthos standing crop.

The seasonal variation in the standing crop of benthic organisms in the cooling reservoir was not characteristic of most natural bodies of water (Sublette 1957). A maximum occurred in late spring and early summer rather than late winter and early spring. A minimum occurred in late summer which is typical of many lakes. The maximum cooling reservoir standing crop of 2.5 g/m^2 ($7623/m^2$) occurred in June 1979 and the minimum standing crop of 0.01 g/m^2 ($58/m^2$) occurred in August 1979 (Fig. 11).

Entrainment Sampling

No significant differences were found between depths or between dates for total biomass or numbers of organisms entrained. The calculated 24-hour estimate of benthic macroinvertebrates entrained ranged from a high of 1,010,625 organisms (325 g) on June 29-30, 1979 to no organisms entrained on December 18-19, 1979 (Table 8). Chironominae larvae had a mean entrainment of 57,982 organisms (8 g) for the 17 sampling dates. Chironominae pupae had the second highest mean entrainment of 27,151 organisms (12 g). Chaoborus and Caenis spp. had a mean entrainment of 9,666 (1 g) and 3,114 (1 g) organisms respectively. Organisms from the subfamilies Corixinae and Polycentropodinae had a mean entrainment of less than 1,000 organisms. A mean of 98,685 organisms (41 g) were entrained during the sampling period. A peak in total numbers (590,626) and biomass (194.6 g) occurred in June 1979 (Fig. 12). The low numbers entrained during August 1979 agree with the low standing crop found at the in-reservoir stations during this time.

Rip-rap Sampling

Numerically members of the subfamily Chironominae were the major group of organisms found colonizing the baskets. Gravimetrically Physa spp. were the dominant group found colonizing the baskets (Table 11).

Chironominae comprised 65% of total numbers collected from the baskets with Caenis and Physa spp. next most abundant with 12% each. Members of the subfamilies Polycentropodinae and Tanypodinae made up 6% and 2% of total numbers respectively (Table 12).

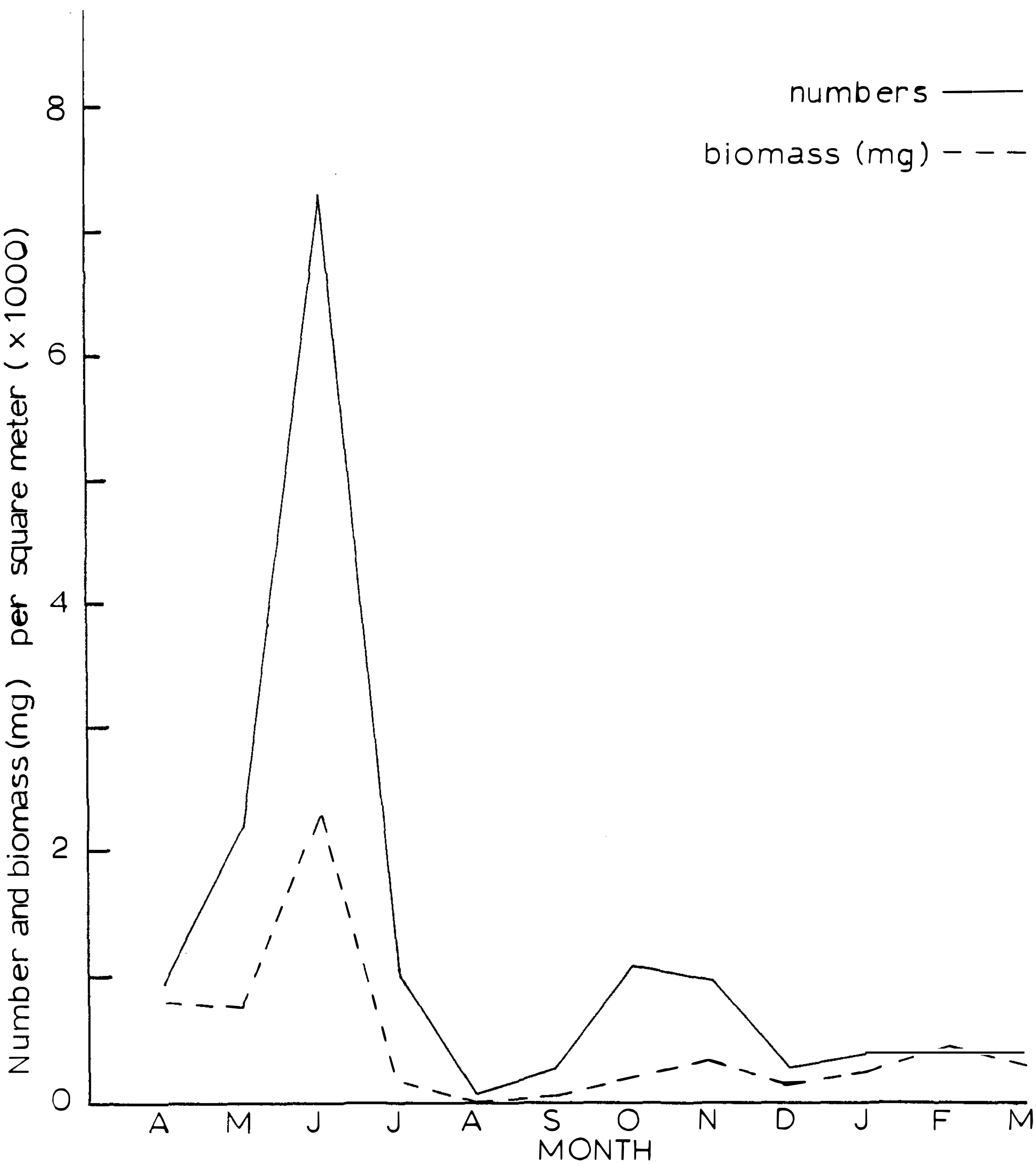

Fig. 11. Monthly variation in benthic macroinvertebrates at Big Stone Power Plant cooling reservoir, South Dakota (April 1979 through March 1980).

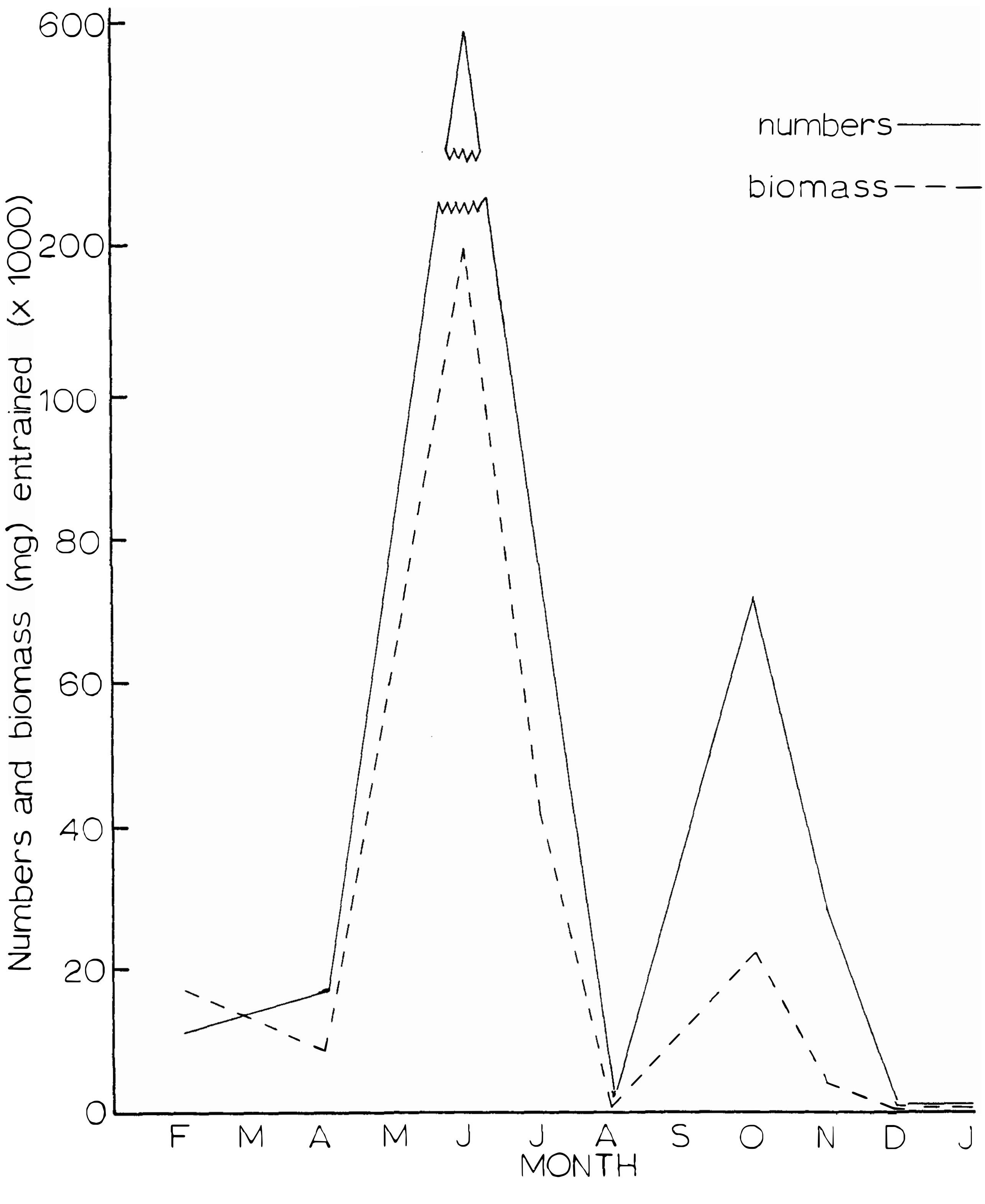

Fig. 12. Calculated 24-hour estimates of benthic macroinvertebrates entrained at Big Stone Power Plant, South Dakota (February 1979 through January 1980).

Table 11. Monthly mean numbers and biomass (mg) per square meter of rip-rap at Big Stone Power Plant cooling reservoir, South Dakota (June 1979 through December 1979). Numbers represent combined samples of nine baskets during the dates indicated. T = less than 1.0.

	6/04/79	7/06/79	8/03/79	9/06/79	10/11/79	11/02/79	12/06/79	Total	Mean
Caenis									
Number	2	103	71	69	54	13	4	316	45
Dry weight	T	12	8	7	7	2	1	37	5
Chironominae									
Number	209	183	194	182	307	574	56	1705	244
Dry weight	22	42	20	10	36	86	7	223	32
Chironominae Pupae									
Number	2	4	12	7	-	3	-	28	4
Dry weight	2	3	10	6	-	2	-	23	3
Ischnura									
Number	9	2	8	5	7	1	-	32	5
Dry weight	18	3	15	9	13	1	-	59	8
Physa									
Number	83	143	41	7	11	13	8	306	44
Dry weight	308	593	140	59	80	52	33	1265	181
Polycentropodinae									
Number	3	98	45	4	2	1	1	154	22
Dry weight	2	66	45	3	1	1	1	119	17
Tanypodinae									
Number	4	11	10	-	-	-	-	25	4
Dry weight	T	T	T	-	-	-	-	1	T
Other									
Number	8	6	19	-	1	-	-	34	5
Dry weight	19	13	24	-	28	-	-	84	12
Total									
Number	320	550	400	274	382	605	69	2600	373
Dry weight	371	732	262	94	165	144	42	1811	258

Annual mean standing crop for the rip-rap area of the cooling reservoir was 258 mg/m^2 ($373/m^2$). A significant difference existed between dates for total biomass. No other significant differences were found for the rip-rap data. The thermal effluent from the power plant did not seem to affect the benthos of the rip-rap area in the cooling reservoir, except for the scour protection area surrounding the discharge point.

Basket 1 (Area I) had the highest standing crop (433 mg/m^2) and numerical abundance ($827/m^2$) (Table 13). Basket 8 (Area III) was second highest with a standing crop of 370 mg/m^2 and a numerical abundance of $249/m^2$. In July 1979 a peak in both numbers ($550/m^2$) and biomass (732 mg/m^2) occurred. This peak for biomass reflected the high number of *Physa* spp. collected at that time (Table 11). Another higher peak in numbers ($605/m^2$) occurred in November 1979 and corresponded with the highest number of Chironominae larvae collected (Table 11).

Summary

The Big Stone Power Plant cooling reservoir has been filled for 5 years. A one-year study of the reservoir benthic macroinvertebrates revealed an annual mean number of $1460/m^2$ and an annual mean biomass of 0.6 g/m^2. These values indicated that the reservoir was lower in annual number and biomass than other cooling reservoirs and natural lakes in North America. However, the standing crop of the cooling reservoir is higher than Lake Kampeska, South Dakota a natural prairie pothole lake approximately 50 km southwest of the cooling reservoir.

Table 12. Abundance and biomass determinations of the principal benthos collected from the rip-rap area of the Big Stone Power Plant cooling reservoir, South Dakota (June1979 through December 1979). All values are percentages based upon the mean number and dry weight per square meter of rip-rap. T = less than 1.0.

Basket		*Caenis*	Chironominae	Chironominae Pupae	*Ischnura*	*Physa*	Polycentropodinae	Tanypodinae	Other
1	Number	13	75	1	3	5	2	1	1
	Dry weight	2	16	1	10	64	6	T	1
2	Number	13	60	1	3	9	10	3	T
	Dry weight	2	14	1	9	63	10	T	T
3	Number	18	55	1	1	8	16	T	-
	Dry weight	2	5	1	2	85	6	T	-
4	Number	19	66	1	1	1	10	2	-
	Dry weight	10	44	4	5	20	19	T	-
5	Number	26	55	1	-	6	11	1	T
	Dry weight	5	19	2	-	55	20	T	T
6	Number	10	71	2	-	5	7	5	1
	Dry weight	3	22	4	-	43	11	T	17
7	Number	5	66	1	T	23	1	1	T
	Dry weight	1	11	1	T	80	6	T	T
8	Number	1	53	1	1	43	-	-	1
	Dry weight	T	4	T	1	90	-	-	4
9	Number	-	43	2	2	43	-	-	10
	Dry weight	-	4	1	2	89	-	-	5
Total	Number	12	65	1	1	12	6	2	1
	Dry weight	2	13	1	3	71	7	T	3

Table 13. Mean number and dry weight (mg) of the principal benthos per square meter collected from the rip-rap area of the Big Stone Power Plant cooling reservoir, South Dakota (June 1979 through December 1979). T = less than 1.0.

Basket		*Caenis*	Chironominae	Chironominae Pupae	*Ischnura*	*Physa*	Polycentropodinae	Tanypodinae	Other	Total
1	Number	107	616	4	23	43	20	9	5	827
	Dry weight	10	70	4	43	275	27	T	4	433
2	Number	29	136	2	7	19	24	7	1	225
	Dry weight	3	21	2	13	91	14	T	T	144
3	Number	51	15	2	3	22	45	-	-	138
	Dry weight	6	13	2	5	225	15	-	-	266
4	Number	73	25	4	2	4	36	8	-	152
	Dry weight	8	37	3	4	17	16	T	-	85
5	Number	69	15	3	-	15	29	3	1	135
	Dry weight	8	31	3	-	90	33	T	T	165
6	Number	56	42	11	-	29	40	31	5	214
	Dry weight	7	57	9	-	112	28	1	43	257
7	Number	21	28	4	1	99	4	3	14	174
	Dry weight	3	35	4	1	247	18	T	1	309
8	Number	1	133	1	2	108	-	-	4	249
	Dry weight	T	14	1	4	335	-	-	16	370
9	Number	-	56	3	2	56	-	-	14	131
	Dry weight	-	9	3	4	233	-	-	13	262
Total	Number	407	1,066	34	40	395	198	61	44	2,245
	Dry weight	45	287	31	74	1,625	151	T	78	2,291

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APPENDIX

Appendix Table 1. Abundance and biomass (mg) determinations of the principal macrobenthic organisms collected during April 1979 from the Big Stone Power Plant cooling reservoir, South Dakota. T = less than 1.0.

Stations		*Caenis*	*Chaoborus*	Chironominae	Chironominae Pupae	Oligochaetae	Tanypodinae	Other	Total
1	Number	–	–	653	–	–	344	–	997
	Dry weight	–	–	484	–	–	37	–	521
2	Number	–	–	617	7	–	495	14	1133
	Dry weight	–	–	1102	12	–	11	T	1125
3	Number	–	–	689	50	–	86	–	825
	Dry weight	–	–	1628	820	–	2	–	2458
4	Number	–	–	452	–	22	129	7	610
	Dry weight	–	–	1272	–	2	3	T	1277
5	Number	–	–	316	–	43	29	–	388
	Dry weight	–	–	738	–	3	1	–	742
6	Number	–	–	545	–	287	553	7	1392
	Dry weight	–	–	344	–	20	12	T	376
7	Number	–	–	2397	72	50	122	7	2648
	Dry weight	–	–	426	225	4	3	7	665
8	Number	7	–	373	7	179	344	–	910
	Dry weight	2	–	432	12	13	8	–	467
9	Number	–	–	179	7	29	29	7	251
	Dry weight	–	–	60	12	2	1	14	89
10	Number	–	–	452	–	–	136	–	588
	Dry weight	–	–	48	–	–	3	–	51

Appendix Table 2. Abundance and biomass (mg) determinations of the principal macrobenthic organisms collected during May 1979 from the Big Stone Power Plant cooling reservoir, South Dakota. T = less than 1.0.

Stations		*Caenis*	*Chaoborus*	Chironominae	Chironominae Pupae	Oligochaetae	Tanypodinae	Other	Total
1	Number	36	-	4191	366	43	474	7	5117
	Dry weight	10	-	652	31	3	78	T	774
2	Number	22	-	2300	104	75	1507	11	4019
	Dry weight	37	-	375	20	5	229	20	686
3	Number	-	-	255	47	22	370	-	694
	Dry weight	-	-	269	9	2	8	-	288
4	Number	-	-	667	222	22	280	-	1191
	Dry weight	-	-	3081	426	2	6	-	3515
5	Number	-	7	179	65	7	251	-	509
	Dry weight	-	1	486	213	1	6	-	707
6	Number	-	-	1758	14	187	2339	-	4298
	Dry weight	-	-	481	23	85	210	-	799
7	Number	-	-	3918	373	144	861	-	5296
	Dry weight	-	-	838	327	10	98	-	1273
8	Number	-	-	660	7	50	940	7	1664
	Dry weight	-	-	430	12	4	165	T	611
9	Number	-	-	502	7	7	122	-	638
	Dry weight	-	-	78	12	1	3	-	94
10	Number	-	-	754	50	29	115	-	948
	Dry weight	-	-	112	54	2	3	-	171

Appendix Table 3. Abundance and biomass (mg) determinations of the principal macrobenthic organisms collected during June 1979 from the Big Stone Power Plant cooling reservoir, South Dakota. T = less than 1.0.

Stations		Caenis	Chaoborus	Chironominae	Chironominae Pupae	Oligochaetae	Tanypodinae	Other	Total
1	Number	29	–	12162	129	244	409	151	13124
	Dry weight	8	–	4217	12	17	42	582	4878
2	Number	7	–	2210	22	101	718	22	3080
	Dry weight	2	–	888	19	7	16	74	1006
3	Number	–	–	2347	29	57	847	–	3280
	Dry weight	–	–	1155	21	4	62	–	1242
4	Number	–	–	6652	50	7	904	–	7613
	Dry weight	–	–	2800	44	1	83	–	2928
5	Number	–	–	3057	7	43	1392	7	4506
	Dry weight	–	–	1494	12	3	151	28	1688
6	Number	–	–	1715	22	1026	2483	64	5310
	Dry weight	–	–	613	35	72	171	224	1115
7	Number	–	–	3818	86	100	2296	14	6314
	Dry weight	–	–	1576	78	7	325	21	2007
8	Number	–	–	6530	22	409	1177	101	8239
	Dry weight	–	–	2543	35	29	125	392	3124
9	Number	7	–	6602	136	–	258	–	7003
	Dry weight	2	–	2718	135	–	6	–	2861
10	Number	–	–	15981	50	–	1722	7	17760
	Dry weight	–	–	4284	82	–	161	84	4611

Appendix Table 4. Abundance and biomass (mg) determinations of the principal macrobenthic organisms collected during July 1979 from the Big Stone Power Plant cooling reservoir, South Dakota. T = less than 1.0.

Stations		Caenis	Chaoborus	Chironominae	Chironominae Pupae	Oligocheatae	Tanypodinae	Other	Total
1	Number	79	-	502	22	57	603	29	1292
	Dry weight	21	-	330	2	4	13	56	426
2	Number	266	-	115	-	144	1450	36	2011
	Dry weight	70	-	77	-	14	146	84	391
3	Number	22	7	179	-	22	775	14	1019
	Dry weight	6	1	206	-	2	59	T	274
4	Number	22	-	524	-	-	316	-	862
	Dry weight	6	-	247	-	-	7	-	260
5	Number	14	-	416	-	-	1105	29	1564
	Dry weight	4	-	409	-	-	84	28	525
6	Number	14	-	108	-	201	847	14	1184
	Dry weight	4	-	72	-	14	45	14	149
7	Number	-	-	323	-	29	725	-	1077
	Dry weight	-	-	514	-	2	55	-	571
8	Number	22	-	122	-	689	488	57	1378
	Dry weight	6	-	110	-	48	29	203	396
9	Number	-	-	366	7	-	79	-	452
	Dry weight	-	-	161	12	-	2	-	175
10	Number	-	-	72	-	-	230	-	302
	Dry weight	-	-	57	-	-	5	-	62

Appendix Table 5. Abundance and biomass (mg) determinations of the principal macrobenthic organisms collected during August 1979 from the Big Stone Power Plant cooling reservoir, South Dakota. T = less than 1.0.

Stations		*Caenis*	*Chaoborus*	Chironominae	Chironominae Pupae	Oligochaetae	Tanypodinae	Other	Total
1	Number	7	-	43	-	-	79	-	129
	Dry weight	2	-	29	-	-	2	-	33
2	Number	-	-	7	-	7	57	-	71
	Dry weight	-	-	5	-	1	1	-	7
3	Number	-	-	7	-	-	86	-	93
	Dry weight	-	-	5	-	-	2	-	7
4	Number	-	-	-	-	-	7	-	7
	Dry weight	-	-	-	-	-	T	-	T
5	Number	-	-	-	-	-	-	-	-
	Dry weight	-	-	-	-	-	-	-	-
6	Number	-	-	-	-	72	29	-	101
	Dry weight	-	-	-	-	5	1	-	6
7	Number	-	-	14	-	36	50	-	100
	Dry weight	-	-	10	0	3	1	-	14
8	Number	-	-	7	-	22	29	-	58
	Dry weight	-	-	T	-	2	1	-	3
9	Number	-	-	7	-	-	-	-	7
	Dry weight	-	-	14	-	-	-	-	14
10	Number	-	-	7	-	-	-	-	7
	Dry weight	-	-	14	-	-	-	-	14

Appendix Table 6. Abundance and biomass (mg) determinations of the principal macrobenthic organisms collected during September 1979 from the Big Stone Power Plant cooling reservoir, South Dakota. T = less than 1.0.

Stations		*Caenis*	*Chaoborus*	Chironominae	Chironominae Pupae	Oligochaetae	Tanypodinae	Other	Total
1	Number	7	–	323	–	–	–	–	330
	Dry weight	2	–	45	–	–	–	–	47
2	Number	–	7	158	–	14	14	–	193
	Dry weight	–	1	105	–	1	1	–	108
3	Number	–	7	431	–	7	65	7	517
	Dry weight	–	1	8	–	1	1	T	11
4	Number	–	43	789	–	7	7	–	846
	Dry weight	–	6	68	–	1	T	–	75
5	Number	–	57	517	–	–	–	7	581
	Dry weight	–	9	40	–	–	–	T	49
6	Number	–	7	395	7	43	36	–	488
	Dry weight	–	1	28	12	3	1	–	45
7	Number	–	22	244	–	14	36	–	316
	Dry weight	–	3	163	–	1	1	–	171
8	Number	–	22	940	–	43	7	–	1012
	Dry weight	–	3	45	–	3	1	–	52
9	Number	–	22	954	–	–	–	–	976
	Dry weight	–	3	26	–	–	–	–	29
10	Number	–	–	–	–	–	–	–	–
	Dry weight	–	–	–	–	–	–	–	–

Appendix Table 7. Abundance and biomass (mg) determinations of the principal macrobenthic organisms collected during October 1979 from the Big Stone Power Plant cooling reservoir, South Dakota. T = less than 1.0.

Station		Caenis	Chaoborus	Chironominae	Chironominae Pupae	Oligochaetae	Tanypodinae	Other	Total
1	Number	-	-	1500	-	-	144	-	1644
	Dry weight	-	-	756	-	-	3	-	759
2	Number	7	7	904	-	86	122	14	1140
	Dry weight	2	1	227	-	6	11	14	261
3	Number	-	72	1629	-	14	93	36	1844
	Dry weight	-	11	1160	-	1	2	T	1174
4	Number	-	57	2502	-	-	100	-	2662
	Dry weight	-	8	1478	-	-	2	-	1488
5	Number	-	29	1493	-	7	86	7	1622
	Dry weight	-	4	651	-	1	2	T	658
6	Number	-	14	481	-	201	57	-	753
	Dry weight	-	2	200	-	14	1	-	217
7	Number	-	-	560	-	-	65	-	625
	Dry weight	-	-	230	-	-	1	-	231
8	Number	-	-	847	-	7	29	-	883
	Dry weight	-	-	183	-	1	1	-	185
9	Number	-	7	1019	-	14	-	-	1040
	Dry weight	-	1	427	-	1	-	-	429
10	Number	-	-	502	-	-	43	7	552
	Dry weight	-	-	161	-	-	14	1	176

Appendix Table 8. Abundance and biomass (mg) determinations of the principal macrobenthic organisms collected during November 1979 from the Big Stone Power Plant cooling reservoir, South Dakota. T = less than 1.0.

Station		Caenis	Chaoborus	Chironominae	Chironominae Pupae	Oligochaetae	Tanypodinae	Other	Total
1	Number	7	7	976	-	93	524	7	1614
	Dry weight	2	1	680	-	7	11	T	701
2	Number	-	7	352	-	208	273	29	869
	Dry weight	-	1	295	-	15	6	40	357
3	Number	-	7	409	-	22	309	14	761
	Dry weight	-	1	498	-	2	7	T	508
4	Number	-	93	1608	-	-	43	-	1744
	Dry weight	-	14	2036	-	-	1	-	2051
5	Number	-	101	890	-	-	79	-	1070
	Dry weight	-	15	637	-	-	2	-	654
6	Number	-	14	323	-	165	445	-	947
	Dry weight	-	2	249	-	12	10	-	273
7	Number	-	-	431	7	22	244	-	704
	Dry weight	-	-	450	12	2	5	-	469
8	Number	-	7	653	-	36	68	-	764
	Dry weight	-	1	683	-	3	2	-	689
9	Number	-	14	660	-	-	151	-	825
	Dry weight	-	2	546	-	-	3	-	551
10	Number	-	-	43	-	-	36	-	79
	Dry weight	-	-	29	-	-	1	-	30

Appendix Table 9. Abundance and biomass (mg) determinations of the principal macrobenthic organisms collected during December 1979 from the Big Stone Power Plant cooling reservoir, South Dakota. T = less than 1.0.

Station		Caenis	Chaoborus	Chironominae	Chironominae Pupae	Oligochaetae	Tanypodinae	Other	Total
1	Number	-	7	545	-	50	402	-	1004
	Dry weight	-	1	709	-	4	9	-	723
2	Number	-	14	129	-	43	258	-	444
	Dry weight	-	2	95	-	3	6	-	106
3	Number	-	7	344	-	29	180	14	574
	Dry weight	-	1	658	-	2	5	T	666
4	Number	-	22	466	-	-	86	-	574
	Dry weight	-	3	962	-	-	2	-	967
5	Number	-	29	144	-	-	144	-	317
	Dry weight	-	4	166	-	-	3	-	173
6	Number	-	-	100	-	251	359	14	724
	Dry weight	-	-	64	-	18	8	T	90
7	Number	-	-	222	-	-	416	7	645
	Dry weight	-	-	256	-	-	9	T	265
8	Number	-	-	158	-	43	57	-	258
	Dry weight	-	-	156	-	3	1	-	160
9	Number	-	-	201	-	-	122	-	323
	Dry weight	-	-	192	-	-	3	-	195
10	Number	-	-	29	-	14	158	-	201
	Dry weight	-	-	29	-	1	3	-	33

Appendix Table 10. Abundance and biomass (mg) determinations of the principal macrobenthic organisms collected during January 1980 from the Big Stone Power Plant cooling reservoir, South Dakota. T = less than 1.0.

Station		*Caenis*	*Chaoborus*	Chironominae	Chironominae Pupae	Oligochaetae	Tanypodinae	Other	Total
1	Number	-	-	710	-	-	883	-	1593
	Dry weight	-	-	947	-	-	19	-	966
2	Number	-	7	72	-	72	266	7	424
	Dry weight	-	1	127	-	5	6	14	153
3	Number	-	22	266	-	29	222	-	539
	Dry weight	-	3	583	-	2	5	-	593
4	Number	7	50	897	-	-	86	7	1047
	Dry weight	2	7	1928	-	-	2	14	1954
5	Number	29	22	316	-	86	101	7	561
	Dry weight	8	3	413	-	51	2	14	491
6	Number	-	-	273	-	79	158	-	510
	Dry weight	-	-	514	-	6	4	-	524
7	Number	-	-	352	-	-	309	-	661
	Dry weight	-	-	446	-	-	7	-	453
8	Number	-	7	129	-	14	93	-	243
	Dry weight	-	1	170	-	1	2	-	174
9	Number	-	-	287	-	-	280	-	567
	Dry weight	-	-	181	-	-	6	-	187
10	Number	-	-	72	-	29	36	-	137
	Dry weight	-	-	84	-	2	1	-	87

Appendix Table 11. Abundance and biomass (mg) determinations of the principal macrobenthic organisms collected during February 1980 from the Big Stone Power Plant cooling reservoir, South Dakota. T = less than 1.0.

Station		*Caenis*	*Chaoborus*	Chironominae	Chironominae Pupae	Oligochaetae	Tanypodinae	Other	Total
1	Number	-	-	510	-	129	344	-	983
	Dry weight	-	-	413	-	9	8	-	430
2	Number	-	-	165	-	122	287	7	581
	Dry weight	-	-	93	-	9	6	T	108
3	Number	-	14	359	-	7	380	7	767
	Dry weight	-	2	1025	-	1	8	T	1036
4	Number	-	7	1012	-	-	79	-	1098
	Dry weight	-	1	3474	-	-	2	-	3477
5	Number	-	14	359	-	-	215	-	588
	Dry weight	-	2	654	-	-	5	-	661
6	Number	-	14	359	-	29	266		668
	Dry weight	-	2	692	-	2	6	-	702
7	Number	-	-	352	-	14	653	-	1019
	Dry weight	-	-	522	-	1	26	-	549
8	Number	-	-	14	-	93	93	7	207
	Dry weight	-	-	29	-	7	2	T	38
9	Number	-	7	136	-	-	158	-	301
	Dry weight	-	1	102	-	-	3	-	106
10	Number	-	-	36	-	36	36	7	115
	Dry weight	-	-	53	-	3	1	T	57

Appendix Table 12. Abundance and biomass (mg) determinations of the principal macrobenthic organisms collected during March 1980 from the Big Stone Power Plant cooling reservoir, South Dakota. T = less than 1.0.

Station		*Caenis*	*Chaoborus*	Chironominae	Chironominae Pupae	Oligochaetae	Tanypodinae	Other	Total
1	Number	136	–	1127	14	7	524	7	1815
	Dry weight	236	–	531	1	1	11	40	820
2	Number	7	–	165	–	7	488	14	681
	Dry weight	2	–	135	–	1	11	14	163
3	Number	–	29	122	–	14	258	14	437
	Dry weight	–	4	436	–	1	6	21	468
4	Number	–	50	675	–	–	165	–	890
	Dry weight	–	7	2197	–	–	4	–	2208
5	Number	–	29	237	–	–	158	–	424
	Dry weight	–	4	305	–	–	4	–	313
6	Number	–	14	115	–	36	280	–	445
	Dry weight	–	2	449	–	3	6	–	460
7	Number	–	–	244	–	–	1715	–	1959
	Dry weight	–	–	477	–	–	14	–	491
8	Number	–	–	36	–	36	136	–	208
	Dry weight	–	–	53	–	3	3	–	59
9	Number	–	7	86	–	–	115	–	208
	Dry weight	–	1	142	–	–	3	–	146
10	Number	–	–	65	–	–	43	14	122
	Dry weight	–	–	101	–	–	1	27	129