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SOME OBSERVATIONS CONCERNING THE EFFECTS OF A POWER STATION'S THERMAL EFFLUENT ON PHYTOPLANKTON DYNAMICS

E. W. WILDE[1], L. L. OLMSTED[2], AND A. GNILKA[3]

ABSTRACT

A limnological study of Lake Wylie Reservoir in North and South Carolina showed that phytoplankton composition and abundance were influenced by the operation of a fossil-fueled electric generating station (Plant Allen). These effects were distinctly localized and no lake-wide effect was observed. Plant Allen utilizes cooling water from one major tributary (Catawba River) to Lake Wylie and discharges it into the other major tributary (South Fork River). The upstream migration of the discharge water (plume) has a dynamic impact on the phytoplankton community of the South Fork. Substantial pulses of phytoplankton taxa characteristic of the Catawba River were detected approximately 2 miles (3.2 kilometers) upstream from the discharge point on 4 of 12 sampling dates. Retention time appeared to be a major factor influencing the phytoplankton quantities in the vicinity of the Plant Allen discharge.

INTRODUCTION

A baseline/predictive environmental investigation was recently completed on Lake Wylie, a multiple-use reservoir located in North and South Carolina (Fig. 1). Objectives of the study were to (1) document ambient biotic and abiotic characteristics of the lake, (2) obtain data required to predict the possible environmental influence of a proposed nuclear power station and (3) document the effects of an operational fossil-fueled power station on the aquatic environment (Industrial BIO-TEST Laboratories, 1974).

The study, conducted between September 1973 and August 1974, included monthly sampling at locations throughout the reservoir and its two major tributaries. Physical, chemical and biological data indicated that the study area was comprised of three distinct water systems: (1) the Catawba River, a well-mixed river environment receiving water from several upstream impoundments; (2) the South Fork River, receiving primarily surface runoff; and (3) the main body of the Lake Wylie reservoir, a seasonally stratified lake system.

Plant Allen, a fossil-fueled electric generating station, withdraws water from the Catawba River, uses it for once-through cooling, and discharges the condenser cooling water into the South Fork River (Fig. 1). This heated effluent has a dynamic impact on the physical, chemical and biological characteristics of a section of the South Fork upstream and downstream from the point of discharge. This paper is an interpretive discussion of the relationship between the thermal plume and the phytoplankton of the South Fork River and is based primarily on the results obtained from three sampling locations in the vicinity of Plant Allen, although results from other sampling locations are considered.

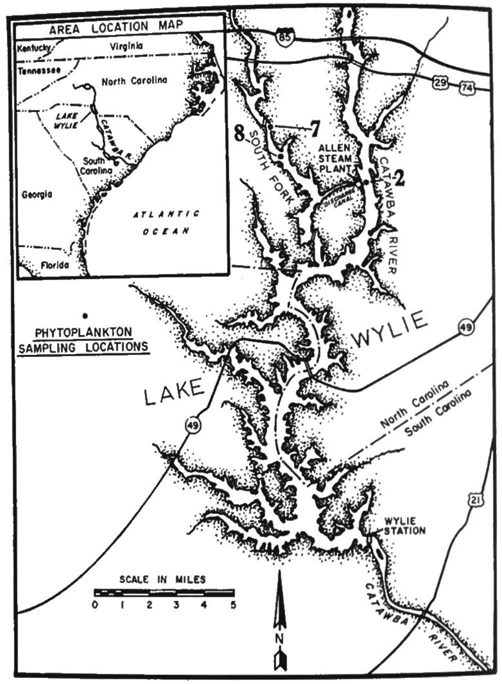

FIG. 1: *Map of Lake Wylie showing phytoplankton sampling locations 2, 7 and 8 in the vicinity of Plant Allen.*

[1] Nalco Environmental Sciences, 1810 Frontage Road, Northbrook, Illinois 60062

[2] Biologist, Duke Power Company, Route 3, Box 90, Huntersville, N.C. 28078

[3] Biologist, Duke Power Company, Charlotte, N.C. 28242

METHODS

Phytoplankton

Monthly duplicate 24 l composite water samples were collected at 12 locations with Van Dorn water samplers. Samples were routinely taken 1 m below the surface and 1 m above the bottom. In order to validate the adequacy of surface and bottom sampling, vertical profiles were collected in November, February, April and July at Locations 2, 10, and 12. These samples were taken from 1 m below the surface, mid-euphotic zone, at the thermocline (when present) and 1 m above the bottom. When the mid-euphotic zone and the thermocline were indistinct, or coincided, collections were made at one quarter depth increments. Immediately following collection, 1.9 l subsamples for phytoplankton analysis were preserved with a 3% solution of "M^3" preservative (Meyer, 1971).

Fifty milliliters of sample were usually processed for diatom analyses, but the exact quantity was dependent on sample turbidity and the density of organisms. Diatoms were cleaned with a concentrated nitric acid/potassium dichromate solution and collected on 0.45μ pore size membrane filters. A portion of each air-dried filter was placed on a slide, cleared with immersion oil and a known area of the preparation examined at 1250X magnification using phase contrast microscopy.

Eight hundred and seventy-five milliliters of sample were processed for analysis of phytoplankton other than diatoms. Organisms were concentrated by settling with detergent (MacKenthun, 1969) and examined using Lackey's (1938) microtransect method at 500X with phase contrast.

Phytoplankton organisms were identified to the lowest positive taxonomic level (usually species). All undamaged diatom valves and complete cells of non-diatom taxa were counted and reported in units/ml. A reporting unit consisted of a single diatom frustule or one cell of a unicellular or colonial non-diatom taxon. Each 25μ length of a filamentous green or blue-green taxon was reported as a unit.

Biovolumes (cell volumes) of all phytoplankton taxa were determined using methods described by Cowell (1960) and Hohn (1969). All biovolumes were expressed as microliters per liter ($\mu l/l$).

RESULTS AND DISCUSSION

Analysis of the phytoplankton data (Wilde and Paulishen, 1974) accumulated during the study revealed that the two major tributaries (Catawba River and South Fork) to Lake Wylie contained distinctive natural phytoplankton communities (Table 1). The waters from the two tributaries are mixed in the South Fork by the diversion of water through Plant Allen, prior to natural mixing that occurs at the confluence of the two rivers (Fig. 1).

TABLE 1: *Phytoplankton taxa characteristic of one tributary to the Lake Wylie Reservoir and rare or absent in the other tributary.*

Characteristic of the South Fork	Characteristic of the Catawba River
Bacillariophyta	Bacillariophyta
Pinnularia spp.	*Melosira* spp.
Nitzschia spp.	*Cyclotella* spp.
Gomphonema spp.	*Stephanodiscus* spp.
Cymbella spp.	
Synedra spp.	Chlorophyta
Achnanthes spp.	*Chlamydomonas* spp.
	Mesostigma viridis
Chlorophyta	
Scenedesmus spp.	Cyanophyta
Nannochloris sp.	*Oscillatoria geminata*
Coelastrum microporum	*Merismopedia tenuissima*
Ankistrodesmus spp.	
	Cryptophyta
Cyanophyta	*Cryptomonas* spp.
Oscillatoria tenuis	
Oscillatoria limnetica	Pyrrhophyta
	Glenodinium spp.
Euglenophyta	
Euglena spp.	Chrysophyta
Trachelomonas spp.	*Mallomonas* spp.
Phacus spp.	

The most obvious effects of Plant Allen's operation on phytoplankton were observed at South Fork Location 8. This location, situated approximately two miles (3.2 km) upstream from the discharge area, was within the influence of the thermal plume during 4 of the 12 monthly sampling periods (September, October, November and June). Unusually large phytoplankton quantities (density and biovolume) were observed near the surface each time the thermal plume extended upstream to Location 8. When the plume did not extend upstream to Location 8, the ratio of phytoplankton biovolume one meter below the surface to that one meter above the bottom was less than 2:1 and species composition was similar at the two depths. However, during sampling periods when the plume was present at the location, the ratio of phytoplankton biovolume one meter below the surface to that one meter above the bottom was at least 9:1 (Fig. 2), and the species composition near the surface was similar to that found in the Catawba River (Location 2). Phytoplankton species composition near the bottom of Location 8 was always typical of ambient South Fork water (Location 7). Phytoplankton abundance and composition were similar at South Fork Locations 7 and 8 from December through May. In June, September, October and November, when the plume extended to Location 8, phytoplankton were much more abundant there and

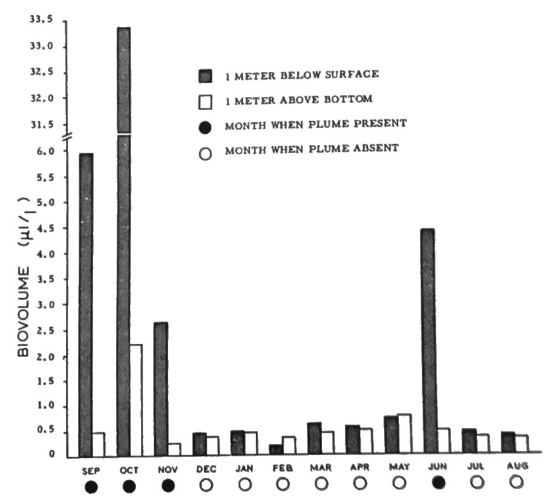

FIG. 2: *Total phytoplankton biovolume at two sampling depths of Location 8, showing influence of the thermal plume from the Plant Allen discharge, Sept. 1973-Aug. 1974.*

the composition near the surface was more like that of the Catawba River than that of the South Fork.

The composition of the diatom assemblage near the surface of Location 8 during the months of plume influence clearly demonstrated that this water was derived primarily from the Catawba River. Samples from the Catawba River had a higher percentage of centric diatoms than pennate diatoms on all sampling dates, while samples from South Fork Locations 7 and 8 always had a higher percentage of pennate diatoms than centric diatoms except near the surface of Location 8 in September, October, November and June (Fig. 3).

Phytoplankton taxa that exhibited pulses at the surface of Location 8 on sampling periods in which the plume was present were different in the fall than summer due to the natural season succession of phytoplankton and included: *Merismopedia tennuissima, Gonyostomum depressum* and *Cryptomonas ovata* in September, *C. ovata* in October, *C. ovata* and *Mesostigma viridis* in November and *Chlamydomonas* spp. and *Gymnodinium* spp. in June. All of these taxa were assumed to have been primarily introduced into the South Fork from the Catawba River by passage through

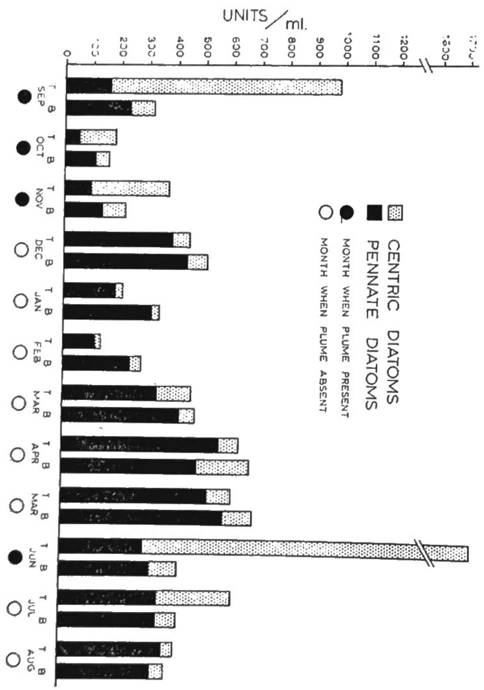

FIG. 3: *Diatom occurrence at two sampling depths (T=1m below surface and B=1m above bottom) of Location 8, showing the difference in the ratio of centric to pennate diatoms near the surface during the months of plume influence, Sept. 1973-Aug. 1974.*

the power station, since they were seldom observed at South Fork Location 7 upstream from Location 8 and were substantially less abundant near the bottom of Location 8 than near the surface (Figs. 4 and 5).

Physical and chemical properties recorded concurrently with phytoplankton sampling at Catawba River Location 2 and South Fork Locations 7 and 8 are presented in Table 3. Water temperature data clearly

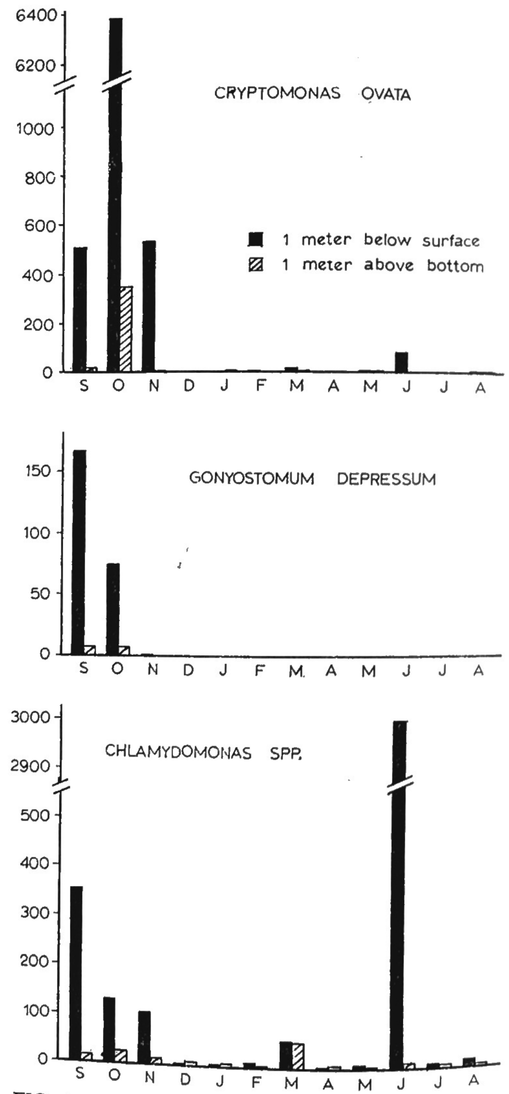

FIG. 4: *Occurrence (units/ml) of* Cryptomonas ovata, Gonyostomum depressum *and* Chlamydomonas *spp. at two sampling depths of Location 8, Sept. 1973-Aug. 1974.*

revealed the presence of the thermal plume at the surface of Location 8 in September, October, November and June. Water temperatures one meter below the surface were 5.9 to 7.3°C higher at Location 8 than at Location 7 during these months, whereas the difference in water temperatures at the two locations was less than 1°C during the other eight monthly sampling periods.

Physical and chemical data illustrated that both the Catawba River and South Fork contained relatively

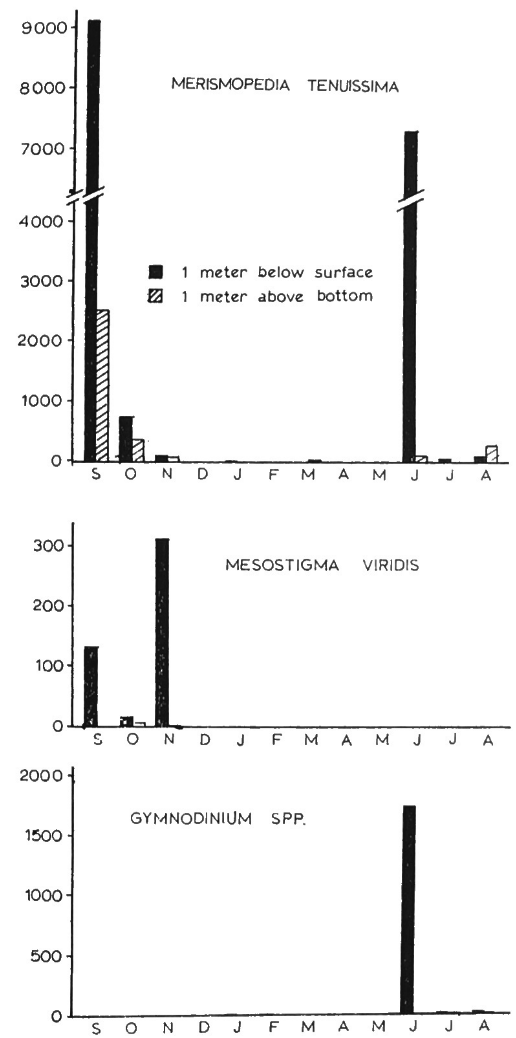

FIG. 5: *Occurence (units/ml) of* Merismopedia tenuissima, Mesostigma viridis *and* Gymnodinium *spp. at two sampling depths of Location 8, Sept. 1973-Aug. 1974.*

soft water in which pH could be significantly influenced by the photosynthetic activity of phytoplankton. The South Fork was usually considerably more turbid and higher in nutrient content than the Catawba River. Physical and chemical properties at South Fork Location 8 closely resembled those of South Fork Location 7 except for the four months of plume influence (September, October, November and June) when properties near the surface of Location 8 tended to be more like those of Catawba River Location 2.

The phytoplankton and physiochemical data from this study indicate that whenever flow conditions and operation of Plant Allen allow the thermal plume from the discharge to extend upstream approximately two miles (3.2 kilometers), large quantities of phytoplankton with taxa characteristic of the Catawba River will be present there. It is possible that some of the phytoplankton taxa which originate in the Catawba River increase their reproductive rate when they are introduced into the relatively nutrient-rich South Fork and are subjected to the increased water temperature from the plume; however, on the dates when the plume was present at Location 8, phytoplankton quantities were considerably larger there than at sampling locations within the influence of the plume downstream from the discharge canal (Wilde and Paulishen, 1974). This indicated that temperature and nutrient enrichment were not the "prime" factors responsible for the increased populations which existed at Location 8. As the Plant Allen discharge water (plume) migrates upstream in the South Fork, the velocity gradually decreases and eventually reaches zero. This velocity gradient upstream results in a slack water area with an increased retention time which allows the phytoplankton populations to build up in this area. No such gradient exists at the downstream locations and populations there do not build up to the same extent.

Many authorities (Blum, 1956; Williams, 1964; Lund, 1965; Reinhardt, 1931; Whitford and Schumacher, 1963) have shown that flow rate is often of overriding importance in determining phytoplankton periodicity in lotic systems. Reinhardt (1931), Blum (1956), and Whitford and Schumacher (1963) have stressed that the development of potamoplankton (the major component of the reservoir and river phytoplankton) is primarily dependent on the "age" (retention time) of the water.

The fact that most of the species exhibiting pulses near the surface at Location 8 during months of plume influence were motile indicated that the mixing action of the two water masses (South Fork and Catawba River) with different temperatures may have caused a concentration of flagellates at the interface. A similar phenomenon has been reported in marine environments where massive concentrations of dinoflagellates often occur when a convergent front results between two distinct water masses and causes organisms to aggregate along the lines of convergence (Fung and Trott, 1973).

Influence of the thermal discharge from Plant Allen on phytoplankton dynamics appeared to be restricted to the area of the South Fork in which the thermal

	Location	4 & 5 Sept 1973	8 & 9 Oct 1973	9 & 10 Nov 1973	10 & 11 Dec 1973	7 & 8 Jan 1974	11 & 12 Feb 1974	11 & 12 Mar 1974	8 & 9 Apr 1974	13 & 14 May 1974	10 & 11 Jun 1974	8 & 9 Jul 1974	12 & 13 Aug 1974
Water temp. (°C)	2	28.2	24.1	17.1	12.2	10.0	8.6	13.4	13.3	21.6	26.9	26.4	26.4
	8	31.4	26.3	20.6	7.2	9.0	6.1	15.8	13.2	18.5	29.4	22.5	22.0
	7	25.5	19.7	13.3	7.3	8.9	5.9	14.6	12.7	18.1	22.6	21.6	21.5
Specific conductance (micro-mhos/cm)	2	62	59	62	68	60	90	65	62	70	76	63	59
	8	80	70	89	77	80	69	116	58	60	82	52	60
	7	125	115	174	71	83	73	118	62	58	99	51	72
Dissolved Oxygen (mg/l)	2	6.3	6.6	7.7	9.1	10.4	10.2	10.3	9.8	8.0	9.6	7.9	5.5
	8	10.0	8.9	8.7	11.4	10.8	12.1	8.6	10.1	8.3	9.8	7.7	7.7
	7	7.0	8.5	9.7	11.8	11.2	12.4	9.5	9.7	8.8	7.5	8.3	8.3
pH	2	6.5	6.2	6.6	6.5	6.5	6.5	-	6.4	6.4	8.3	6.8	6.2
	8	8.0	6.7	6.6	6.8	6.7	6.7	-	6.3	6.4	8.2	6.0	6.2
	7	6.9	6.8	7.1	6.8	6.8	6.8	-	6.5	6.5	6.7	5.8	6.5
Alkalinity (mg/l-CaCo3)	2	14.5	13.5	14.0	14.0	13.0	12.5	11.0	9.0	11.0	12.5	10.5	11.0
	8	17.5	14.5	15.0	15.0	17.0	13.5	19.5	8.0	10.5	13.5	10.0	9.0
	7	26.0	20.5	27.5	16.0	18.0	14.0	19.5	10.0	10.0	18.0	10.0	11.5
Nitrate (mg/l-N)	2	0.010	0.003	0.085	0.180	0.230	0.255	0.295	0.030	0.280	0.035	0.008	0.055
	8	0.025	0.085	0.200	0.500	0.370	0.355	0.450	0.050	0.545	0.095	0.510	0.285
	7	0.480	0.740	0.450	0.500	0.435	0.355	0.455	0.060	0.560	0.630	0.440	0.155
Orthophosphate (mg/l-P)	2	0.005	0.007	0.016	0.057	0.006	0.002	0.006	0.003	0.004	0.001	0.004	0.011
	8	0.025	0.004	0.020	0.063	0.065	0.027	0.076	0.014	0.035	0.003	0.004	0.01[illegible]
	7	0.020	0.160	0.305	0.059	0.078	0.029	0.140	0.010	0.030	0.083	0.011	0.01[illegible]
Total Phosphorus (mg/l-P)	2	0.035	0.023	0.027	0.098	0.032	0.018	0.021	0.042	0.029	0.018	0.031	0.02[illegible]
	8	0.093	0.095	0.096	0.210	0.140	0.115	0.155	0.140	0.250	0.049	0.245	0.25[illegible]
	7	0.285	0.335	0.415	0.225	0.155	0.110	0.150	0.140	0.220	0.140	0.300	0.24[illegible]
Turbidity (J. T. U.)	2	5.0	9.5	5.0	8.0	19.5	51.0	15.0	36.0	12.5	4.7	6.0	11.5
	8	7.5	13.0	7.0	52.5	30.0	51.5	23.0	76.5	155.0	13.5	170.0	16.5
	7	19.5	36.0	14.5	71.0	28.0	39.5	25.5	68.0	140.0	9.5	170.0	14.0
Dissolved solids (Total mg/l)	2	43.5	40.0	47.5	42.0	53.5	68.0	44.5	46.0	53.0	55.0	54.0	54.0
	8	60.0	48.5	64.0	80.0	72.0	65.0	86.0	48.0	47.0	67.0	52.0	55.0
	7	96.0	79.5	115.0	84.0	61.0	65.0	82.0	47.0	46.0	72.0	45.0	57.0
Light penetration (%)	2	12.0	-	16.0	22.0	6.5	2.6	15.0	1.6	17.0	20.0	10.0	9.7
	8	4.7	-	8.5	0.5	2.7	2.9	7.8	<0.1	<0.1	8.5	<0.1	<0.1
	7	4.7	-	4.6	0.2	3.3	4.3	3.1	<0.1	<0.1	<0.1	<0.1	<0.1
Manganese (mg/l)	2	0.105	0.008	0.045	0.060	0.060	0.085	0.040	0.040	0.040	0.021	0.025	0.084
	8	0.015	0.030	0.030	0.140	0.085	0.060	0.100	0.075	0.105	0.038	0.120	0.120
	7	0.135	0.120	0.100	0.150	0.075	0.070	0.070	0.090	0.100	0.100	0.170	0.140
Ammonia (mg/l-N)	2	0.015	0.065	0.090	0.110	0.030	0.040	0.030	0.030	0.030	0.010	0.002	0.075
	8	0.015	0.030	0.090	0.130	0.160	0.060	0.120	0.050	0.070	0.015	0.045	<0.010
	7	0.090	0.150	0.285	0.120	0.210	0.075	0.145	0.060	0.060	0.095	0.035	<0.010
Soluble Silica (mg/l-SiO2)	2	8.6	8.7	8.8	7.6	9.7	10.5	8.3	7.5	9.6	10.5	9.9	8.6
	8	10.0	9.6	10.0	10.3	14.5	11.0	13.0	7.8	10.5	9.7	12.0	10.0
	7	14.5	14.0	15.5	10.5	15.0	11.5	12.5	8.7	9.8	16.5	11.5	14.5

TABLE 3: *Physiochemical properties of the phytoplankton water samples collected 1m below the surface at Catawba River Location 2 and South Fork Locations 7 and 8, Sept. 1973-Aug. 1974.*

plume was present. There were no quantitative or qualitative phytoplankton differences in the Lake Wylie Reservoir (below the confluence of the Catawba River and South Fork) which could be attributed to the operation of the power station (Wilde and Paulishen, 1974).

LITERATURE CITED

Blum, J. L. 1956. The ecology of river algae. Bot. Rev. 22: 291-341.

Cowell, B. C. 1960. A quantitative study of the winter plankton of Urschel's Quarry. Ohio J. Sci. 60:183-191.

Fung, Y. C., and L. B. Trott. 1973. The occurrence of a *Noctiluca scintillans* (Macartney) induced red tide in Hong Kong. Limnol. Oceanogr. 18:(3)472-475.

Hohn, M. H. 1969. Qualitative and quantitative analyses of plankton diatoms. Bull. Ohio Biol. Surv. 3:1-211.

Industrial BIO-TEST Laboratories, Inc. 1974. A baseline/predictive environmental investigation of Lake Wylie. 2 Vols. Report prepared for Duke Power Company, Charlotte, N.C. 743 p.

Lackey, J. B. 1938. The manipulation and counting of river plankton and changes in some organisms due to formalin preservation. U. S. Public Health Report. 53:2080-2093.

Lund, J. W. G. 1965. The ecology of the freshwater phytoplankton. Biol. Rev. 40:231-293.

Mackenthun, K. M. 1969. The practice of water pollution biology. U. S. Dept. Int., F.W.P.C.A., Washington, D.C. 281 p.

Meyer, R. 1971. A study of phytoplankton dynamics in Lake Fayetteville as a means of assessing water quality. Publ. No. 10, Ark. Water Res. Reclamation Center. 59 p.

Reinhard, E. G. 1931. The plankton ecology of the upper Mississippi, Minneapolis to Winona. Ecol. Monogr. 1(4):395-464.

Whitford, L. A. and G. J. Schumacher. 1963. Communities of algae in North Carolina streams and their seasonal relations. Hydrobiologia 22:133-196.

Wilde, E. W. and T. A. Paulishen. 1974. Phytoplankton Study. *In* A baseline/predictive environmental investigation of Lake Wylie. Report prepared by Industrial BIO-TEST Laboratories, Inc. for Duke Power Company, Charlotte, N.C. Vol. 1. Chapt. 4. 277-357.

Williams, L. G. 1964. Possible relationships between plankton-diatom species numbers and water-quality estimates. Ecol. 45(4):809-823.