THE EFFECTS OF A THERMAL DISCHARGE ON THE INSHORE BIOLOGICAL COMMUNITIES OF LAKE MICHIGAN

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Introduction

The plankton, periphyton, and benthos communities of inshore waters were studied near the Point Beach Nuclear Power Station during 1971 to determine the biological effects of once-through cooling. These aquatic communities are characteristically vital in the trophic system as primary producers (periphyton and phytoplankton), consumers, and food organisms for other animals. Alteration of photosynthetic activity or food chain relationships could result in detrimental impact to the local inshore ecology near a thermal discharge. It is evident from a review of the literature that the extent of biological impact due to thermal discharges varies tremendously and depends upon the aquatic habitat, species compositions, and specific operational criteria of the generating station. Although it is often possible to demonstrate an effect on a species or functional group of organisms, it is extremely difficult to evaluate the overall significance (impact) of that effect on the ecology of Lake Michigan. The approach of these preliminary studies was to search for measurable effects on the communities of local inshore waters which would warrant future study based on the potential significance of those effects.

Methods

Benthos

Bottom-dwelling organisms were collected at each of the sampling stations at monthly intervals from May through August using a Ponar grab sampler [see Table 1, Introduction (Spigarelli)]. Samples were preserved in 10% formalin, stored in plastic bags and later separated by means of a standard series of sieves (4 to 0.125 mm). The few organisms collected were identified to family and enumerated.

Periphyton

Artificial substrate samplers (Lucite) were attached in a horizontal position to permanent anchors (10 stations) by Scuba divers and allowed to be colonized for at least 41 days. Each substrate consisted of a 13" x 13" tray with 20 slides (2.5" x 1") attached at the periphery. Upon retrieval, sedimentary material (clay) was washed from the substrate surface and the periphyton attached to the tray portion was scraped, dried (60° C), and weighed. Reported values have been corrected for area scraped and exposure time.

Slides attached to the periphyton trays were used to estimate relative primary productivity (^{14}C technique) at three locations in September. Four slides from each tray were removed, placed individually in 300-ml reagent bottles (3 light bottles, 1 dark bottle) which were filled with filtered (0.5 μ) lake water. Each bottle was spiked with 1 μCi of ^{14}C-labeled $NaHCO_3$ and resuspended near the bottom for 3 hr. Once retrieved, each sample was fixed with Lugols iodine solution. Labeled periphyton was later removed from the bottles, scraped and collected on Whatman #1 filters. Samples were then placed in a tritium-carbon oxidizer, and counted in a liquid scintillation spectrometer. The ^{14}C uptake values represent the average of the 3 light bottles minus the dark bottle, normalized for the total oxidizable dry periphyton weight.

Plankton

Samples of plankton were collected at representative stations each month by two methods. Vertical tows (bottom and surface) were made with a 12" diameter Wisconsin net of 10-μ mesh, and the samples were fixed in 10% formalin. These samples were later filtered through preweighed Whatman #1 filters, dried (50° C), and reweighed to obtain dry solids weight.

In addition, water samples were collected in a nonmetallic Kemmerer bottle from the surface and bottom at each station and filtered (20 psi) through 0.5-μ Millipore filters. Filters were individually stored and frozen in plastic bags until analyzed. Relative values of chlorophyll a concentration (proportional to phytoplankton productivity) were determined by means of the fluorometric procedure of Yentsch and Menzel.[1] Fluorescence measurements were made using a Turner Model III Fluorometer; excitation was in the 415- to 520-mμ range and detection in the 595- to 750-mμ range. Values reported are fluorescence units of chlorophyll a corrected for phaeophytin and blanks:

$$Fc = K\ Fo\ (Fo/Fa-1)$$

where

Fc = chlorophyll a fluorescence,
K = proportionality constant,
Fo = total fluorescence minus blank, and
Fa = fluorescence after acidification minus blank.

Results and Discussion

In general, studies of the plankton, periphyton, and benthos communities near the Point Beach Station did not reveal any major widespread effects due to the waste heat. The benthic community of the inshore areas (< 40') was found to be very sparse, even at the control stations. The apparent reason for restricted benthic populations is the nature of the substrate in this general area of Lake Michigan (i.e., primarily a combination of shifting clay with some sand, gravel, and rock). The clay sediment frequently is resuspended by wave action, resulting in severe turbidity in nearshore waters. An unstable substrate such as this is no doubt quite rigorous for benthic species and restricts the density and diversity of the benthos.

The most common organism collected was the amphipod, Pontoporeia affinis (0 to 100 individuals/m^2). This density is extremely low compared to that in other areas of the lake; near Zion, Illinois, Lamble[2] found densities ranging from 4000 to 16,000/m^2. Other benthic animals, such as dipteran larvae (Chironomidae) and snails, were occasionally collected.

Plankton

Biomass of plankton (> 10 μ) collected in vertical tows and chlorophyll a fluorescence values from one-liter water samples at each station are shown in Table 1.

There is no apparent relationship with temperature or spatial trend in the vertical-tow weights. It is improbable that condenser or plume entrainment could result in immediate (< 1 hour) increases in phytoplankton densities. It is possible, however, that plankton entrained in the cooling cycle are damaged and that net plankton biomass decreases at some distance from discharge. But this was not evident from the data; no stations were consistently low in plankton weight, given the same plume direction. Weights of plankton at all stations were relatively low in June ($\bar{X}$ = 35 μg/l) and September ($\bar{X}$ = 23 μg/l) and high in July ($\bar{X}$ = 73 μg/l) and August ($\bar{X}$ = 57 μg/l). There was no apparent correlation between vertical tow weights and fluorescence values.

The proportionality between chlorophyll a and biomass of phytoplankton is a well-established principle;[3] it follows that, under optimum conditions (light, nutrients, and temperature) chlorophyll a and primary production are correlated.[4] Fluorometric analysis of chlorophyll extracts provided a sensitive means of measuring chlorophyll a concentrations in water. The data reported in Table 1 are relative fluorescence values. In June and July surface samples, (Fig. 1) the fluorescence values decreased at station 4 and increased at station 5 relative to the mean ambient (non-plume) value. At greater distances from the discharge, in the direction of plume flow, the fluorescence values generally decreased from the peak values observed at station 5. Bottom water samples collected during these months (Fig. 1) were not consistent in terms of fluorescence changes with distance in the plume. In June, a general decrease relative to the ambient value was observed at stations 4 and 5 with an increase at station 7 (3600') and eventual decrease at the control stations. In July large increases were observed at stations 4 and 5 and gradual decreases to near ambient level at the control stations. It cannot be inferred from these limited data that chlorophyll a values near the discharge always exceeded ambient levels since ambient (non-plume) concentrations were quite variable and occasionally were as high as at plume stations.

TABLE 1. Physical and Biological Measurements at Point Beach Nuclear Power Station

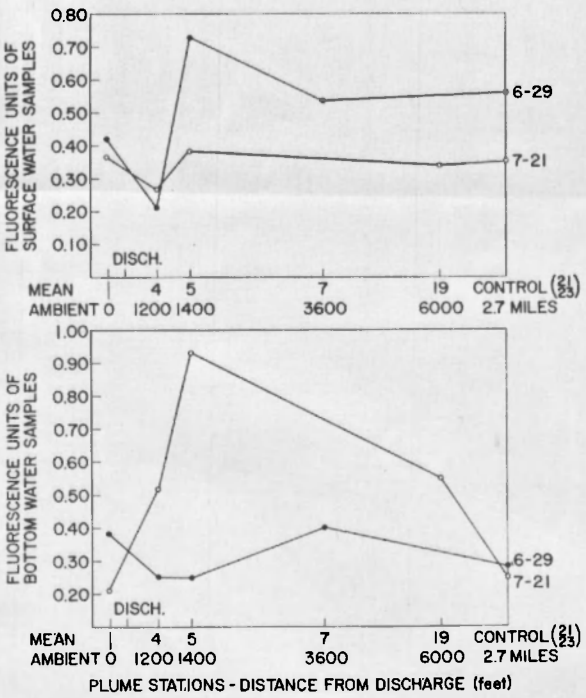
Day, 1971	Station	Depth, ft	Temperature, °C Surface	Mid	Bottom	Particulate matter > 10μ, g/l x 10^{-6}	Relative Chlorophyll Fluorescence Surface	Bottom	Periphyton growth g/m^2/day	^{14}C uptake μCi/g	Secchi depth, ft
June 29	Discharge	12	21.0	21.5	21.0		0.46	0.03			
	4	16	15.5	11.0	10.5		0.21	0.25			
	3	16	12.0	11.5	11.0		0.39	0.23			
	1	16	12.0	11.0	10.5		0.31	1.00			
	7	16	12.5	12.0	12.5		0.53	0.40			
	21	16	12.5	12.0	12.2		0.57	0.28			
	5	16	14.5	13.0	12.0		0.75	0.25			
June 30	23	36	14.0	11.0	11.0	48	0.20	0.26			14
	22	22	13.0	11.5	10.5	78					
	21	16	12.5	11.5	11.0	59					
	7	16	12.5	12.0	10.5	51					
	19	30	13.0	10.5	10.5	17	0.12	0.35			
	5	16	12.5	11.5	11.0	11					
	16	30	13.5	10.5	10.0	20	0.26	0.13			
	4	16	12.5	11.0	10.5	25					
	3	16	14.0	12.5	11.0	16					
	1	16	13.5	12.0	10.5	35					
	14	30	13.0	10.6	10.6	23	0.25	0.36			
July 21	5	16	14.0	12.5	12.0	32	0.32	0.93			9
	21	16	12.5	12.0	11.5	88	0.26	0.33			11
	23	36	12.5	12.5	10.5	80	0.47	0.17			9
	4	16	16.0	11.5	11.0	85	0.27	0.52			8
	16	30	11.5	11.0	10.5	89	0.35	0.12			10
	19	30	12.5	11.5	11.0	84	0.34	0.55			10
July 22	Discharge	12	16.5				0.38				
	1	16	9.0	8.0	7.0	76	0.17	0.36			6
	14	30	8.0	7.0	6.5	19	0.17	0.77			8
	3	16	11.0	8.5	8.0	106	0.73	0.98			5
Aug. 24	5	16	18.0	17.5	16.5	13	0.21	0.15			2.5
	4	16	21.0	17.0	17.0	91	0.23	0.33			2.0
	3	16	21.5	17.5	17.5	49	0.37	0.36			1.5
Aug. 25	14	30	16.5	16.5	16.5	107		0.25			11.0
	16	30	18.0	18.0	16.5	43	0.21	0.17			6.0
	21	16	17.0	17.0	17.0	52	0.17	0.13			3.0
	23	36	17.0	17.0	16.5	87	0.09	0.26			9.0
Sept. 16	3	14							0.35[a]	0.10	
	4	14							0.34		
	5	14							0.33		
	7	14							0.11		
	14	28							0.14	0.47	
	16	28							0.12		
	19	28							0.10		
	21	14							0.10	0.08	
	23	34							0.12		
Sept. 28	1	16	11.8	10.5	10.0	43					
	14	30	10.5	10.0	8.0	28					
	16	30	10.5	9.8	8.8	12					
	3	16	10.8	10.2	10.2	8					
	5	16	11.0	10.5	10.0	17					
	7	16	11.0	10.5	10.2	25					
	19	30	11.8	10.2	9.2	9					
	23	36	11.8	10.0	8.8	17					
Sept. 29	21	16	12.5	11.2	10.5	28					
Oct. 26	1	14							0.11[b]		
	3	14							0.18		
	4	14							0.32		
	5	14							0.13		
	7	14							0.10		
	14	28							0.03		
	16	28							0.06		
	19	28							0.05		
	21	14							0.07		
	23	34							0.05		

(a) Growth time = 85 days at indicated depths.

(b) Growth time = 41 days at indicated depths.

It is impossible at this time to evaluate the significance of the small trends in the data. There was no linear correlation of fluorescence with water temperature, implying that a time lag occurs prior to physiologic response by phytoplankton. It appears that the initial effect of condenser passage and plume entrainment was inhibitory, and a delayed stimulation occurred at some distance from the discharge. However, the data indicate that these effects may be nonstatistical if compared with the natural fluctuations which occur in inshore waters. Also, any stimulation of chlorophyll a activity due to heat seemed to be negated as a result of eventual plume cooling.

No correlation was evident between nutrient concentration of water and chlorophyll a fluorescence except on July 22 during an upwelling. The



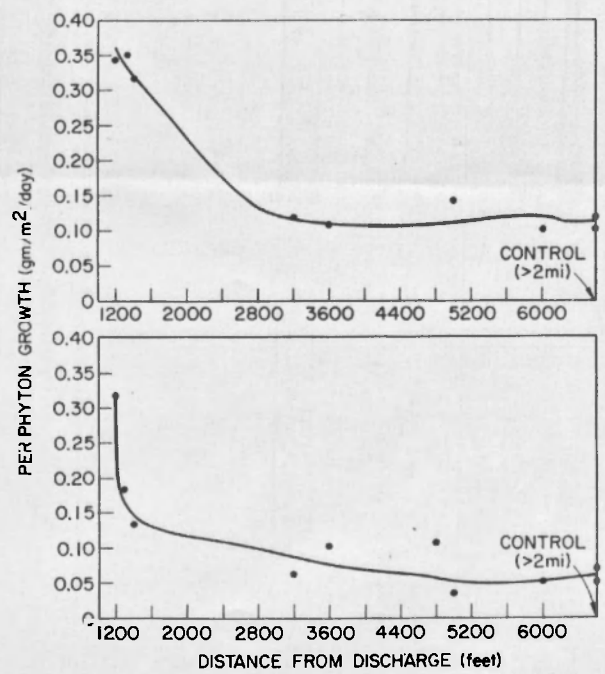


FIG. 1.--Chlorophyll a fluorescence of phytoplankton samples from plume stations near Point Beach Nuclear Power Station.

FIG. 2.--Periphyton growth at Point Beach Nuclear Power Station during late summer (85-day growth period) and fall (141-day growth period).

water samples collected from ambient stations (1, 14) were lower in chlorophyll a than during the previous day, while those at the plume station were considerably higher than the previous day. Thus, it seems that the increased concentrations of nitrate, orthophosphate, and silicate in water, resulting from the upwelling, were only stimulatory to phytoplankton in the heated water.

Periphyton

Biomass of periphyton colonizing the artificial substrates at each station are shown in Table 1. Figure 2 shows the growth rates at various distances from the discharge. In both the September and October samples, periphyton growth was significantly greater at the nearest stations (3, 4, and 5) than at the distant stations. At distances beyond 3200 feet, the differences between stations were primarily a function of depth contour, the shallower stations showing slightly greater growth in October.

It is difficult to specifically correlate the increased growth near the discharge with temperature since no thermal monitoring data are available. However, it is certain that by virtue of their proximity to the discharge, these stations were most often exposed to elevated temperatures. However, it is doubtful that the temperature increases on the bottom at these stations ever exceeded 1 or 2° C above ambient during the summer. Such temperature elevations in combination with increased current, apparently are sufficient to cause significant stimulation to periphyton.

On September 26, estimates were made of the primary productivity of the periphyton colonizing substrates at stations 3, 14, and 21. Stations 3 and 14 lay along the centerline of the plume, while station 21 was not influenced by plume water. ^{14}C values reported in Table 1 are the means of uptakes in light bottles corrected for dark bottle assimilation. ^{14}C assimilation rate was highest at station 14 (5000') while the rates at stations 3 (1300'), and 21 (2.5 miles) were significantly lower. Temperature recordings during the 3-hr incubation period show that station 3 was the warmest (17.5° C), while stations 14 and 21 were lower in temperature (16° and 15.5° C). It is difficult to explain the discrepancy between the periphyton weights and the ^{14}C uptake data, particularly in light of the warmer temperature at station 3. Apparently, the many conditions which affect primary production (temperature, light intensity, nutrients) were more favorable at station 14 at this particular time, although no cause and effect relationship was observed.

Conclusions

1. The benthic community near the Point Beach Station is extremely sparse, primarily because of the unfavorable substrate common to this area of Lake Michigan. The most common benthic species is Pontoporeia affinis, which occurs at much lower population densities than in other areas of the lake.

2. Vertical tows for plankton revealed no differences between plume and non-plume water in terms of plankton biomass. In general, plankton weights/liter were greatest in July and August samples.

3. Fluorometric analyses of phytoplankton samples showed considerable variation in chlorophyll a concentration at the sampling stations. Initially (nearest the discharge) there seemed to be an inhibition in chlorophyll a; at some distance an increase occurred; at a greater distance, the levels decreased to near-ambient concentrations. A significant increase in chlorophyll a concentration was observed in the plume in July when an upwelling resulted in elevated nutrient concentrations.

4. Periphyton growth was significantly greater at the three stations nearest the discharge. Growth at all other stations was similar to that at control areas. Periphyton productivity was significantly higher at a distant plume station than at other stations; elevated temperature was apparently not stimulatory to periphyton production during the period of study.

5. In general, the observed biological effects of the thermal discharge at Point Beach were extremely localized and beyond the measurable plume boundaries were not statistically different from ambient conditions.

References

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