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PHYTOPLANKTON COMMUNITY ABUNDANCE AND DIVERSITY IN DARDANELLE RESERVOIR, ARKANSAS, 1981-1990

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ABSTRACT

Phytoplankton samples were collected quarterly from 1981-1990 at five stations representing discharge water from Arkansas Nuclear One, a nuclear generating station, and four "control" or "dispersal evaluation" stations. Seventy-five taxa representing five divisions were identified and enumerated. Community structure was evaluated using abundances, number of taxa, and Margalef's Richness, Shannon's Heterogeneity and Pielou's Evenness indices. No long-term trends were identified, but the beginning of cyclic variations, with a 7-year periodicity, in abundance, number of taxa, and Shannon's and Pielou's indices were apparent. Margalef's index values were constant during most of the study period. For all samples, t-tests and Mann-Whitney U tests between station 5 (discharge) and each of four "control" stations, revealed no significant differences with any variable.

INTRODUCTION

In the late 1960s Arkansas Power and Light Company began construction on a two-unit nuclear generating facility located on the north shoreline of Dardanelle Reservoir. Environmental studies were initiated at that time and have continued until the present. The principal objective of these studies has been to determine the environmental compatibility of the construction and operation of the generating station. Secondary objectives have included, but not been limited to, describing resident taxa, population dynamics, diversity and community structure of benthos, phytoplankton and zooplankton. Rickett and Watson (1983) reported on the phytoplankton community dynamics during the first time-segment (1975-1982) following the beginning of commercial operation of Unit I, which uses reservoir water once through for condenser cooling. The earlier report emphasized taxon-specific abundance variations and community dominance. Phytoplankton diversity and abundance did not reveal similar trends but included strong temporal variations. Another secondary objective was the use of specific features of the phytoplankton community as a back-up indicator of general water quality. That algal species assemblages may be used as indicators of general water quality and of fluctuations in the concentrations of selected metal ions was determined by Meyer (1971) and Rice and Meyer (1977), respectively.

This report presents additional data (since 1983) and emphasizes a more detailed analysis of diversity in addition to taxa and abundances.

SITE DESCRIPTION

Dardanelle Reservoir was created on the main channel of the Arkansas River by the Kerr-McClellan Navigation System in the early 1960s and is managed by the U.S. Army Corps of Engineers. Rickett and Watson (1985) reported morphometric data on the reservoir and a general description of watershed components. Since 1985, additional housing and urban development have occurred north and west of the city of Russellville, and limited development of agriculture and silviculture has occurred elsewhere in the watershed. There have also been minor development projects such as roads, small businesses and individual housing units in the watershed area.

Five stations were established to sample all major reservoir microhabitats (Figure 1). The intake and upstream control stations (16 and 21, respectively) were distanced beyond the influence of the thermal effluent (discharge, station 5), whereas the mid-lake station (11) was expected to be within its influence. Further downstream in the reservoir, no residual effects of discharge were expected, and station 15 was established to test this.

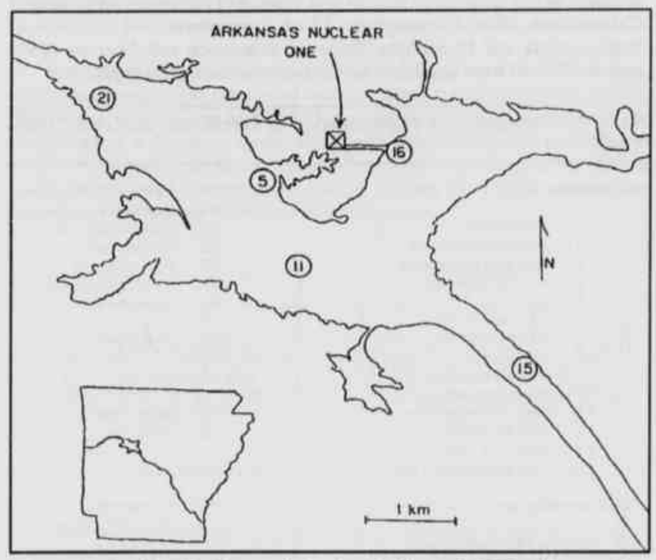


Figure 1. Dardenelle Reservoir in the vicinity of ANO with sampling sites noted.

METHODS

Depth-integrated phytoplankton samples were collected quarterly at five stations on the reservoir during the years 1981-1990. Two hundred liters of water were pumped through a Wisconsin-style plankton net having 80-micron mesh size, and the filtrate was preserved with Meyer's fixative. Approximately two-thirds of the volume was taken from the surface to 0.3 m depth, whereas the remaining third was taken equally from 0.3 to 3.0 m, which generally represented the depth of the euphotic zone. In the lab, sample aliquots were placed in a Sedgwick-Rafter counting cell and viewed at 100x with a Nikon inverted microscope equipped with a mechanical stage. Cells were identified to genus and tabulated as cells per liter.

Abundances per season at station 5 were compared with those at each of the four "control" stations. Data pairs with non-significant ($\alpha = 0.05$)

F-tests were further compared with t-tests, whereas those with significant F-tests (too much heterogeneity for t-tests) were compared with Mann-Whitney U tests. Three indices were used to describe community diversity: Margalef's Richness, Shannon's Heterogeneity and Pielou's Evenness. The Margalef formula considers the number of taxa in a sample and the total number of organisms comprising those taxa. The Shannon index evaluates how the individuals are distributed among the taxa, whereas the Pielou Evenness index is somewhat more sensitive than Shannon's in that it relates that distribution back to the number of taxa in the sample. Formulae and notations are given in the Appendix. For all indices used, an increase in the number of taxa or a decrease in the number of individuals or individuals per taxon may produce a larger calculated value, a feature which must be considered for interpretation.

RESULTS AND DISCUSSION

Seventy-five genera in five divisions were identified (Table 1). Chlorophyta exhibited the most extensive adaptive radiation with the greatest variety of taxa (34), followed by Chrysophyta (23) and Cyanophyta (14). Euglenophyta and Pyrrophyta were represented by two taxa each. Chrysophyta life cycles were most stable and consistent, showing numerical dominance in all seasons with the peak of abundance in summer (Figure 2). The abundance peak for Cyanophyta also occurred in the summer when water temperatures were highest and overall river discharge was usually lowest. The peak of abundance for Chlorophyta occurred in fall (Figure 2). Rickett and Watson (1983) reported 30 taxa of Chlorophyta, 20 of Chrysophyta, 11 of Cyanophyta, and two each of Euglenophyta and Pyrrophyta. Seasonal abundance and diversity of the period 1975-80 were similar to those observed during this study.

Table 1. Taxonomy of Phytoplankton in Dardenelle Reservoir, 1981-1990.

Cyanophyta

1. *Anabaena*
2. *Anabaenopsis*
3. *Aphanizomenon*
4. *Arthrospira*
5. *Borzia*
6. *Chroococcus*
7. *Gloeocapsa*
8. *Lyngbya*
9. *Merismopedia*
10. *Microcystis*
11. *Oscillatoria*
12. *Scytonema*
13. *Spirulina*
14. *Trichodesmium*

Chlorophyta

1. *Actinastrum*
2. *Ankistrodesmus*
3. *Bambusina*
4. *Cerasterias*
5. *Closteriopsis*
6. *Closterium*
7. *Chlorella*
8. *Chodatella*
9. *Coelastrum*
10. *Cosmarium*
11. *Dictyosphaerium*
12. *Dimorphococcus*
13. *Euastrum*
14. *Eudorina*
15. *Eutetramorus*
16. *Gonium*
17. *Hyalotheca*
18. *Kirchneriella*
19. *Microspora*
20. *Mougeotia*
21. *Oedogonium*
22. *Pandorina*
23. *Pediastrum*
24. *Platydorina*
25. *Pleodorina*
26. *Pleurotaenium*
27. *Scenedesmus*
28. *Schroederia*
29. *Sphaerocystis*
30. *Spirogyra*
31. *Staurastrum*
32. *Ulothrix*
33. *Volvox*
34. *Zygnema*

Euglenophyta

1. *Euglena*
2. *Phacus*

Pyrrophyta

1. *Ceratium*
2. *Peridinium*

Chrysophyta

1. *Asterionella*
2. *Bacillaria*
3. *Centrionella*
4. *Cyclotella*
5. *Cymbella*
6. *Diatomella*
7. *Dinobryon*
8. *Ellipsoidion*
9. *Fragilaria*
10. *Gyrosigma*
11. *Melosira*
12. *Meridion*
13. *Navicula*
14. *Netrium*
15. *Nitzschia*
16. *Rhizochrysis*
17. *Stauroneis*
18. *Stephanodiscus*
19. *Surirella*
20. *Synedra*
21. *Synura*
22. *Tabellaria*
23. *Tribonema*

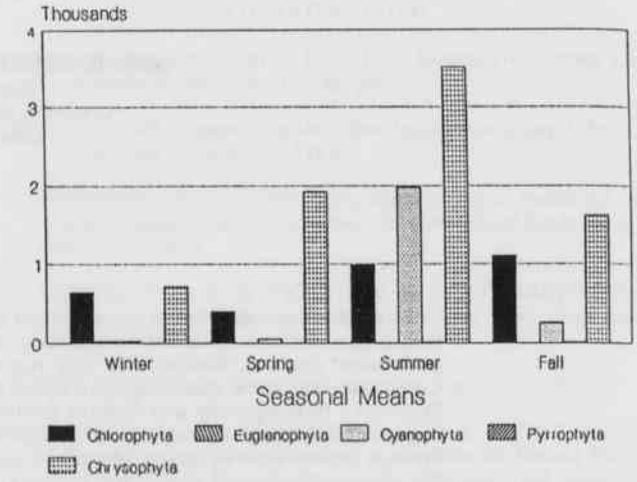


Figure 2. Seasonal abundances of phytoplankton groups in Dardenlle Reservoir, 1981-1990.

There was a strong overall abundance peak about mid-year for all years except 1982, 1983, 1987 and at stations 11 and 21 in 1981. These peaks were commonly five to 10 times greater than the trough on either side of the peak. Station 21 exhibited the fewest peaks. Peaks of abundance at station 5 declined more-or-less steadily from about 20,000 in 1981 to less than 5,000 in 1990, while peaks at station 16 rose more-or-less steadily from about 11,500 in 1981 to nearly 18,000 in 1988 and dropped sharply off to 3,500 in 1990.

River discharge (Q) variations from 1978 through 1990 are given in Figure 3 (U.S.G.S. 1978-90). Relatively low flows from 1978 to 1982 could, on the basis of nutrient depletion, explain the depressed phytoplankton counts prior to 1983 (Figure 4), but otherwise, a correlation between discharge and abundance was not present.

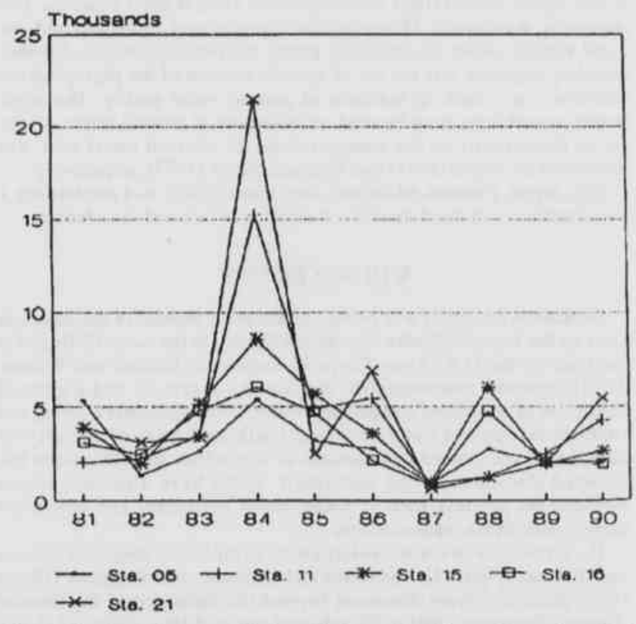
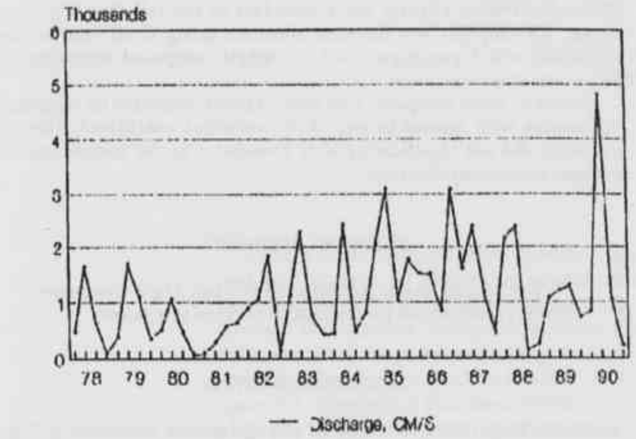


Figure 3. Annual means of phytoplankton aboundance (organisms/liter) in Dardenelle Reservoir, 1981-1990.



Data from USGS

Figure 4. Mean quarterly discharges (Q) in m³/s at the dardenelle gaugin station, 1981-1990.

When "control" stations were plotted one at a time with station 5, most peaks of abundance coincided (Figure 5). T-tests and Mann-Whitney U tests did not reveal any significant differences of abundance, which indicated thermal effluent had no depressing effect on phytoplankton abundance. The number of phytoplankton taxa varied considerably among the quarterly samples, but annual means revealed slight evidence of a seven-year periodicity with low points in 1981 and 1987, a high point in 1984 and possibly headed for another high point in 1991 or 1992 (Figure 6). Rickett and Watson (1983) reported very similar abundances between station 5 and each of the four "control" stations.

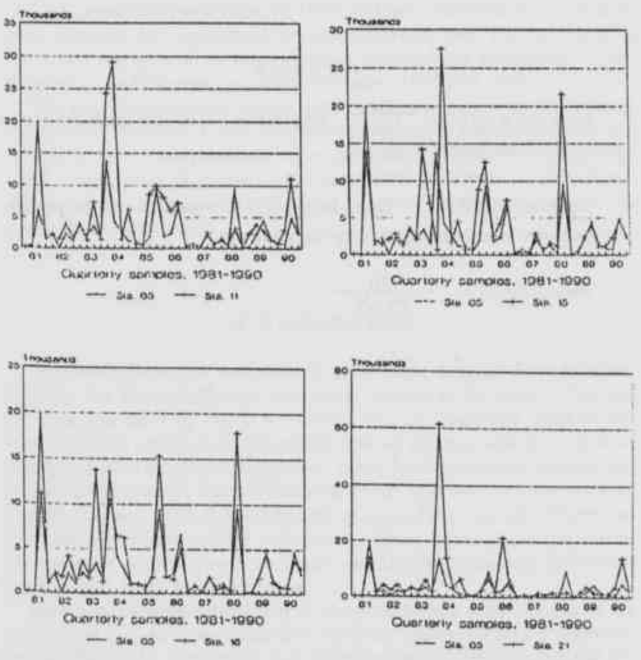


Figure 5. Phytoplankton abundances (organisms/liter) at the discharge station compared with each of the "control" stations, Dardenelle Reservoir, 1981-1990.

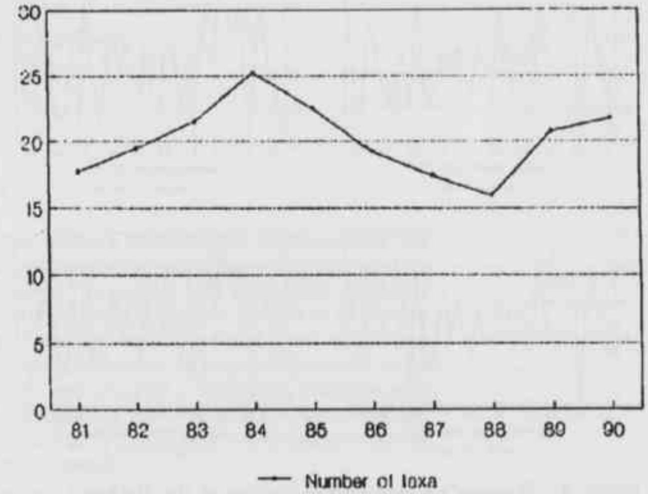


Figure 6. Annual means of the number of phytoplankton taxa in Dardenelle Reservoir, 1981-1990.

Quarterly Margalef Richness index values exhibited much variation, so annual means were calculated to make any general trend more visible. There was a gentle rise in 1984-85 and another in 1989-90, perhaps the beginning of a repeating cycle. Prominent individual peaks in 1987 and 1988 were present at all stations. When quarterly samples for station pairs were plotted, curves were similar (Figure 7). T-tests revealed no significant differences between any station pairs.

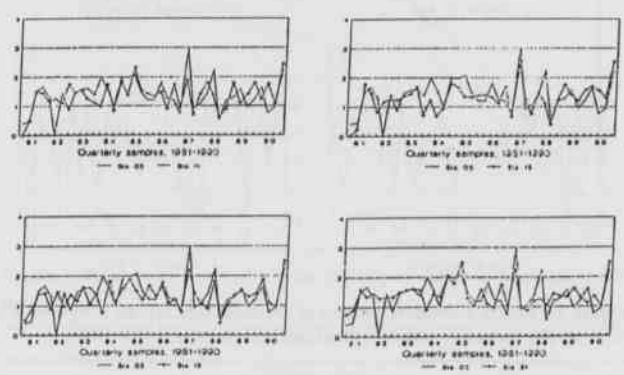


Figure 7. Margalef's Richness indices at the discharge station compared with each of the "control" stations, Dardenelle Reservoir, 1981-1990.

Shannon's Heterogeneity index values exhibited a maximum in 1982-83 then declined and leveled off for the rest of this reporting period. When "control" stations were paired with station 5 and plotted (Figure 8), most of the peaks and troughs coincided. T-tests did not reveal any significant differences.

Pielou's Evenness index values also exhibited maximum values in 1982-83, declining later and then leveling off. Plots of paired stations showed many coincidental peaks and troughs (Figure 9), and t-tests revealed no significant differences.

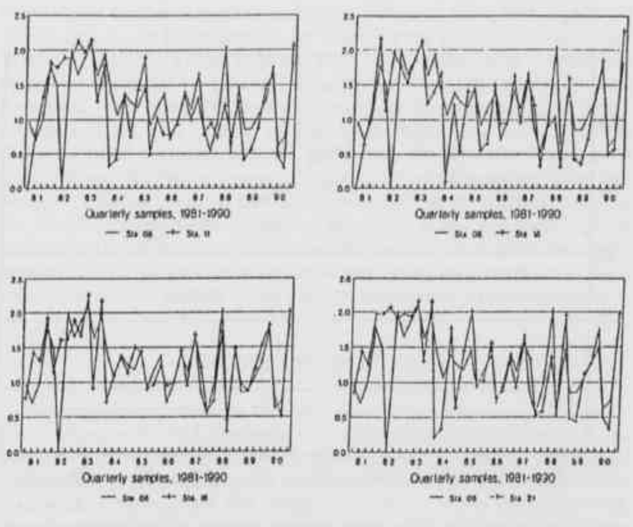


Figure 8. Shannon's Heterogeneity indices at the discharge station compared with each of the "control" stations, Dardenelle Reservoir, 1981-1990.

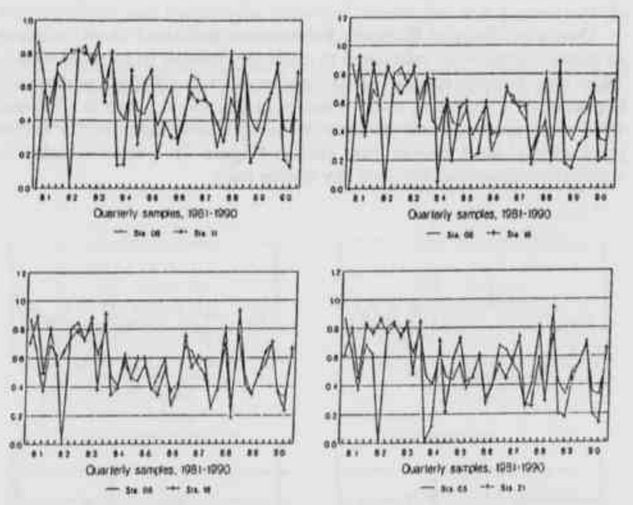


Figure 9. Pielou's Eveness indices at the discharge station conpared with each of the "control" stations, Dardenelle Reservoir, 1981-1990.

The maxima displayed in most of the diversity indices in 1981-1983 corresponded to the period of lowest overall abundance., but samples during this period still contained many taxa, producing a false sense of community diversity.

SUMMARY

Although considerable season-by-season variation existed for all tested variables, no long-term trends were identified. Annual means of abundances, numbers of taxa, and Shannon's Heterogeneity and Pielou's Evenness indices indicated the possible beginning of a cyclic oscillation with a 7-year periodicity. Margalef's Richness index was constant during the last eight years of the study period. Low abundances during 1981-1983 were probably related to a 4-year period of relatively low river discharge (1978-1982).

Cyanophyta and Chrysophyta were more abundant in summer and Chlorophyta were slightly more abundant in the fall than any other season. Chrysophyta was the most abundant group in all seasons, and they along with Cyanophyta and Chlorophyta comprised approximately 98 percent of all organisms.

Station 5, when compared with other stations, exhibited no significant differences with respect to any of the variables considered. Thermal discharge did not significantly alter abundance or the indices used to evaluate community diversity.

ACKNOWLEDGMENT

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REFERENCES CITED

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

RICE, R. G. and R. L. MEYER. 1977. Algal assemblage distribution as related to seasonal fluctuations of selected metal concentrations. Proc. Ark. Acad. Sci. 31:90-91.

RICKETT, J. D. and R. L. WATSON. 1983. Phytoplankton community structure in Dardanelle Reservoir, Arkansas, 1975-1982. Proc. Ark. Acad. Sci. 37:70-73.

RICKETT, J. D. and R. L. WATSON. 1985. Fluctuations and relationships of selected physicochemical parameters in Dardanelle Reservoir, Arkansas, 1975-1982. Proc. Ark. Acad. Sci. 39:98-102.

U.S. GEOLOGICAL SURVEY. 1978-1990. Water quality data for Arkansas. U.S.G.S., Dept. of Interior, Washington, D.C.

APPENDIX

Margalef's (MRI) = $\frac{S-1}{\log N}$, where S and N are the numbers of taxa and individuals, respectively.

Shannon's (SHI) = $-\Sigma (p_i) \log_{10} (p_i)$, where p_i is the proportion of the entire sample comprised by the ith taxon.

Pielou' (PEI) = $\frac{SHI}{\log_{10} N}$