Acid precipitation: the biotic response in Florida lakes

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The progressive cultural acidification of lakes by acidic precipitation has been well documented for Scandinavia[1], Canada[2], and the northeastern United States[3], but the impact on aquatic systems in other areas including the southeastern United States in general and Florida in particular is largely unknown. The present investigation was part of an integrated study funded by the U.S.E.P.A. to determine the extent of acid precipitation in Florida and its associated effects on aquatic ecosystems.

Numerous poorly buffered oligotrophic lakes are located in the leached sandy soils of the central highlands region that runs along the length of the Florida peninsula. Our results indicate that the acidity of rainfall is not uniform over the length of the highlands ridge (330 km) but is most pronounced in northern Florida with a mean annual pH for 1978–79 of 4.58 in the north compared to a mean of 5.56 in the south.[4]

Thirteen poorly-buffered lakes (Trail Ridge) in northern Florida that are influenced by acid precipitation and seven comparable lakes in southern Florida (Istokpoga Ridge) that are little influenced by acid precipitation were monitored quarterly (1978–1979) for water chemistry, chlorophyll, phytoplankton, zooplankton, and benthic invertebrates. For comparative purposes, the northern Florida lakes are referred to as acidic ($pH < 5.6$) while those of southern Florida are referred to as nonacidic ($pH > 5.6$) lakes.

Comparison of the present data with that collected over the past 20 years indicates that the mean pH of the Trail Ridge lakes has declined an average of 0.5 pH units since 1960. The current mean annual pH of the acidic lakes (pH = 4.98) is significantly different ($p = .05$) from that of the nonacidic lake group (pH = 6.21). In addition to the progressive acidification, sulphate concentrations have increased, and the low levels of alkalinity present in the 1960's have been completely titrated in the acidic lakes during the past 20 years.

Mean annual chlorophyll *a* concentrations were significantly lower ($p = 0.5$) in the acidic lakes ($\bar{x} = 1.88$ mg/m^3) as compared to the non-acidic lake group ($\bar{x} = 7.53$ mg/m^3). Chlorophyll values displayed a pronounced increase with increasing phosphorus concentrations for all pH intervals (0.5 pH units) greater than pH 5.6, while the response in the more acidic lakes was diminished (Figure 1). These data suggest that algal productivity in the acidic lakes may be responding more to pH and possible increased concentrations of aluminum and heavy metals[5] than to the availability of inorganic phosphorus.

Both the number of taxa and the total abundance of phytoplankton were significantly lower ($p = .05$) in the acidic than in the non-acidic lake group (Figure 2). The mean number of taxa in the acidic lakes was 10.8 compared to 16.5 for the non-acidic lakes, while mean abundance in the two groups was 5,700/mL and 14,000/mL, respectively.

As commonly observed for acid-stressed temperate lakes[6], blue-green algae in Florida lakes were replaced by green algae with increasing acidification (Figure 3). In lakes of pH 6.51–7.0, blue-green algae made up 63% of total phytoplankton abundance, while green algae were responsible for only 31%. This pattern was reversed in the most acidic lakes (4.5–5.0) with greens and blue-greens accounting for 60% and 25%, respectively. Highly acidic lakes were dominated by *Staurastrum, Scenedesmus, Ankistrodesmus, Peridinium*, and several species of small coccoid green algae. The principal blue-green algae in acidic lakes were *Oscillatoria limnetica* and *Anacystis*

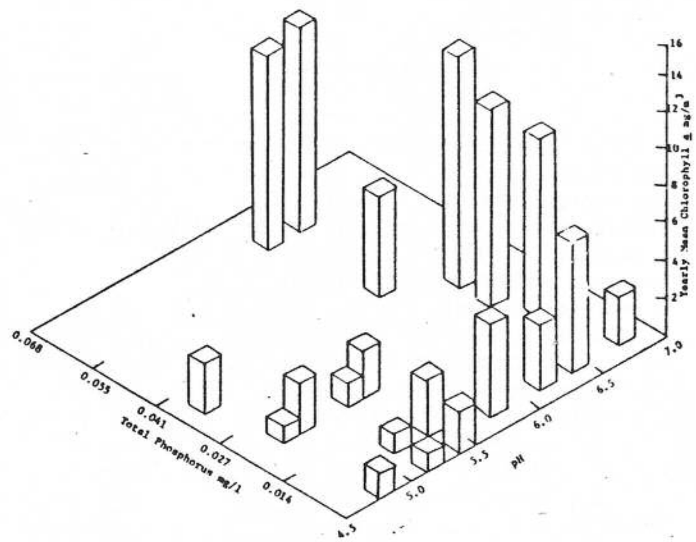
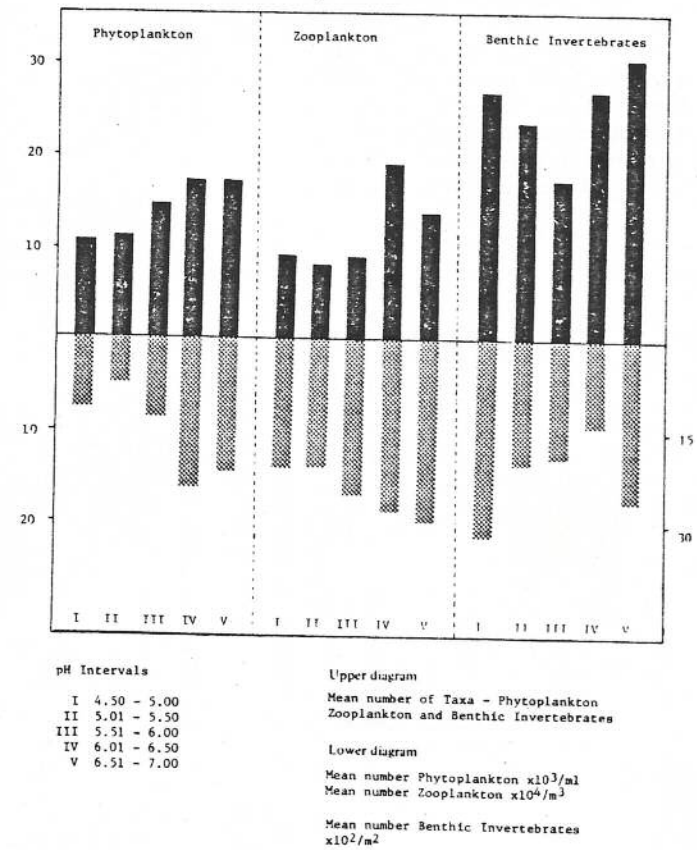


Figure 1. Isometric plot of mean annual phosphorus, pH, and chlorophyll a for the twenty Florida lakes.



Firgure 2. Mean annual number of taxa and abundance for phytoplankton, zooplankton, and benthic invertebrates from twenty Florida lakes grouped by pH interval.

incerta, with *Amigdalum, Anabaena, Spirulina*, and *Microcystis* increasing in importance in the nonacidic lakes.

As demonstrated for phytoplankton, zooplankton in acidic lakes were significantly different from nonacidic lakes ($p=.05$) with respect to both mean number of taxa (8 versus 17) and mean abundance of $75 \times 10^3/m^3$ versus $145 \times 10^3/m^3$. The distinctness of the acidic and nonacidic zooplankton communities is demonstrated further through a Q-mode analysis of log-transformed quantitative zooplankton data and Czekanowski's index (Figure 4). Of the 35 taxa encountered in our survey, 5 were restricted to nonacidic lakes and 3 to the acidic lakes, while *Diaptomus floridanus, Cyclops varicans, Mesocyclops edax, Bosmina longirostris, Daphnia ambigua*, and *Keratella cochlearis* were dominant in all lakes. Thus, zooplankton differences were due principally to the importance of the rarer species and the overall structure and abundance of the zooplankton community. The importance of pH versus phytoplankton abundance and composition as the principal controlling factor for zooplankton in Florida lakes can not be determined from the present data base.

Benthic invertebrates did not display as pronounced a response to acidification as was seen for either phytoplankton or zooplankton. Neither the mean number of taxa (27 versus 25) nor the mean abundance of benthic invertebrates (2084 versus 2523 organisms/m²) was significantly different between the nonacidic and acidic lakes (Figure 2). Oligochaetes (32 versus 10%) were replaced by chironomids (30 versus 62%) as the dominant benthos in acidic lakes, and with the exception of a total elimination of molluscs below pH 5.5, no major species replacements were noted with increased acidification. Changes in the structure of the benthic community may be predominantly a reflection of a reduction in overall lacustrine productivity and habitat quality than a direct response to acidification.

Gamefish populations were sampled qualitatively in the two most acidic lakes of the survey, McCloud (pH 4.71) and Anderson-Cue (pH 4.89). Adult (2–4 years old) bream (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*) were collected in both lakes with a mean condition factor (K) for bass in McCloud and Anderson-Cue of 1.00 and 1.19, respectively. No evidence of gill necrosis was found on any specimen. Our initial results suggest that the general reduction in the fitness of gamefish in acidic Florida lakes is due principally to the low availability of food and not to pH and aluminum as reported for temperate systems[7].

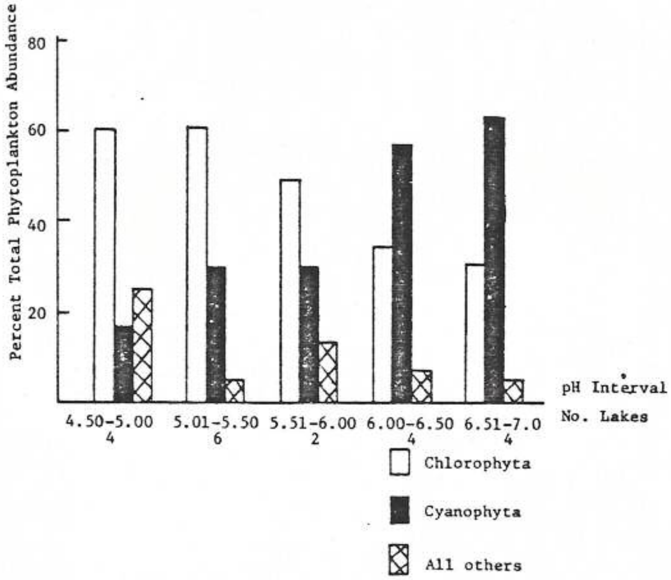


Figure 3. Partitioning of the annual algal abundance of Florida lakes into green (Chlorophyta) and blue-green (Cyanophyta) algae by pH intervals.

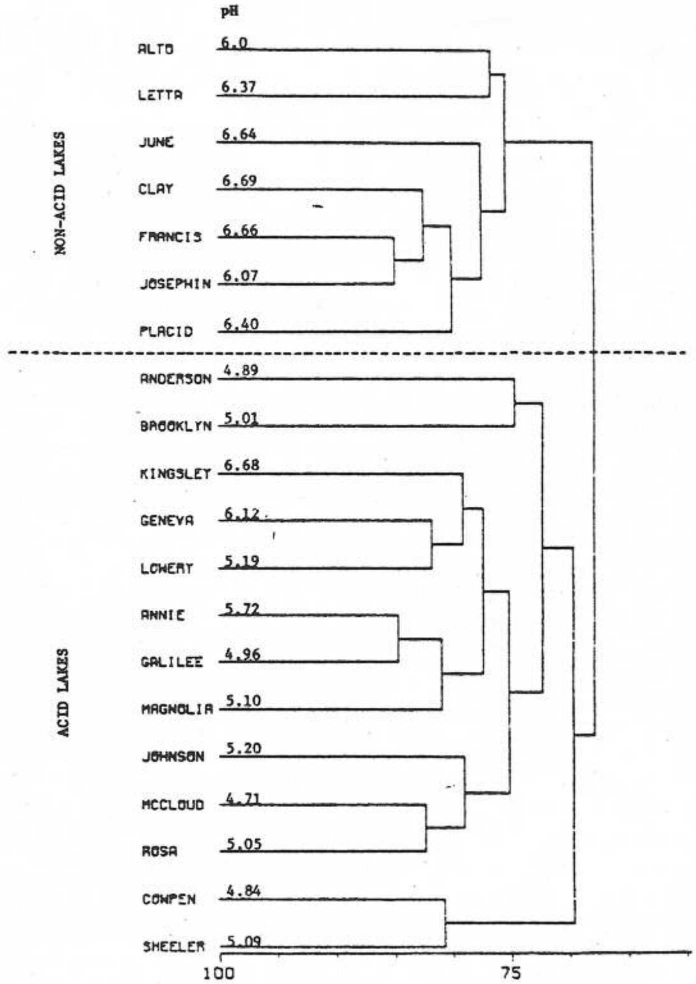


Figure 4. Classification of Florida lakes based on Czekanowski's Similarity Index and quantitative zooplankton data.

The most pronounced response to the acidification of Florida Lakes was displayed by the phytoplankton. The replacement of blue-green by green algae in acidic lakes is likely associated with alterations in water chemistry including the availability of carbon dioxide,[8] phosphorus, heavy metals, and aluminum. The response of the higher trophic levels was less pronounced and consisted primarily of alterations in the number of taxa and the total abundance of the community rather than major species replacements. Thus, reductions in both the complexity and abundance of heterotrophic communities may be a reflection of low autotrophic production rather than a direct result of acidification. Further investigation of trophic-level interactions in acid Florida lakes is currently underway.

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