

TEMPERATURE AND OXYGEN IN AN EVERGLADES ALLIGATOR POND

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Abstract

The Everglades is a large subtropical marsh ecosystem. Ponds, maintained through the activity of alligators, are abundant and ecologically important components of this system. Temperature in a 18 x 12 m study pond was controlled primarily by ambient air temperature, with significant temporal lags because of thermal resistance caused by plant growth. Temperatures changed seasonally being 10° to 15°C lower in summer than winter. Diurnal temperatures fluctuated 7°C in summer and 4°C in winter. Maximum temperature exceeded 34°C. Dissolved oxygen fluctuated between 50 to 85% saturation in winter to supersaturation in summer. During the dry season water levels fell and oxygen fluctuated markedly, for example from 4 to 200% saturation within a diurnal cycle.

The relation of water temperature to air temperature was similar to other reported ponds but continued fluctuation in winter differed from some results from other ponds. The distinct seasonality has important effects on biological components. Fluctuation of dissolved oxygen can result from high animal density and plankton in the dry season and can lead to massive mortality of aquatic animals. The physio-chemical conditions of Everglades alligator ponds are controlled by a combination of seasonal temperature and insolation, water level changes and biologic factors such as fish density, bird predation and alligator activity.

Introduction

The Everglades is a large, shallow sedge and gramnoid marsh occupying much of the subtropical southern tip of Florida peninsula. Scattered throughout the marsh are small ponds, one to 20 m in diameter, which depend for their existence on the activities of the American alligator (*Alligator mississippiensis*) (Kushlan, 1974a). Alligator

ponds appear to be of critical importance to fish populations and their dependent predators. Ponds in the nearby Big Cypress Swamp have been shown to function as refugia for fish and aquatic invertebrates that become concentrated there during the dry season and which in turn serve as food sources for mobile predators such as ciconiiform wading birds (Kushlan, 1976).

Despite their importance, little is known about the fluctuation of water chemistry parameters in the alligator ponds of the Everglades. This reflects a general paucity of available information on tropical and subtropical ponds in general. Some data exist for a pond in Florida located in a seasonally flooded Bald Cypress forest in the Big Cypress Swamp (Kushlan & Hunt, 1979). There have been a few pond studies in other subtropical or tropical regions (Klimowicz, 1961; George, 1961; Vaas & Sachlan, 1955; Sitaramaiah, 1966; Michael, 1969; Weir, 1969; Rao, 1971; Munawar, 1974; Young, 1975). It has been shown that temperature and oxygen levels may be the most critical fluctuating parameters to aquatic animals (Macan, 1963; Macan & Maudsley, 1966). No data are available on temperature and oxygen fluctuations in Everglades ponds. The purpose of this report is to document the thermal and oxygen characteristics of an Everglades alligator pond particularly in reference to other subtropical and tropical ponds.

Study site

The alligator pond, called Cottonmouth Pond, is located in the southern Everglades about 25° N latitude. The pond is 18 m x 12 m at high water. It is approximately 1.5 m deep and contains about 200 m³ of water. The pond was

surrounded by willows (*Salix caroliniana*). Floating leafed spatterdock (*Nuphar advena*), sawgrass (*Cladium jamaicense*), and pickerelweed (*Pontedaria lanceolata*) grew around the edge. The center was without plant growth. The water level in the pond fluctuates seasonally. A typical pattern of fluctuation based on data for 1965 is shown in Fig. 1.

Methods

Temperature and dissolved oxygen were measured in situ by remote probes attached to recorders designed by the U.S. Geological Survey (Kolipinski & Higer, 1966). Samples were collected at a depth of 15 cm (unless otherwise indicated) about every two hours for 24 hours once per month between the 19 and 28th day in 1965 and 1966.

Results

The temperature of small ponds is usually controlled primarily by ambient air temperature. While this was generally true of the study pond, temperature fluctuation lagged behind and was not as extensive as air temperature fluctuation. Fig. 2 shows a diurnal temperature cycle including a fairly cool evening. Air temperature dropped from 26°C to about 10°C over an 8 h period. Water temperature dropped only from 19.7°C to 16.1°C.

The lessened daylight, lowered radiation and somewhat cooler temperature during the winter did have a longterm effect. Both minimum and maximum temperatures decreased in the winter (October to March) (Fig. 3). The lowest temperature occurred in December. Temperatures then were 10° to 15°C lower than during the summer. To demonstrate these differences more clearly, Fig. 4 shows a typical pattern of diurnal temperature fluctuation in

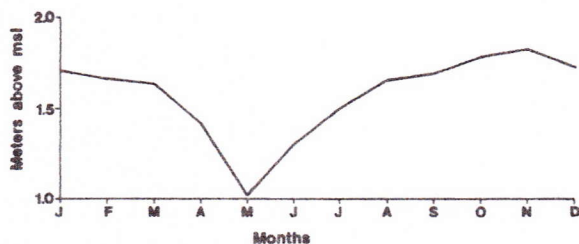


Fig. 1. The seasonal variation of water levels in the Everglades. Monthly medians are plotted for 1965.

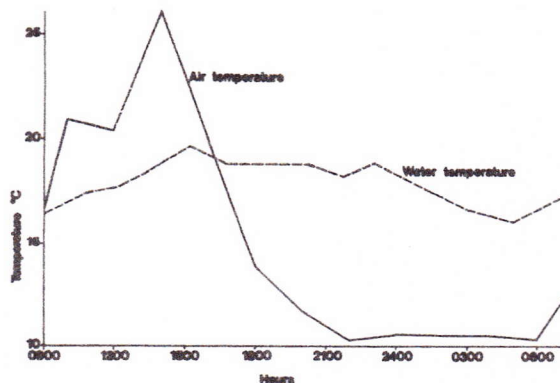


Fig. 2. Variations of water and air temperature at Cottonmouth Pond in December. Air temperature (taken 60 cm above water) dropped considerably but water temperature (taken 60 cm below the surface) did not.

summer and winter. In June diurnal water temperature reached 34°C and did not drop below 27°C. In November diurnal water temperature reached only 25°C but dropped less to 21°C.

One of the important effects of temperature is its effect on biologically critical dissolved gases. During high water, seasonal levels of temperature, as well as sunlight and plant growth, are probably the determining factor in the concentration of dissolved oxygen in the pond (Fig. 5). Oxygen concentration fluctuated daily. In fall and winter it ranged from about 85 to 50% saturation. In summer, however, oxygen became supersaturated because of the photosynthesis of aquatic plants.

During the dry season more drastic fluctuations occur (Fig. 6). During this period oxygen was highest in the afternoon reaching nearly 200% of saturation. It fell dramatically at night to about 4% of saturation. This

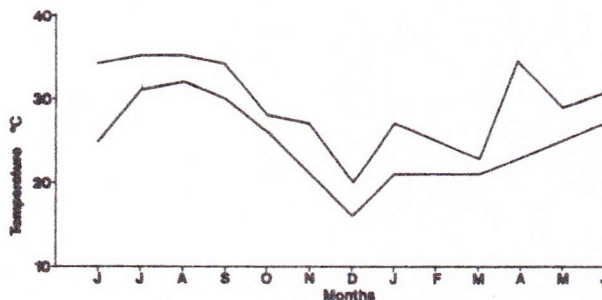


Fig. 3. Seasonal changes in maximum and minimum water temperature at a depth of 15 cm at Cottonmouth Pond.

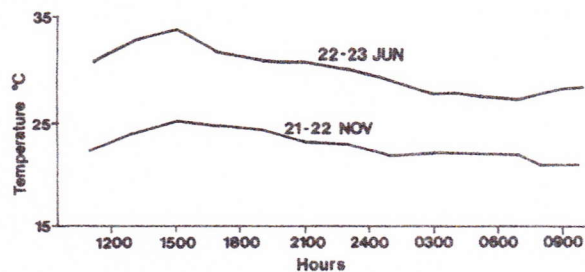


Fig. 4. Diurnal fluctuation of water temperature at a depth of 15 cm at Cottonmouth Pond in summer (June) and winter (November).

massive diurnal fluctuation was typical of ponds during the dry season. Temperatures during this period are rising (Fig. 3) as is the daily insolation. In addition high nutrient loading associated with drying causes plankton blooms which significantly affect oxygen levels.

Discussion

On the average water temperature in both tropical and temperate ponds tend to change with air temperatures (Young, 1975). This is also the case in the subtropical Everglades alligator pond. The pond water cools in winter and warms in summer, having a 10° to 15°C seasonal temperature differential.

The relationship between air and water temperature on a daily basis is not so clear cut however. This relation within a pond is determined partially by its size. A small water body can be expected to respond quickly and significantly

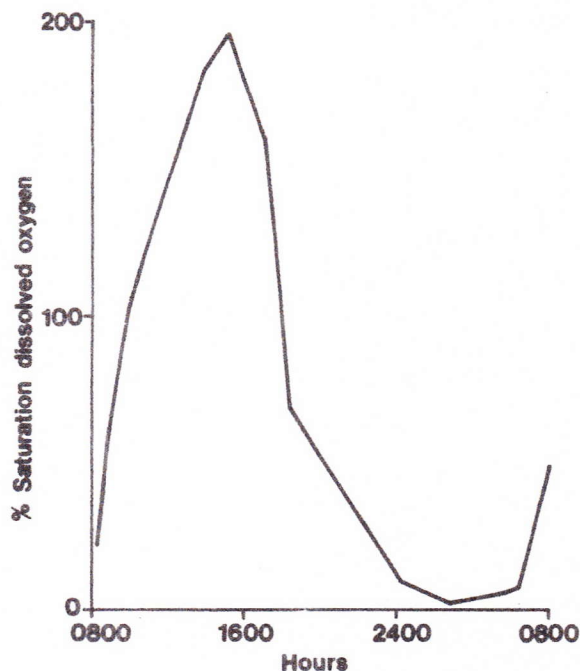


Fig. 6. Diurnal fluctuation of dissolved oxygen at Cottonmouth Pond during the spring (29-30 April) period of low water.

to air temperature whereas a larger body may have substantial delays (Vaas & Sachlan, 1955; Gorham, 1958; Macan & Maudsley, 1966). Despite its small size, the study pond showed only a slight nightly decline in temperature, totaling only 23% of the decrease in air temperature. This can be accounted for in part by the resistance of the pond to mixing. Plants surrounding the pond,

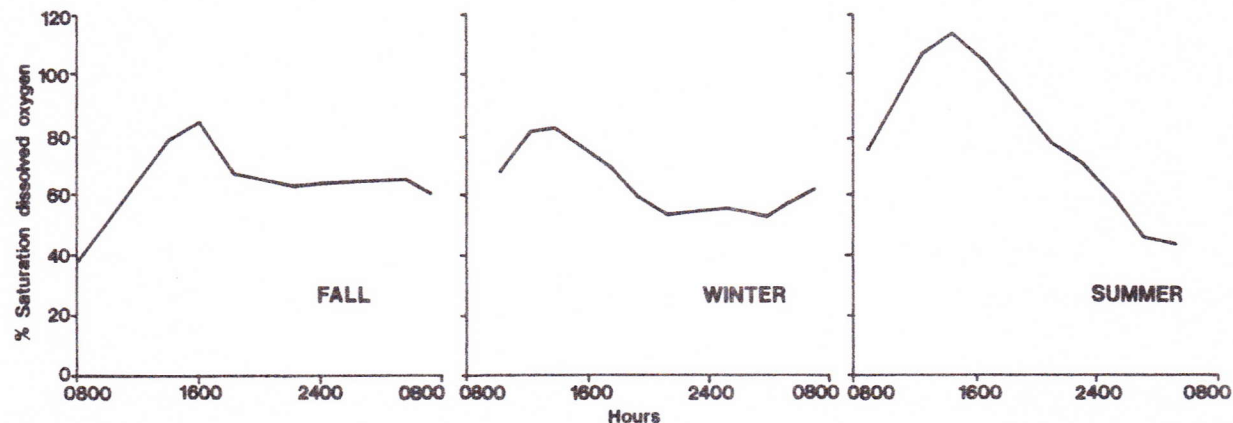


Fig. 5. Comparison of the diurnal fluctuation of dissolved oxygen at Cottonmouth Pond in 3 seasons of high water level, summer (21-22 July), fall (21-22 September) and winter (27-28 December).

especially the hedge of willow trees 4 m high, effectively reduce the potential impact of wind in mixing the water. This dampening is further controlled by emergent and floating leaf plants within the pond. A similar resistance to mixing was found in a larger swamp pond (Kushlan & Hunt, 1979). In that pond at one place in less than 1 m of water there was a thermal difference from top to bottom the equivalent to 12 C/m.

Temperature in both temperate and tropical ponds fluctuates only slightly in cooler months (Martin, 1972; Young, 1975). To the contrary, however, temperature fluctuates in Everglades ponds year around (Fig. 3). For example temperature fluctuated 4°C in November and 6°C in the summer (Fig. 4). Young (1975) demonstrated that the absence of diurnal temperature fluctuation in the winter in other areas indicated that such ponds are in thermal equilibration with ambient low temperatures, which do not change much diurnally. In sub-tropical south Florida, however, air temperatures change markedly diurnally year around and so can effect water bodies.

There is therefore a distinct seasonality to water temperatures, being 10° to 15°C lower in winter. Such information on seasonal changes of temperature in warm climates is scarce (Young, 1975). Michael (1969) suggested that since seasons are not clearly demonstrated in the tropics, rainfall and water levels play the dominant role in determining the temperature of ponds. He found a 20°C seasonal temperature differential attributable to changes in pond water depth. In the Everglades, the total annual variation was less and probably influenced primarily by air temperature. This has also been demonstrated in shallow tropical ponds (Vaas & Sachlan, 1955; Rakusa-Suszczewski, 1964). It is, of course, to be expected in temperate ponds (Macan & Maudsley, 1966; Martin, 1972).

Oxygen levels also fluctuated considerably. During high water, fluctuations were similar irrespective of season (Fig. 5). This has also been found in other studies (Michael, 1969). The somewhat higher maxima in summer, which characteristically exceeded saturation, were probably a result of increased insolation and resulting photosynthesis. Oxygen concentrations were, however, especially effected by water levels. The effect of rainfall and water depth on water constituents has been well documented (Vaas, 1954; Tucker, 1958; Carter, 1960; Michael, 1969). In the Everglades, water levels drop during the dry season bringing about significant changes in ponds. Alligator ponds are not isolated bodies but are, for most of the year, confluent with surrounding marshes. As water levels

fall, aquatic organisms move into the ponds (Kushlan, 1976). Among the results of this movement is increased biological oxygen demand, which daily lowers oxygen levels. Concurrent plankton blooms and respiration of other aquatic plants elevate oxygen levels during the day, but further contribute to oxygen depletion at night.

Dry season oxygen fluctuation has critical biological implications in the Everglades. Repeated episodes of low oxygen concentration lead to stresses on the aquatic fauna to the point where highly susceptible fish species begin to die. This initiates an accelerated oxygen decline which results in additional mortality (Kushlan, 1974b). Such fish kills can eliminate 99.7% of the fish concentrated within a pond during periods of prolonged deoxygenation (Kushlan, 1976). It is notable therefore that predation pressure by wading birds can reduce fish populations to below critical carrying capacity (Kushlan, 1976). Oxygen levels therefore depend on temperature, season, plant growth, fish density and predation history, and determine, in turn, the survivorship of aquatic organisms through the dry season.

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References

- Carter, G. S. 1960. Tropical climates and biology, Nature 187: 843.
- George, M. G. 1961. Diurnal variation in two shallow ponds in Dehli, India. Hydrobiologia 18: 263-273.
- Gorham, E. 1958. The physical limnology of northern Britain: An epitome of the bathymetrical survey of the Scottish freshwater lochs, 1897-1909. Limnol. Oceanogr. 3: 40-50.
- Klimowicz, H. 1961. Daily temperature variations in a small water pool in Cairo. Polskie Arch. Hydrobiol. 9: 195-202.
- Kolipinski, M. C. & Higer, A. L. 1966. Hydrologic investigations in Everglades National Park. W.R.D. Bull. U.S. Geological Survey, Jan-Mar. 32-35.
- Kushlan, J. A. 1974a. Observations on the role of the American alligator (*Alligator mississippiensis*) in the southern Florida wetlands. Copeia 1974: 993-996.
- Kushlan, J. A. 1974b. Effects of a natural fish kill on the water quality, plankton, and fish population of a pond in the Big Cypress Swamp, Florida. Trans. Amer. Fish. Soc. 103: 235-243.
- Kushlan, J. A. & Hunt, B. P. 1979. Limnology of an alligator pond in south Florida. Scientist 42: 65-84.

- Kushlan, J. A. 1976. Wading bird predation in a seasonally fluctuating pond. *Auk* 93: 464-476.
- Macan, T. T. 1963. *Freshwater ecology*, London, Longmans, 338 p.
- Macan, T. T. & Maudsley, R. 1966. The temperature of a moorland fishpond. *Hydrobiologia* 27: 1-22.
- Martin, N. A. 1972. Temperature fluctuations within English lowland ponds. *Hydrobiologia* 40: 455-469.
- Michael, R. B. 1969. Seasonal trends in physicochemical factors and plankton of a freshwater fishpond and their role in fish culture. *Hydrobiologia* 33: 144-160.
- Munawar, M. 1974. Limnological studies in freshwater ponds of Hyderabad, India. IV. The biocenose. Periodicity and species composition of unicellular and colonial phytoplankton in polluted and unpolluted environments. *Hydrobiologia* 45: 1-32.
- Rao, V. A. 1971. An ecological study of three freshwater ponds of Hyderabad, India, I— The environment. *Hydrobiologia* 38: 213-223.
- Rukusa-Suszczeński, S. 1964. Temperature variations in shallow water pools (Brazil). *Polskie Arch. Hydrobiol.* 12: 421-444.
- Sitaramaiah, P. 1966. Studies on the ecology of a freshwater pond community. *Hydrobiologia* 27: 529-548.
- Tucker, D. S. 1958. The distribution of freshwater invertebrates in ponds in relation to annual fluctuations in the chemical composition of the water. *J. Anim. Ecol.* 27: 115-123.
- Vaas, K. F. 1954. On the nutritional relationships between plankton and fish in Indonesian freshwater ponds. *Indo-Pac. Fish. Council Proc. Sec. II*: 5: 90-97.
- Vaas, K. F. & Sachlan, M. 1955. Limnological studies on diurnal fluctuations in shallow ponds in Indonesia. *Verh. Int. Ver. Limnol.* 12: 93-116.
- Weir, J. S. 1969. Studies on Central African pans III. Fauna and physicochemical environment of some ephemeral pools. *Hydrobiologia* 33: 93-116.
- Young, J. O. 1975. Seasonal and diurnal changes in the water temperature of a temperate pond (England) and a tropical pond (Kenya). *Hydrobiologia* 43: 513-526.