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Stratification of Iowa Artificial Lakes

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The southern half of Iowa is well supplied with artificial impoundments in the form of water supply reservoirs, industrial pits, farm ponds and State owned artificial lakes. Individually these water areas are relatively small, but collectively they furnish several thousand acres of fishing water. One important aspect of the management of these waters has been concerned with the education of the fisherman in the values of increased harvest of pan fish. An unknown share of the success of the harvest is related to the reaction of fish to the stratification of these artificial lakes and ponds. The fisherman must be informed of the nature of this phenomenon and how it may effect his fishing.

Little was known about the stratification of southern Iowa waters until Lewis (1949) pointed out that Red Haw and East Lake, in Lucas County, were stratified during the summer of 1948. In 1949 Sprugel (1951) found that McFarland's Pond, in Story County, showed evidence of a pronounced stratification. During a special fisheries survey of the Des Moines City Reservoir in 1949, prior to opening the area to public fishing, E. T. Rose of the Conservation Commission found that this body of water was stratified. But it was not until several years later that a definite program was intiated in an effort to find out which lakes were affected and to what extent. Determination of the extent of chemical and thermal stratification became an integral part of the Conservation Commission's southern Iowa lakes survey program in 1952. This resulted in only one set of data for each lake each season (usually midsummer) except for a few key lakes that were visited two to four times each season as time would permit.

This report is the result of an attempt to consolidate and summarize the data secured during the past four years. During this period thirty-six lakes have had one or more checks to determine whether or not the lake was stratified. Over 1,000 separate temperature readings were recorded and about 350 dissolved oxygen and hydrogen ion determinations were made during 132 visits to these lakes.

Location and Description of Lakes

The thirty-six lakes included 17 State owned artificial lakes and 19 city reservoirs. All but three of these impoundments lie south of U. S. Highway number six and they are fairly well distributed east and west across the State. Most of the State owned lakes are located in narrow, steep-sided valleys, surrounded by wooded ridges and hills. The city reservoirs are located in about the same topographical situations but often lack the shelter from wind action afforded by timber.

Individually they are rather small lakes, varying from 16 to a little less than 400 surface acres; over 50 per cent of the lakes fall in a group having an area between 70 and 130 acres. Maximum depths range from 7 to 55 feet. The average depth is approximately 22 feet. Seventy percent of the lakes occur in a group 15 to 25 feet in depth. About the same averages in size and depth occur if the two groups of lakes are treated separately. The State owned lakes do not have the extreme variation in depth that is found in the city reservoirs.

Although there is considerable variation in the watershed ratios among these lakes, none have permanent streams as a source of water, but depend entirely on runoff to maintain water levels. Turbidity due to suspended soil particles is often high following heavy runoff, but usually settles out in a short time. Turbidity due to plankton organisms is quite variable from lake to lake and if present it is likely to be persistent. Due to the use of copper sulfate the city reservoirs consistently have less turbidity due to plankton than the State owned lakes. Rooted aquatics, predominately *Potamogeton* spp., are usually abundant, forming dense bands of vegetation along shorelines and often completely taking over the shallow portions of a lake.

Materials and Methods

A single station was selected for each lake, preferably the deepest part of the lake. In the early part of this work several stations were selected for each lake but the data agreed with the single station to the extent that it was felt that one set of data at the time of each visit would delineate the stratification for the entire lake.

Temperature data were secured with a system of three minimum-maximum thermometers attached to a plastic cord. The cord was marked at three food intervals. The thermometers were attached at the one, two and three foot marks respectively. Temperture in ^{0}F was recorded for surface (4 inches below water level) and each three foot depth to the bottom. A Whitney electrical resistance thermometer was available for a small amount of this work and where this instrument was used all readings were recorded in meters and ^{0}C. For purposes of this paper all temperatures will be expressed as ^{0}F and all depths in feet.

Water samples were taken with a one litter Kemmerer water bottle at depths corresponding to stratification as indicated by temperature gradients. This was usually 3 to 5 samples. Dissolved oxygen and hydrogen ion concentrations were determined from each water sample. The amount of dissolved oxygen was determined by the Winkler method and expressed in parts per million. Hydrogen ion concentrations were determined by colorimetric method, using phenol red as an indicator with a pH range of 6.8 to 8.4.

During the summer of 1954, twenty-five lakes were sampled for alkalinity of the surface water. These were completed only on surface water because of the possible relation to electric shocker efficiency. Both phenolphthalein and methyl orange alkalinity were ascertained from the water samples and recorded in parts per million.

Water transparency was measured with a Secchi disc, recording the depth at which the disc disappeared from view.

Recognition of Stratification

Stratification of lakes is commonly separated into thermal and chemical components. Thermal stratification was considered present if the temperature readings indicated that a thermocline existed (1.62 °F drop in temperature per three foot drop in depth) even though a hypolimnion was not present. Apparently the relatively shallow depths prevented the formation of a hypolimnion in most instances; thus the thermocline extended to the bottom of the lake. Chemical stratification was considered present if the amount of dissolved oxygen approached minimum requirements for fish at any depth. The decision as to what constituted minimal oxygen levels under various conditions of stratification is admittedly difficult and any statements made hereafter are strictly the opinion of the investigator.

Results

Each of the 36 lakes examined in this study can be placed in one of three general groups; one, those that do not stratify; two, those that have a temporary and/or a very limited stratification; three, those that have a strong stratification each summer (appendix table 1). It is rather difficult to draw a sharp line between any two of these groups.

Group one: This is a minor group. Only four (11 per cent) of the lakes fall in this catagory. These lakes have three things in common. They are comparatively shallow, ranging from 7 to 13 feet in depth. Secondly they are exposed to wind action, allowing complete circulation of the entire body of water. All four lakes have had a history of high turbidity and no vegetation. Secchi disc readings seldom exceed twelve inches. Water temperatures in these lakes more or less follow the air temperatures.

Group two: Ten lakes (28 per cent) can be placed in this group having either a temporary stratification or a very limited layer of water unsuitable for fish life. Lakes that stratify once in three or four years and those that stratify 2 out of three years are also included in this group. These lakes are also rather shallow, averaging 18 feet in depth (range 14 to 23) and are exposed to considerable wind action. A prolonged warm period with comparatively little wind will allow these lakes to stratify to a limited extent. An epilimnion may be formed with thermocline temperatures present in a very small volume of water in the deepest area of the lake. Bottom temperatures in these lakes are rather high. Temperatures below 70°F were rare and many times the deepest areas of these lakes had water temperatures of 75°F or higher, even though the lakes were considered stratified. In a number of instances the qualification for thermal stratification was met with only the minimum temperature gradient (1.62°F drop per 3 foot of depth).

Chemical stratification in these lakes was often very slight. Occasionally dissolved oxygen was depleted in the deeper area but more often there would be some reduction but sufficient oxygen in the thermocline to support fish.

Due to the relatively small volume of water involved and/or the temporary nature of the stratification, the fish populations and other organisms in these lakes are not seriously affected by these conditions.

Group three: Twenty-two of the 36 lakes (61 per cent) show evidence of consistent thermal and chemical stratification each year. As a group these lakes are deeper than either of the first two groups, averaging 24 feet in depth (range 13 to 55). Surrounding hills and wooded watersheds afford protection from wind action.

The stratification of these lakes is often characterized by early formation of a thermocline and a considerable change in temperature between the lower limits of the epilimnion and the upper limits of the thermocline during midsummer. This difference in temperature reached a maximum in the Williamson Pond on July 20, 1955, when a 15 degree decline in temperature was recorded as the thermometer was moved from six to nine feet. A 7.4 degree drop was recorded for a one foot difference in depth at Nine Eagles Lake on June 3, 1953. The average change in temperature from epilimnion to thermocline was six degrees. Total temperature decline within the thermocline often exceeded 20 degrees. Bottom temperatures were quite cool (usually 60 to 65 °F), particularly in the deeper lakes where temperatures of 50°F and lower were common. Total temperature decline from surface to bottom was greater than 35 degrees in several instances. It was noted that where a hypolimnion was present the bottom temperatures did not increase to any extent during midsummer. Table 1 also indicates that stratification may be evident as early as the first week in May but normally and in most lakes it is later.

Table 1.
Surface and bottom temperatures of three lakes in Group Three taken at three intervals during 1953.

Lake	Date	Max. Depth	Stratified	Surf. temp.	Bottom temp.
Geode	May 4	41 ft.	No	55.4	48.2
	June 4	41 ft.	Yes	75.2	49.6
	July 23	41 ft.	Yes	82.0	51.0
Keosauqua	May 4	27 ft.	Yes	55.7	47.3
	June 4	27 ft.	Yes	80.0	47.0
	July 30	27 ft.	Yes	87.0	51.0
Nine Eagles	May 5	33 ft.	No	54.6	49.0
	June 3	33 ft.	Yes	75.2	49.2
	Aug. 6	33 ft.	Yes	81.0	51.0

Chemical stratification usually follows the thermal stratification quite closely. In the deeper lakes oxygen depletion was evident in the hypolimnion in June and by the last of July or the first part of August the oxygen concentrations were approaching minimum amounts in the thermocline in most lakes of this group.

Hydrogen ion concentrations seldom fell below 7.0, even in the hypolimnion, but reduction in dissolved oxygen was usually accompanied by a reduction in hydrogen ion concentration. The hydrogen ion change was probably due to an increase in carbon dioxide.

The depth of the epilimnion appears to be quite consistent in each of the lakes that stratify regularly but varied from 6 to 21 feet, depending more on topography and surface area than on the depth. The average epilimnion extended to a depth of 9 feet. The thickness of the midsummer epilimnion of an individual lake seldom varied more than three feet from one year to the next.

The width of the thermocline varied from year to year in all lakes, especially in those lakes in which a hypolimnion was formed only during certain years. If we consider lakes of both groups two and three we find that most of the thermoclines extended to the bottom of the lake.

Turbidity of the lakes in groups two and three varied a great deal. Secchi disc readings from 2.5 inches to 14 feet were recorded, but transparency was usually two feet or more.

Alkalinity determinations were made on lakes in all three groups. Electric shocker work had indicated that there were less electrolytes in the southern Iowa impounded waters than in the northern natural lakes. This was born out to some extent by the fact that the methyl orange alkalinity of twenty-five lakes averaged 109 parts per million (range 65-155), less than half of that found in the

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average natural lake waters. Only four lakes had phenophthalein alkalinity. Eighteen parts per million was the highest reading.

Volume of Lakes Encompassed by Epilimnion

When dissolved oxygen concentrations reach minimum levels for fish life in the two lower layers of water, leaving only the epilimnion for living space, we realize that stratification can have a decided effect on the fish populations. Time and space does not permit a thorough discussion of this phase of stratification but some idea of the limitations that are imposed can be gained if we compute the percentage of the total volume of water available to fish in the epilimnion of a few of the lakes in group three (table 2).

Table 2.
Per cent of total lake volume encompassed by the epilimnion of three southern Iowa artificial lakes.

Lake	County	Depth of Epilimnion[1]	Per cent of total volume
		6 ft.	38
Nine Eagles	Decatur	9 ft.	52
		9 ft.	31
Geode	Henry	12 ft.	46
		12 ft.	64
Lake Wapello	Davis	15 ft.	71

[1] Usual depths of epilimnion for the individual lake.

Summary

The determination of thermal and chemical stratification became a routine part of the Conservations Commission's southern Iowa lakes survey program in 1952. During the past four years 36 lakes have received one or more visits with over 1,000 separate temperature readings recorded and some 350 dissolved oxygen and pH determinations made during 132 visits.

The lakes ranged from 16 to about 400 acres in surface area and 7 to 55 feet in depth, averaging about 100 and 22 respectively.

These lakes were placed in three groups: Those that do not stratify, those that have a temporary or very limited stratification, and those that have a strong stratification each year. Epilimnions extended from 5 to 21 feet, averaging about 9 feet. Thermoclines usually extended to the bottom except in the deeper lakes. Temperature declines within the thermocline varied from minimum to over 20 degrees. Transparency was usually over two feet except in group one where the turbidity was always high. Alkalinity of the surface waters of 25 lakes varied from 65 to 155 parts per million. Epilimnions of three lakes of group three encompassed 31 to 71 per cent of total lake volumes.

Literature Cited

Lewis, William M., 1949. Fisheries Investigations of Two Artificial Lakes in Southern Iowa. Ia. State Coll. Jour. Sci., Vol. 23, No. 4, 355-361.

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Appendix Table 1.

Name and location by county of thirty-six southern Iowa artificial lakes placed in three groups according to extent of thermal and chemical stratification.

Group	Ave. Max. Depth	Lake	County
ONE	10 feet	Allerton Reservoir	Wayne
		West City Reservoir at Osceloa*	Clarke
		Lake McKinley*	Union
		Summit Lake*	Union
TWO	18 feet	Lake McBride	Johnson
		Loch Ayr*	Ringgold
		Lake Darling	Washington
		Corydon Reservoir	Wayne
		Fisher Lake*	Davis
		Green Valley	Union
		Rock Creek	Jasper
		Lake of three fires	Taylor
		Crystal Lake*	Lucas
		Humeston Reservoir*	Lucas
THREE	24 feet	Fairfield Res. #1*	Jefferson
		Nodaway Lake*	Adair
		Geode	Henry
		Lake Keomah	Mahaska
		Lake Keosauqua	Van Buren
		Lake Wapello	Davis
		Des Moines C. Res*	Dallas-Polk-Madison-Warren
		Lake Ahquabi	Warren
		Afton Reservoir*	Union
		Lower Albia Res.*	Monroe
		Upper Albia Res.*	Monroe
		Cold Springs	Cass
		Centerville Res.*	Appanoose (upper lake)
		Centerville Res.*	Appanoose (lower lake)
		East City Res. at Osceola*	Clarke
		Corning Res.* (old)	Adams
		Montezuma Res.*	Poweshiek
		Nine Eagles	Decatur
		Williamson Pond	Lucas
		Red Haw Hill	Lucas
		Springbrook	Guthrie
		Beeds Lake	Franklin

***City owned, under management agreement with Conservation Commission.**