SURFACE LEVEL FLUCTUATION IN CEDAR CREEK BOG, MINNESOTA [1]

MURRAY F. BUELL AND HELEN FOOT BUELL
North Carolina State College, Raleigh

"Quaking bog" is the term popularly applied to a bog which has developed upon a mat of Carex or Sphagnum growing out over a water surface. The quaking characteristic is to be explained by the presence of a stratum of water or at least loose, unconsolidated peat below a more or less mature surface layer. Occasionally portions of such bogs break loose and drift out into the lake or pond where they continue to grow and may attain considerable size as islands. When the water is low they become stranded but are set free again to drift before the wind at high water. Changes in the absolute level of such floating-island bogs obviously occur in consonance with any changes in the water level of the lake. Similar changes in the surface level of Carex or Sphagnum mats surrounding a bog lake are equally obvious. But there may be some question as to how readily and to what degree the level of a forested bog might fluctuate. Records kept on one location on a forested bog in Michigan showed an extreme fluctuation of 2.2 feet (Gates '40). The following is a report on a study of levels along a transect from the upland to the open water carried out at Cedar Creek Bog, a bog-lake in an advanced stage of development.

Cedar Creek Bog is located just west of Cedar Creek where it crosses the Isanti-Anoka county boundary thirty miles north of Minneapolis, Minnesota (N.W.–N.W. Sec. 27, T. 34 N.R. 23 W.). It consists of a very deep deposit of peat occupying a large outwash pit in the Anoka sand plain (Cooper '35). Only a remnant of the ancestral lake is left; in the final stages of filling in, the lake is less than one quarter of its original width. Its depth has been reduced sufficiently so that during the drier seasons wild rice occurs nearly throughout, being rooted in the soupy mass of organic lake deposit.

The pond is surrounded by an open sedge mat about twenty meters in width. This, although formed in the main by *Carex filiformis* L., is at the present time being built upon a coarse framework of the woody rhizomes of *Decodon verticillatus* (L.) Ell., the pioneer along the major portion of the edge of the mat. Throughout the mat *Thelypteris palustris* Schott. and *Muhlenbergia racemosa* (Michx.) BSP. are extremely important, and locally there are dense patches of *Eleocharis palustris* (L.) R. & S. *Typha latifolia* L. occurs scattered here and there. *Salix petiolaris* Sm., *S. bebbiana* Sarg., and seedlings of *Larix laricina* (DuRoi) Koch are conspicuous, especially on the older portions near the edge of the bog forest.

The pioneer trees are Larix, and in the open border of the forest grow *Ledum groenlandicum* Oeder., *Rhamnus alnifolia* L'Her., *Andromeda glaucophylla* Link, *Rhus vernix* L. and several species of Salix. A dense growth of *Thuja occidentalis* L. forms the mature bog forest. It begins ten or fifteen meters back from the open sedge mat and forms a complete girdle 100 meters or more wide around the pond.

On the surrounding sandy upland *Quercus ellipsoidalis* E. J. Hill and *Pinus banksiana* Lamb. are the characteristic trees. The regional climax (Daubenmire '36) of maple-basswood is barely suggested in the presence of a small group

[1] This is the second paper of a series, "Ecological studies of a senescent lake." The first paper entitled, "The developmental history of Cedar Creek Bog, Minnesota," by R. L. Lindeman, appears in *The American Midland Naturalist* **25**: 101, 1941.

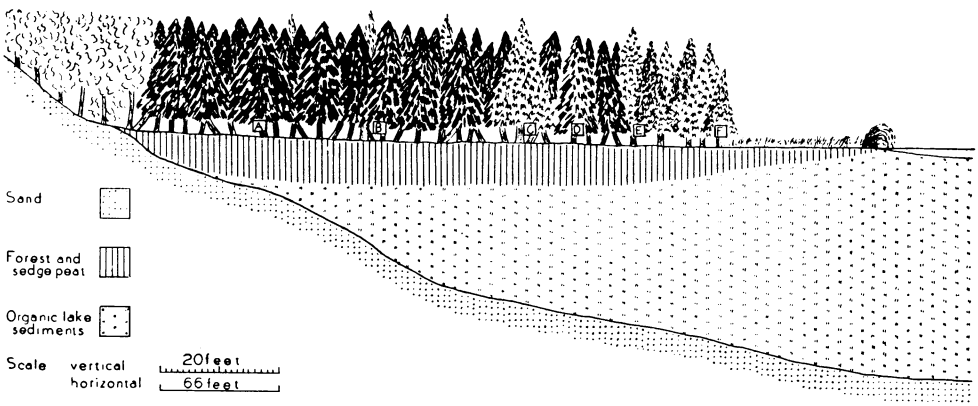

FIG. 1. Profile of Cedar Creek Bog under line of transect, constructed in part from data kindly furnished by Mr. R. L. Lindeman. The sand is quartz and garnet sand characteristic of the outwash plain; the oozy, organic lake sediments have a pH of 8.2–8.0; the forest and sedge peat has a pH of 7.6–7.4.

of these dominants with their characteristic companion species on an upland area close to the bog.

Of particular interest from a geographic standpoint is the presence of both *Decodon verticillatus* and *Rhus vernix* which reach their northernmost known limit of distribution in Minnesota in this vicinity.

In the three years during which this study was being made the most obvious change in the vegetation was the increase of *Typha latifolia* throughout the sedge mat. The period was also favorable for willows, which appear to have grown and increased considerably. Decodon, which had grown poorly in the dry year of 1934, was as vigorous as ever in 1939.

In the fall of 1934 we were impressed by the changes effected by a series of dry years culminating in the severe drouth of that summer. In walking on the sedge mat it seemed quite firm and did not quake as previously. The pond had shrunk to a small, shallow pool about half to three-quarters of the size it had been. This exposed a broad expanse of saturated gray-black ooze or lake sediments. *Zizania aquatica* was growing on this and, especially at the northern end of the pond, formed a very broad zone. In the bog forest even the deepest depressions of the irregular forest floor had dried out.

It was obvious that there had been a sufficient amount of water lost from the bog to result in a distinct lowering of the surface, at least toward the center. To get an exact determination of the extent of this lowering of the bog we instigated a series of semiannual surveys lasting over a period of three years. The surveys show some interesting results, particularly since they were begun at the climax of a series of drouth years.

A Gurley transit was used in running the levels. To handle the instrument an advanced student in the civil engineering department at the University of Minnesota was engaged. A permanent bench mark was established on high ground by driving a railroad spike into the base of a large white oak. This bench mark was given the arbitrary elevation of 100 and all other elevations are relative to it. As a precaution this was supplemented by similar auxiliary bench marks established in the base of both an adjacent white pine and a pin oak. Six permanent stations were then similarly established on the bog by driving railroad spikes into cedar and tamarack trees in the bog forest (fig. 1). These are all located along a permanent transect 140 meters long running from high ground to the water's edge. The vegetation on this transect was mapped, and the trees bearing the spikes were in-

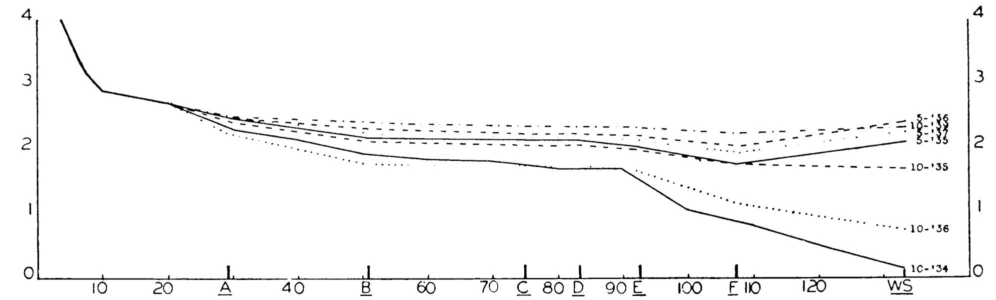

FIG. 2. Bog surface profiles, showing levels at the various dates surveyed. Permanent stations indicated by letters along the baseline. Vertical scale in feet, horizontal scale in meters.

dicated on the transect map. The transect gives the exact location of these stations as well as a picture of the immediate forest environment of each. The stations are scattered through the bog forest, the sixth being in one of the larger pioneer tamaracks at the margin. The water surface, which indicates essentially the position of the edge of the sedge mat, fluctuating directly with it, is the seventh and last station for elevations along the transect.

The surveys were made each year the last week in October and the last week in May. The October survey hence follows a period of five months with a decidedly higher average monthly precipitation than the seven months' period ending with the survey made in May (table II).

The effect of the low precipitation during the colder months with their very low evaporation is in striking contrast with the summer conditions. The effect of the winter precipitation, of course, is cumulative, the ice and snow being liberated as water during the short spring period. The cold season was entirely responsible for any accumulation of water in the bog. The total reduction in amount of bog water that invariably occurred during the warmer months depended upon how greatly evaporation exceeded precipitation during that period.

The greatest fluctuation of the water surface in the open pond was 2.3 feet from the extreme low of October, 1934, to the extreme high of May, 1936. Unfortunately no data were obtained during this period on fluctuations of small lakes of similar size in sandy (rather than peaty!) basins in this region. From our general observations of such bodies of water it was obvious that the drouth period affected them far in excess of 2 feet of water. The results of this study bear concrete evidence in support of Dachnowski-Stokes' emphasis on the importance of peatlands in the conservation of water. (Dachnowski-Stokes '35.)

Changes in elevation during this period occurred throughout the bog, the magnitude of the fluctuation diminishing with increasing distance from the pond (fig. 2 and table I). Stations A and B, 30 and 51 meters respectively from the contact of the peat and the sandy upland, are both in dense bog forest. At point A, cedars 2 or more inches in diameter occur with a density of somewhat more than 1 tree per square meter with, in addition, nearly as many young cedar trees under 2 inches in diameter, and scattered tamaracks 4–8 inches in diameter. At B, cedars with a diameter of 2 or more inches occur with a frequency of only about 1 per 3 square meters, but of young cedars under 2 inches in diameter there is about 1 per square meter. Scattered tamaracks are also present at B. Stations A and B are underlain respectively by 4 and 7 meters of peat, chiefly fibrous. The maximum fluctuation of the surface at these two points was 0.38 and 0.45 foot respectively. Peculiarly, unlike the other stations, these were at their lowest level in October, 1936, instead of in October, 1934 (table I).

TABLE I. *Altitudes in feet of stations on the bog, relative to the bench mark which was given the arbitrary figure 100; for the period 1934–37 and for Fall, 1939.*

Station	Fall				Spring			Maximum fluctuation
	1934	1935	1936	1939	1935	1936	1937	
A	95.28	95.40	*95.12*	95.51	95.44	**95.50**	95.43	.38
B	95.31	95.51	*95.14*	95.77	95.57	**95.69**	95.59	.45
C	*94.82*	95.20	94.83	95.41	95.22	**95.30**	95.25	.48
D	*94.70*	95.14	94.76	95.39	95.16	**95.26**	95.17	.56
E	*94.45*	94.98	94.57	95.31	94.95	**95.18**	95.09	.64
F	*93.97*	94.87	94.33	95.45	94.87	**95.27**	95.01	1.30
Water surface	*92.13*	93.70	92.76	94.36	94.12	**94.43**	94.26	2.30

Note.—The lowest levels attained at each station for the period 1934–37 are printed in italics, the highest levels in bold-face. Compare figures for Fall, 1939.

Stations C, D, and E are 75 meters, 84 meters, and 93 meters respectively from the contact of the bog and the upland. They are all in young cedar forest, most of the cedar trees being under 2 inches in diameter. Tamaracks are scattered liberally throughout. By far the larger proportion of the underlying peat here is soft, oozy, sedimentary material. At stations C, D, and E, the extreme fluctuation of the surface was approximately half a foot, being 0.48, 0.56, and 0.64 foot, respectively.

Station F, 107 meters from the margin of the peat, is marked by a spike driven into a tamarack on the edge of the open sedge mat. This was the last tree in the transect. Between stations E and F is open tamarack woods with no cedars. The peat at F is well over 10 meters deep. Fluctuations of the bog surface itself at this point are especially interesting. Disregarding the survey made in the fall of 1939, the total maximum fluctuation was 1.3 feet from the low level of 92.87 in October, 1934, to the high of 94.17 in May, 1936.[2] Comparing these figures with those of the water surface, which fluctuated 2.3 feet from the low of 92.13 feet of October, 1934, to the high of 94.43 feet in May, 1936, it will appear that there is something more significant here than merely comparison in the total fluctuation at each point. In the fall of 1934 the relatively dry, firm bog surface was very little above the water table; while in the spring of 1936 it was *below* the water level of the pond, submerged to the extent of 0.26 foot or thereabouts.

Similar inundation of this area occurred each year the survey was made. The lag of this area following the raising of the water table was especially noticeable since the sedge mat appears to fluctuate freely and directly with the water level. Hence in late May one climbs up to the floating sedge mat from the submerged margin of the bog forest. Unfortunately we have no data on the level of this submerged portion during the following month of June. We believe that, at the time the survey was made each year in late May, this area was in the process of rising and probably would reach its highest level sometime in June. In this connection the high level of the bog in October, 1939, is of considerable interest since the bog surface at station F was then on a level with the water surface. This condition in the fall shows the result of adjustment of this area to a continued high water table.

Since 1937 when our regular surveys ceased, Mr. R. L. Lindeman of the Department of Zoology of the University of Minnesota has kept records of the fluctuations of the pond surface. These data, kindly furnished by him, show diminishing fluctuations from 1936 until the present. Last year, 1939, the level was the same in October as in May (table II). In October, 1939, Mr. Lindeman ran levels along the transect and the results (table I) show that the bog was slightly higher throughout than at any time during the three years of our regular surveys and much higher than at any previous fall survey.

[2] Station F, the permanent point for taking levels was on top of a spike about 1.1 ft. above the general level of the bog surface.

TABLE II. *Water levels of pond in feet relative to the permanent bench mark of 100, and precipitation records; 1934–39.*

Date	Level	Change	Precipitation in inches for intervening period		
			Departure from normal	Average monthly	Total
Oct. 1934	92.13		− .47	3.16	15.81
May 1935	94.12	Up 1.99	+1.64	1.86	13.02
Oct. 1935	93.70	Down .42	+ .08	3.27	16.36
May 1936	94.43	Up .73	− .94	1.49	10.44
Oct. 1936	92.76	Down 1.67	−8.96	1.46	7.32
May 1937	94.26	Up 1.60	+1.89	1.90	13.27
Oct. 1937	94.00	Down .26	−5.56	2.14	10.72
May* 1938	94.83	Up .84?	+3.50	2.13	14.88
Oct. 1938	94.33	Down .50	−2.43	2.77	13.85
May 1939	94.36	Up .03	−1.29	1.48	10.35
Oct. 1939	94.36	No change	−1.06	3.04	15.22

* Level taken in June.

The significance of these data concerning the fluctuation of the bog surface lies mainly in their relation to pollen studies and the construction of peat profiles. Series of samples for pollen studies are most commonly taken from the deepest part of a bog. Several series are frequently taken from different parts of the same bog. If these are not taken at about the same time, correlation between levels in two locations cannot be made with any certainty that they are the same levels; also, the annual swelling and compressing in the upper layers must have some effect in the mixing of the strata.

Of fully as great importance is the possible effect of such surface changes on profile studies. Unless the field work connected with the construction of a profile of a bog is completed all at one time there is evident danger of error. Obviously a fluctuation of more than two feet, such as occurs in parts of Cedar Creek Bog during the course of a year, will seriously distort all horizons of a profile. It is important therefore to make all borings at the same time.

We take this opportunity to thank Dr. W. S. Cooper and Dr. Russell Artist for their assistance in the continuance of the study during the second and third years, and Mr. Ray Lindeman who kindly furnished additional data.

SUMMARY

A series of levels run across a bog semiannually over a period of years revealed considerable fluctuations in the bog surface. The extent of this fluctuation in bog level varies from a small but appreciable change (about 4 inches) in mature bog underlain by rather solid peat, to a foot and one-half and more in marginal bog forest of tamarack underlain by less compact peat. The sedge mat, which varied directly with the water surface showed a maximum fluctuation of 2.3 feet. With the possible exception of the summer of 1939 the accumulation of precipitated moisture during the seven colder months contributed all the water responsible for raising the bog surface. The relative excess of evaporation over precipitation in the warmer months determined the extent of the usual annual lowering of the bog. The fluctuations over the deeper parts of the bog are sufficient to affect materially the results of peat profile studies and possibly sampling for pollen analyses.

LITERATURE CITED

Cooper, W. S. 1935. The history of the upper Mississippi River in late Wisconsin and post-glacial time. *Minn. Geol. Surv. Bull.* **26**.

Dachnowski-Stokes, A. P. 1935. Peat land as a conserver of rainfall and water supplies. *Ecology* **16** (2): 173–177.

Daubenmire, R. F. 1936. The "Big Woods" of Minnesota, its structure and relation to climate, fire, and soils. *Ecol. Monographs* **6**: 233–268.

Gates, F. C. 1940. Bog levels. *Science* **91**: 449–450.

Lindeman, R. L. 1941. The developmental history of Cedar Creek Bog, Minnesota. *Amer. Midl. Nat.* **25**: 101–112.