Cranberry Bog: Hydrological and Nutrient Budgets

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ABSTRACT

This study continues the hydrological budget first started in the summer of 1995. In addition to the water budget, budgets were created for calcium, nitrates, and total phosphorous. The budgets show the fluctuations of the area's hydrologic cycle and nutrient loading between 9/6/95 and 11/26/95. During this period the level of water rose roughly 1.5 feet, indicating that the water volume in the bog nearly tripled. As the water levels rose, the bog showed an increased ability to retain a greater percentage of the incoming total phosphorous and nitrates. There is a consistent and relatively large amount of calcium entering the bog from a source other than the sources monitored in this study. The data on calcium concentrations for this time period may lend some support to the stipulation made in the previous study that a significant amount of groundwater is entering this system.

INTRODUCTION

Analysis and study of the chemical constituents in natural waters are a large part of limnology. One reason for this is that the interactions between the geology and biology of an aquatic system are allied to the system's water chemistry. Chemical limnology, both inorganic and organic, is an important fact of the dynamics of an area's water cycle.

Phosphorus is absolutely necessary to all life. It functions in the storage and transfer of cell energy (ATP) and in genetic systems (Cole, 1979). The main source of this element is the mineral apatite. The decay and mineralization of plant and animal corpses also serve as a source of phosphorus for ecosystems. Too little of this element can have limiting effects on an aquatic habitat.

Nitrogen, although absolutely necessary for life, is not as crucial as phosphorus because of its abundance and its many sources for organisms. Due to the high atmospheric concentration of nitrogen a common source is fixation by blue-green algae.

Calcium is often the predominant mineral in fresh water (Dunne, 1978). In limestone regions this is most often the case with groundwater.

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METHODS

Hydrological Budget

The time period for this study begins on 9/6/95, exactly where the previous study ends. Several devices were installed to collect field data for the last study and were also used in this research project. First, the inflow from the contributing streams were fitted with weirs (Figure 1). A weir enables the measurement of flow over time. This is done by measuring stream height over the crest and plugging this data into a conversion formula (US Gov., 1967). This was done on a regular basis so that an accurate account of all water flowing into the system was obtained. A weir was also placed at the outflow. The regions of the watershed monitored by these weirs provided models upon which the contribution of surface runoff by the unmonitored regions was estimated. Altogether, four weirs were placed, and the amounts of water going into and coming out of the bog were recorded. Information about weirs may be obtained from The U.S. Department of the Interior's Water Measurement Manual, 1967.

A rain gauge was placed in the area allowing for the monitoring of precipitation. The bog is divided into two sections, one large body of water (about 30 acres standing water) drains into a much smaller body (about 0.5 acres). A staff gauge was placed in each body of water so that the level of water could be constantly recorded during the course of the study. This helped keep tabs on how much the volume of water fluctuated over time.

In addition to the weirs, two electronic devices were added (American Sigma Streamline 800SL Sampler with Integral Flowmeter). These devices were programmed to keep a log of stream flow at ten minute intervals. One of these was placed at the outflow, and one was placed at the major contributing stream. The data from these devices was then transferred to data processing software at the Biological Field Station. The other two incoming streams were monitored weekly by recording the stream's height over the weir (via installed staff gauge). The collected data was manually plugged into a flow conversion formula.

Evaporation and evapotranspiration values for this time period were calculated from a standardized set of value for this latitude and time of year (Dunne, 1978). All together, these data provided measurements of all water going into and out of the bog (Table 1a-c).

Nutrient Budgets

These nutrient budgets account for the total volumes of total phosphorous (Table 2a-c), nitrates (Table 3a-c) and calcium (Table

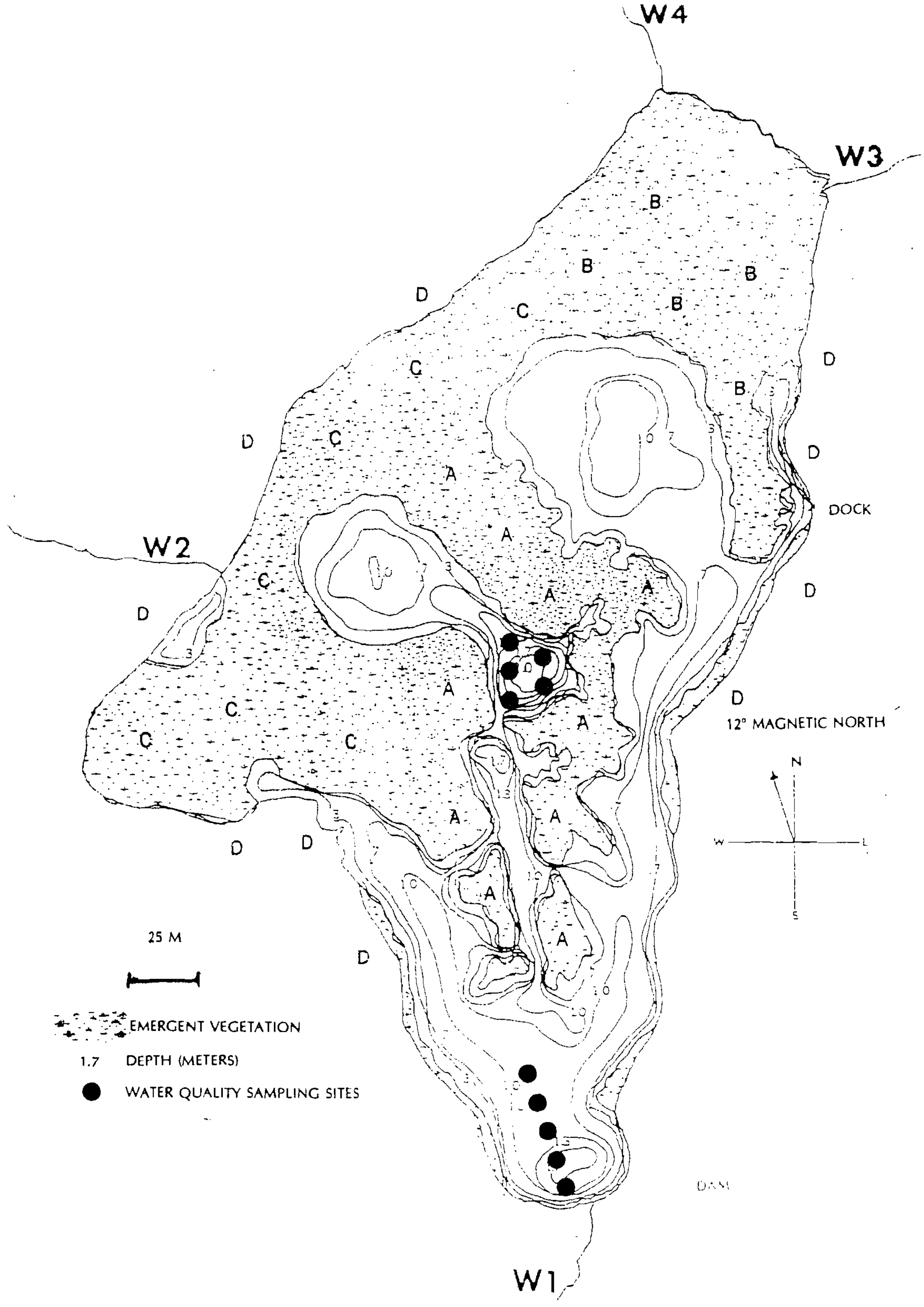

Figure 1. Cranberry Bog, Greenwoods Conservancy.

RESULTS

Hydrological Budget

TABLE 1a
WATER BUDGET FOR 9/6-10/6
(values in cubic feet)

	UPPER BOG	LOWER BOG
ACTUAL START VOLUME	2,180,003	24,641
+ RAIN VOLUME	1,483,906.2	10,159.01
+ WEIR 2	4,695.63	0
+ WEIR 3	64.80	0
+ WEIR 4	5,016.96	0
+ UNMONITORED VOL.	550	391.4
= TOTAL	3,674,236.59	35,191.41
- WEIR 1	0	9,758.23
- EVAPORATION	817,662.6	5,597.91
= ESTIMATED FINAL VOLUME	2,856,573.99	19,835.27
- ACTUAL FINAL VOLUME	3,028,422	41,953
= TOTAL	-171,848.01	-22,117.73
UPPER TO LOWER FLOW	- 22,117.73	+ 22,117.73
TOTAL UNACCOUNTED	-193965.74	0

A brief explanation of table.

Actual start volume - the volume of water in the bog at the beginning of the time period (based on staff gauge readings).

Rain volume - water contributed by rain.

Weir 2,3,&4 - water contributed by the incoming streams which were monitored by weirs.

Unmonitored volume - water contributed by those regions of the watershed not monitored by weirs.

Weir 1 - water coming out of the bog.

Evaporation - The amount of water released into the atmosphere due to evaporation and evapotranspiration.

Estimated final volume - The calculated amount of water remaining in the bog.

Actual final volume - The amount of water actually remaining in the bog (based on staff gauge readings).

Upper to lower flow - To account for the separation of the two water bodies of the bog, it has been assumed here that any missing amount of water in the lower body is fully replenished by the upper body.

Total unaccounted for - A positive value shows that there is less water in the bog then estimated. A negative value shows that there is more water in the bog then estimated.

TABLE 1b
WATER BUDGET FOR 10/6-11/6
(values in cubic feet)

	UPPER BOG	LOWER BOG
ACTUAL START VOLUME	3,028,422	41,953
+ RAIN VOLUME	1,271,919.6	8,707.78
+ WEIR 2	490,393.04	0
+ WEIR 3	169,107.62	0
+ WEIR 4	396,846.9	0
+ UNMONITORED VOL.	1,606,000	40,850
= TOTAL	6,962,689.161	91,510.78
- WEIR 1	0	551,382.75
- EVAPORATION	606,351.4	4,377.2
= ESTIMATED FINAL VOLUME	6,356,337.76	-464,249.17
- ACTUAL FINAL VOLUME	5,457,690	55,114
= TOTAL	898,647.76	-519,363.17
UPPER TO LOWER FLOW	- 519,363.17	+ 519,363.17
TOTAL UNACCOUNTED	379,284.59	0

TABLE 1c
WATER BUDGET FOR 11/6-11/26
(values in cubic feet)

	UPPER BOG	LOWER BOG
ACTUAL START VOLUME	5,457,690	55,114
+ RAIN VOLUME	454,257	3,109.92
+ WEIR 2	381,417.3	0
+ WEIR 3	363,937.78	0
+ WEIR 4	388,943	0
+ UNMONITORED FLOW	4,070,502	33,398.2
= TOTAL	11,116,747.08	91,622.12
- WEIR 1	0	3,566,515.27
- EVAPORATION	425,798.1	3,052.56
= ESTIMATED FINAL VOLUME	10,690,948.98	-3,477,945.71
- ACTUAL FINAL VOLUME	6,066,215	53,366
= TOTAL	4,624,733.98	-3,531,311.71
UPPER TO LOWER FLOW	- 3,531,311.71	+ 3,531,311.71
TOTAL UNACCOUNTED	1,093,422.27	0

NUTRIENT BUDGET

To understand the following tables refer back to the explanation under Table 1a. Substitute the specific nutrient in where ever water appears in the explanation.

TABLE 2a
TOTAL PHOSPHOROUS BUDGET FOR 9/6-10/6
(values in grams)

	UPPER BOG	LOWER BOG
ACTUAL START VOLUME	1819.98	24.76
+ RAIN VOLUME *	2107.15 *	14.43 *
+ WEIR 2	1.59	0
+ WEIR 3	0.024	0
+ WEIR 4	1.47	0
+ UNMONITORED VOL.	0.23	0.13
= TOTAL	3930.44	39.32
- WEIR 1	0	4.86
= ESTIMATED FINAL VOLUME	3930.44	34.46
- ACTUAL FINAL VOLUME	2391.15	51.05
= TOTAL	1539.29	-16.59
UPPER TO LOWER FLOW	- 16.59	+ 16.59
TOTAL UNACCOUNTED	1522.70	0

* Rain input of total phosphorous was found to be about 1.42*10E-03 grams per cubic feet of rain (Albright, In prep).

Table 2b
TOTAL PHOSPHOROUS BUDGET FOR 10/6-11/6
(values in grams)

	UPPER BOG	LOWER BOG
ACTUAL START VOLUME	2391.15	51.05
+ RAIN VOLUME	1808.14	13.05
+ WEIR 2	178.05	0
+ WEIR 3	42.58	0
+ WEIR 4	213.72	0
+ UNMONITORED VOL.	403.7	14.86
= TOTAL	5037.35	78.96
- WEIR 1	0	621.16
= ESTIMATED FINAL VOLUME	5037.35	-542.20
- ACTUAL FINAL VOLUME	4448.24	38.21
= TOTAL	589.11	-580.41
UPPER TO LOWER FLOW	- 580.41	+ 580.41
TOTAL UNACCOUNTED	8.71	0

* Rain input of total phosphorous was found to be about 1.42*10E-03 grams per cubic feet of rain (Albright, In prep).

TABLE 2c
TOTAL PHOSPHOROUS BUDGET FOR 11/6-11/26
(values in grams)

	UPPER BOG	LOWER BOG
ACTUAL START VOLUME	4,448.24	38.21
+ RAIN VOLUME	647.82	4.64
+ WEIR 2	136.44	0
+ WEIR 3	54.66	0
+ WEIR 4	96.55	0
+ UNMONITORED VOL.	518.1	11.36
= TOTAL	5,901.81	54.22
- WEIR 1	0	2,268.62
= ESTIMATED FINAL VOLUME	5,901.81	-2,214.41
- ACTUAL FINAL VOLUME	14,987.13	26.28
= TOTAL	-9,085.32	-2,240.69
UPPER TO LOWER FLOW	- 2,240.69	+ 2,240.69
TOTAL UNACCOUNTED	-11,326.01	0

* Rain input of total phosphorous was found to be about 1.42*10E-03 grams per cubic feet of rain (Albright, In prep).

TABLE 3a
NITRATE BUDGET FOR 9/6-10/6
(values in grams)

	UPPER BOG	LOWER BOG
ACTUAL START VOLUME	4,318.59	27.89
+ RAIN VOLUME *	3,518.37 *	24.09 *
+ WEIR 2	11.99	0
+ WEIR 3	0.53	0
+ WEIR 4	64.49	0
+ UNMONITORED VOL.	5.06	1.0
= TOTAL	7,919.03	52.98
- WEIR 1	0	44.31
= ESTIMATED FINAL VOLUME	7,919.03	8.68
- ACTUAL FINAL VOLUME	5,142.26	71.24
= TOTAL	2,776.77	-62.56
UPPER TO LOWER FLOW	- 62.56	+ 62.56
TOTAL UNACCOUNTED	2,714.21	0

* Rain input of nitrates was found to be about 3.87 * 10E-05 grams per square foot of surface area per day (Hetling, 1975).

TABLE 3b
NITRATE BUDGET FOR 10/6-11/6
(values in grams)

	UPPER BOG	LOWER BOG
ACTUAL START VOLUME	5,142.26	71.24
+ RAIN VOLUME	3,522.30	25.43
+ WEIR 2	926.12	0
+ WEIR 3	542.43	0
+ WEIR 4	5,108.11	0
+ UNMONITORED VOL.	5,142.5	77.14
= TOTAL	20,383.71	173.80
- WEIR 1	0	1,586.27
= ESTIMATED FINAL VOLUME	20,383.71	-1,412.46
- ACTUAL FINAL VOLUME	12,356.21	124.78
= TOTAL	8,027.50	-1,537.24
UPPER TO LOWER FLOW	- 1,537.24	+ 1,537.24
TOTAL UNACCOUNTED	6,490.26	0

* Rain input of nitrates was found to be about 3.87 * 10E-05 grams per square foot of surface area per day (Hetling, 1975).

TABLE 3c
NITRATE BUDGET FOR 11/6-11/26
(values in grams)

	UPPER BOG	LOWER BOG
ACTUAL START VOLUME	12,356.21	124.78
+ RAIN VOLUME	2,355.88	16.89
+ WEIR 2	981.16	0
+ WEIR 3	1,072.51	0
+ WEIR 4	2,539.60	0
+ UNMONITORED VOL.	10,175.00	81.7
= TOTAL	29,480.36	223.37
- WEIR 1	0	8,001.79
= ESTIMATED FINAL VOLUME	29,480.36	-7,778.43
- ACTUAL FINAL VOLUME	12,017.17	181.23
= TOTAL	17,463.19	-7,959.66
UPPER TO LOWER FLOW	- 7,959.66	+ 7,959.66
TOTAL UNACCOUNTED	9,503.53	0

* Rain input of nitrates was found to be about 3.87 * 10E-05 grams per square foot of surface area per day (Hetling, 1975).

TABLE 4a
CALCIUM BUDGET FOR 9/6-10/6
(values in grams)

	UPPER BOG	LOWER BOG
ACTUAL START VOLUME	395,631.83	4,471.9
+ RAIN VOLUME	33,662.83	230.46
+ WEIR 2	2,587.1	0
+ WEIR 3	14.73	0
+ WEIR 4	2,257.8	0
+ UNMONITORED VOL.	137.5	215.46
= TOTAL	434,291.79	4,917.82
- WEIR 1	0	14,303.4
= ESTIMATED FINAL VOLUME	434,291.79	-9,385.58
- ACTUAL FINAL VOLUME	549,604.81	7,613.72
= TOTAL	-115,313.02	-16,999.30
UPPER TO LOWER FLOW	- 16,999.30	+ 16,999.30
TOTAL UNACCOUNTED	-132,312.32	0

TABLE 4b
CALCIUM BUDGET FOR 10/6-11/6
(values in grams)

	UPPER BOG	LOWER BOG
ACTUAL START VOLUME	549,604.81	7,613.72
+ RAIN VOLUME	28,886.03	208.52
+ WEIR 2	179,666.2	0
+ WEIR 3	31,453.4	0
+ WEIR 4	130,326.7	0
+ UNMONITORED VOL.	298,100.00	14,820.00
= TOTAL	1,218,037.14	22,642.24
- WEIR 1	0	1,138,994.8
= ESTIMATED FINAL VOLUME	1,218,037.14	-1,116,352.56
- ACTUAL FINAL VOLUME	990,473.81	10,002.21
= TOTAL	227,563.33	-1,126,354.77
UPPER TO LOWER FLOW	- 1,126,354.77	+ 1,126,354.77
TOTAL UNACCOUNTED	-898,791.44	0

TABLE 4c
CALCIUM BUDGET FOR 11/6-11/26
(values in grams)

	UPPER BOG	LOWER BOG
ACTUAL START VOLUME	990,473.81	10,002.21
+ RAIN VOLUME	10,349.3	74.2
+ WEIR 2	70,302.1	0
+ WEIR 3	52,678.5	0
+ WEIR 4	82,387.4	0
+ UNMONITORED VOL.	500,500.00	5,852.00
= TOTAL	1,706,691.11	15,928.41
- WEIR 1	0	5,201,744.5
= ESTIMATED FINAL VOLUME	1,706,691.11	-5,185,816.09
- ACTUAL FINAL VOLUME	1,100,910.29	9,684.98
= TOTAL	605,780.82	-5,195,501.07
UPPER TO LOWER FLOW	- 5,195,501.07	+ 5,195,501.07
TOTAL UNACCOUNTED	-4,589,720.3	0

4a-c), entering, leaving, and remaining in this system. Weekly water samples were taken from weir 1, 2, 3, and 4, the upper bog water body, and lower bog water body. The samples were then taken to a Biological Field Station laboratory and analyzed to determine the concentration of the above nutrients. Linearity was assumed between the weekly samples so that a time vs. concentration graph could be created using spreadsheet software. By using other software and integrating under the curve of the said graph, the import and export rates and total volumes of the nutrients were found. These values only provided data on the monitored portions of the watershed and so they serve as models upon which to calculate the loading rates of the unmonitored regions.

Since manual samples could not be conveniently taken during storm events (during which nutrient loading tends to increase dramatically) two Sigma samplers were programmed to take a series of samples upon significant increase in stream height. One of these samplers was placed at the outflow. The other sampler was placed at one of the inflow streams and thus served as a model for storm events for the other streams and unmonitored areas of the watershed. The 24 samples taken from each storm event were then composited (the samples were prorated based on their flow rates) using spreadsheet software. The composited samples were then analyzed for nutrient content.

The contribution of total phosphorous and nitrates, from precipitation, for this land area were estimated from literature values (Albright, in prep.; Hetling, 1975). Calcium input by rain was estimated by testing a precipitation sample.

DISCUSSION

The input of water into the bog during this study was always much larger than the amount coming out, yet the hydrological budget showed a consistently lesser amount of water present in the bog then estimated. One explanation for the water loss may lie in the fluctuations of the water table. During the winter season (especially during snow accumulation) the water table tends to drop considerably (Dunne, 1978). This drop coupled with a porous basin of the bog may cause a significant amount of infiltration to occur thus causing a water debt to occur in the budget.

With a consistently larger amount of calcium being present in the bog than estimated from the monitored input, the calcium budget may indicate that an incoming source of calcium was not monitored in this study. One possible source may be groundwater. In limestone regions (common in this area) the groundwater usually contains high concentrations of calcium (Dunne, 1978).

The budgets for total phosphorus and nitrates show nitrates being in greater abundance than total phosphorus (a common situation). They also show similar trends between the two nutrients and the water levels of the bog. Both nutrients appear to have rate of absorption by the bog as being related to the increased water volume of the bog. The percentage of incoming total phosphorus and nitrates retained by the bog increased as the water level rose. This trend stopped with both nutrients as absorption dropped dramatically. This abrupt halt may be attributed to extreme cold during this time frame, as chemical reactions slow significantly in cold temperatures.

Overall, the nutrient budgets seem to show a characteristic common to water bodies like Cranberry Bog. The term "nutrient sink" best describes the chemical dynamics of this system. A "nutrient sink" is a system where chemical constituents enter and never leave either because they sediment out or become involved in some chemical processes of biological or geological origin.

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