EFFECTS OF SNOW AND ICE ON WETLAND WATER CHEMISTRY

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Introduction

Although wetlands are important aquatic systems, they have been relatively little studied until recently. Much of the research completed has focussed on wetland inventories and hydrologic studies. Virtually no consideration has been given to winter cover formation and how it influences water chemistry. A good deal is known about the abiotic conditions in wetlands during the ice-free months. However, very little of the literature has discussed the effects of winter and winter cover formation. One way of overcoming this deficiency is use of literature on lake winter regimes (e.g. Adams 1981a, b; Greenbank 1945; Jackson 1979; Welch et al 1976; Wolfe 1977, 1980) as a basis for speculation on winter processes in wetlands.

The type of ice found on wetlands may well often be like lake littoral zone ice such as that described by Archer and Findlay (1966). Wolfe (1977) discovered that the snow cover on margin ice was relatively thick and that the white ice tended to form faster and achieve maximum values in the littoral zone. Similarly, the greatest spatial variation in cover type, both ice and snow, was found in this margin zone by Adams and Prowse (1981).

Since a great deal of vegetation grows in and around wetlands, large amounts of snow may be captured, resulting in conditions which favour slushing events and therefore white ice formation, should cracking occur. However, on one pond (Danks 1971a, b), the very thick snow cover simply reduced ice growth. In a swamp stream, such as that studied here, characteristics of both lake ice and stream ice might be expected (e.g. Gilfilian et al 1977; Michel 1971). Frazil ice, or other running water ice forms, could make up a certain proportion of the ice cover.

Water chemistry in wetlands is largely influenced by the fact that they have higher retention efficiencies for allochthonous matter (Mullholland 1981). This results in high concentrations of cations such as calcium (Bellamy and Rieley 1967). The standing waters are typically oxygen-depleted and darkly coloured with dissolved humic acids (Schlesinger 1978). Lastly, because of the small water volume, heating and cooling are closely related to ambient temperatures (Nagel and Brittain 1977). These distinctive conditions provide the background upon which ice cover formation is superimposed.

For this study it was hypothesized that:
1) Winter cover in wetlands would be similar to margin ice and snow on lakes;
2) Winter cover formation will have more pronounced effects on wetland water chemistry than on that of lakes because of the smaller volumes involved.

Methods

The wetland chosen is located in southern Ontario at 78°17'35"N and 44°20'40"W Campbell 1983). It is in a glacial channel now occupied by a stream. The stream's outflow was blocked when a highway was built. Vegetation is relatively similar throughout. In shallow zones (water 10-50 cm), dense, low lying, bushes dominate.

Water levels were monitored with a calibrated stake. Ice cover extent along the shoreline was also observed regularly. Water temperature and conductivity data were collected with a temperature-conductivity meter, while air temperature was obtained with maximum-minimum thermometers housed in a Stevenson screen. Blocks of ice and water samples were collected and used to determine conductivity, calcium concentrations and pH. Oxygen samples were collected regularly using a 1 litre Van Dorn water bottle (before Christmas) and an automatic water pump (after Christmas). All samples were placed in Biological

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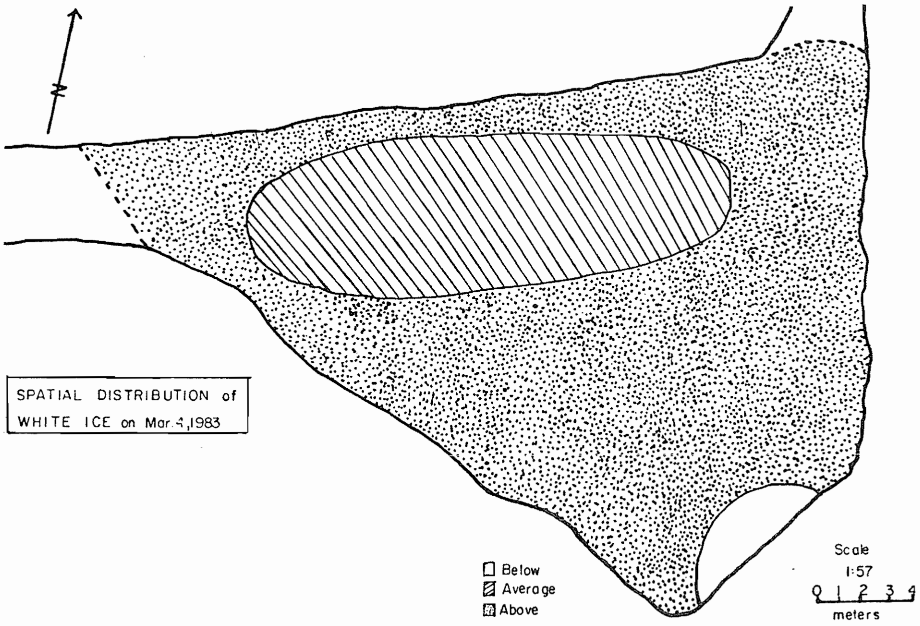

Fig. 1

Spatial distribution of white ice at 'peak' mean = ±1.86

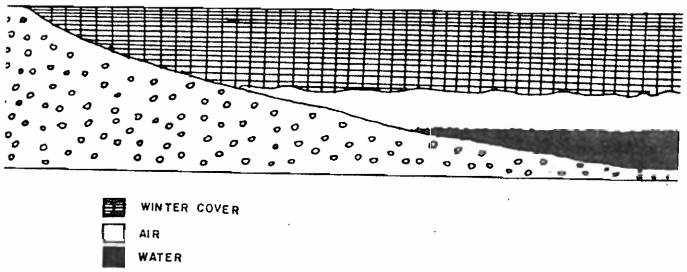

Fig. 2

Cross-section of Littoral Zone after water levels dropped.

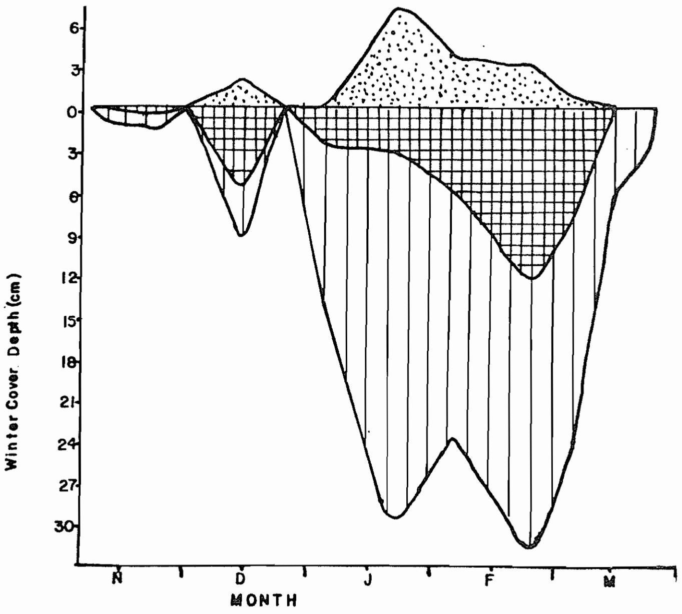

Fig. 3

Temporal pattern of winter cover.

Oxygen Demand bottles and had 2 ml each of manganese sulphate reagent (A) and alkaline-iodide-azide reagent (B) added. Winter cover, including snow cover, white ice and black ice, was measured with a metre stick after a hole had been dug with either an ice corer or a cup auger.

There were three main sampling periods: before ice formation, after initial ice formation and at peak ice. Methodology changed as the winter progressed and problems arose. Temperature and conductivity values were determined at 0.25 metre intervals from 4 points. Oxygen samples were collected every 0.5 metres. Changes in water level, ice formation and extent, and air temperatures were recorded bi-weekly until December 18, 1982. During sampling period two, five points were monitored by measuring cover components and temperature and conductivity. Oxygen (one sample), temperature and conductivity (every 25 cm) samples were obtained every two weeks after the sampling period. The final sampling period was almost identical to the second. Exceptions included the collection of oxygen, temperature and conductivity data at every point where the ice was not frozen to the sediments.

Dissolved oxygen samples were analyzed using the Stainton et al (1977) method of the Winkler technique. Water and ice samples were analyzed for calcium concentrations, pH and conductivity. Ice samples were sieved to remove large detrital matter. The latter two were measured using pH meter model No. YSl model 33 and a temperature-conductivity-salinity meter.

Results

The 1982-83 winter was very unusual for the region. Temperatures and rainfall were extremely high whereas snowfall was very low (Campbell 1983). As a result, water levels were high, rising in the fall and only beginning to decline in late February.

The winter cover melted completely on two occasions in December. Although initial ice formation was white ice, black ice dominated throughout this low snowfall winter (Fig. 3). White ice present in January soon disappeared. White ice was thickest around the margins especially at locations where vegetation resulted in the accumulation of snow (Fig. 1). This pattern, which became more pronounced towards the end of the ice season, closely reflected the distribution of snow cover. Black ice distribution tended to be the reverse of that of white ice. Falling water levels produced open spaces between the ice and the water surface (Fig. 2).

Water temperatures were isothermal by 18 November but 'inverse' (Wetzel 1975) stratification was not apparent until late January (Fig. 4).

Conductivities were high throughout the winter (Fig. 6), increasing as ice developed. Maximum conductivity coincided with peak ice formation. The conductivity of the black ice (77.5 hw cm^{-1}) was low compared with the water column. The pH of the water was 6.65 as compared with 7.71 for black ice.

Discussion

The temporal and spatial evolution of snow, white ice and black ice (Figs. 1-3) on the wetland demonstrated the interrelationships between these winter cover components. Snow is a key control of white ice growth and together these two components greatly influence black ice growth. Initial ice formation occurred during snow producing white ice (Michel 1971). Some white ice was produced by rain-on-snow and rain-on-ice events. The mild, low snowfall winter, caused the dominance of black ice in the winter cover. The spatial patterns of ice and snow, with clear centre-margin trends, were more like those of a miniature lake than of a lake margin. Little or no influence of stream flow was detected in the cover.

The fact that 'inverse' temperature stratification was not pronounced and occurred only in late January (Fig. 4) when a relatively thick ice and snow cover had developed may in part have been due to the influence of stream flow. It may also reflect the late, intermittent freeze-up and a balance of radiation input at the surface and of heat input from sediments which are relatively important in small, highly organic, water bodies (e.g. Greenbank 1945).

Oxygen declined until the water body became anerobic in February (Fig. 5). Anerobic conditions are common in ice-covered ponds with submerged vegetation (Nagel 1981) and in shallow water bodies where sediment decomposition is relatively important (Welch et al 1978).

In this case, anerobic conditions were delayed by the thin snow and white ice cover which resulted in relatively high light levels with prolonged photosynthesis and oxygen production. Oxygen losses from slushing (Jackson 1979) were slight and there were some gains following the penetration of the cover by rain. The slight flow through the wetland may also have assisted in reducing oxygen deficit. The absence of prominent temperature stratification for much of the winter allowed oxygen to diffuse throughout the water column.

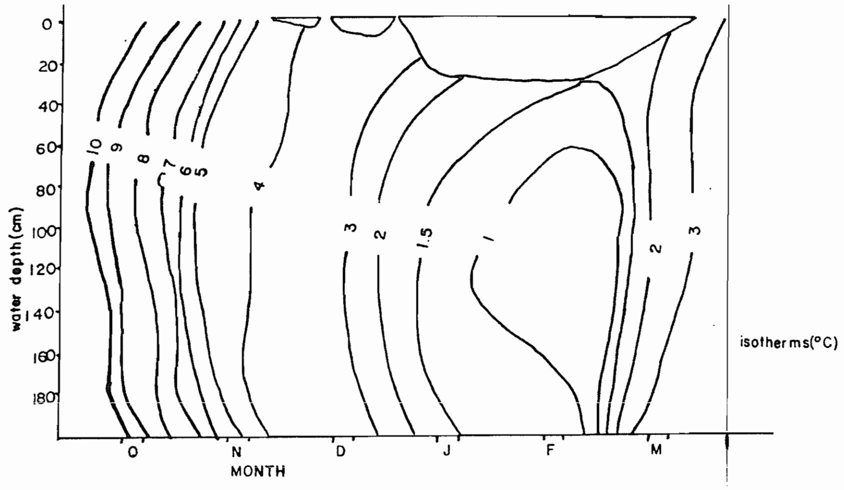

Fig. 4

Temperature regime

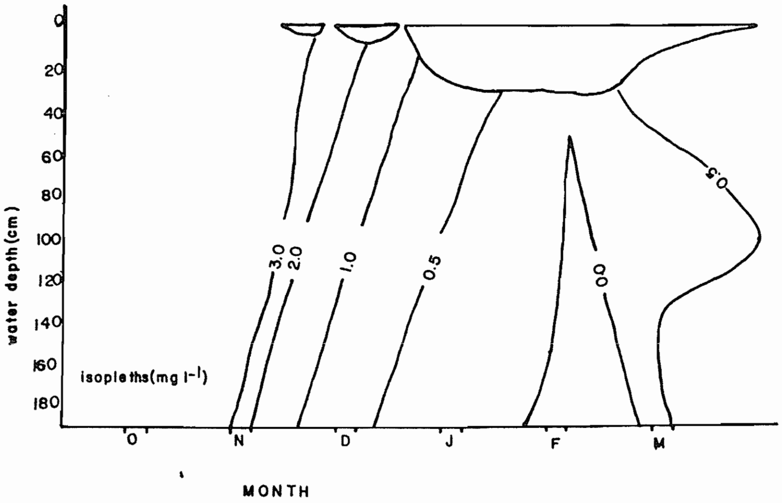

Fig. 5

Oxygen regime

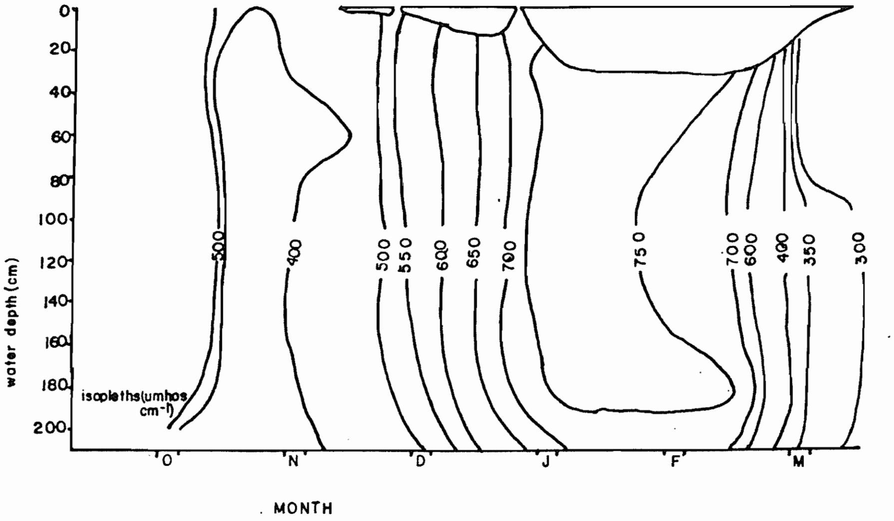

Fig. 6

Conductivity regime

The high conductivities (Fig. 6) were to be expected in such a small, relatively stagnant water body in which the surface area of sediments per unit volume is high. Conductivities increase under ice as a result of exsolution of gases and solids as water freezes (Adams and Lasenby 1982). Again, a shallow water body would be relatively greatly affected by this process. Once the water became anerobic, conductivity might be further increased by ions such as iron entering the water column from the sediments (Wetzel 1975).

In general, it would appear that the growth of ice on a water body of this type has more pronounced effects on water chemistry and other properties than is the case in a lake.

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