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WINTER TEMPERATURE STRUCTURE IN LAKE HURON*

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ABSTRACT. Water temperatures at depths 15, 25, and 50 m below the surface and 2 m above the bottom were continuously recorded at 17 mooring sites in Lake Huron during the 1974–75 winter. Monthly isotherm patterns show that the shore regions rapidly cooled to near 0° C by early February, while the deep northern basin reached a minimum of 1.5° C in mid-April. The initial stages of the fall overturn at depths greater than 100 m exhibited temperature fluctuations due to wind mixing and advection. By mid- to late December, Lake Huron was isothermal at all recording stations and remained so through April, except in the deep basins where a weak winter thermocline developed in March.

INTRODUCTION

The earliest comprehensive study of water temperatures in the Great Lakes was done by Millar (1952), who used data from ship intakes to construct monthly temperature charts for each of the lakes for the summer months and extrapolated data to construct charts for the winter months. Bolsenga (1976) and Ayers *et al.* (1956) obtained summer temperatures in Lake Huron from research vessel surveys. For a number of years, airborne radiation thermometer (ART) surveys have provided surface temperatures during all seasons (Richards and Irbe 1969). Six stations in Lake Huron and a number of sites in Lake Michigan were occupied during the winter season in the early sixties as part of the Great Lakes-Illinois River Basin Project (GLIRBP) (Noble and Michaelis 1968, Noble and Ewing 1968). Winter temperatures in Lake Ontario were obtained at nine moorings at depths of 15–16 m and 75 m and by ship surveys from December 1972 through March 1973 as part of the International Field Year for the Great Lakes (IFYGL) (Pickett 1977, Marmorino 1978).

The first continuous large-scale synoptic collection of winter temperatures in Lake Huron was obtained during the 1974–75 winter (Saylor and Miller 1976). The purpose of the study, a cooperative effort of the Great Lakes Environmental Research Laboratory, the Canada Centre for Inland Waters, and the Environmental Protection Agency, was to determine the character of winter current flow and thermal structure in Lake Huron. Twenty-one moorings were set in late November 1974 and 19 were recovered in spring 1975 (Figure 1). Temperatures were measured at 15 and 25 m below the water surface in the western third of the lake and at 15, 25, and 50 m below the water surface and 2 m above the bottom in the remainder of the lake.

MONTHLY MEAN TEMPERATURES

Monthly temperature patterns (shown in Figures 2–6) were constructed from available data at 15-, 25-, and 50-m depths. At all stations but three the water was isothermal from 15 m to the bottom after late December. The three stations placed in the deepest basins exhibited a weak winter thermocline in March. The loss of moorings 114 and 117, together with sensor and recorder malfunctions at several other moorings, caused gaps in the coverage, primarily in the eastern coastal region.

In December the lake temperature, except in Saginaw Bay and adjacent nearshore areas,

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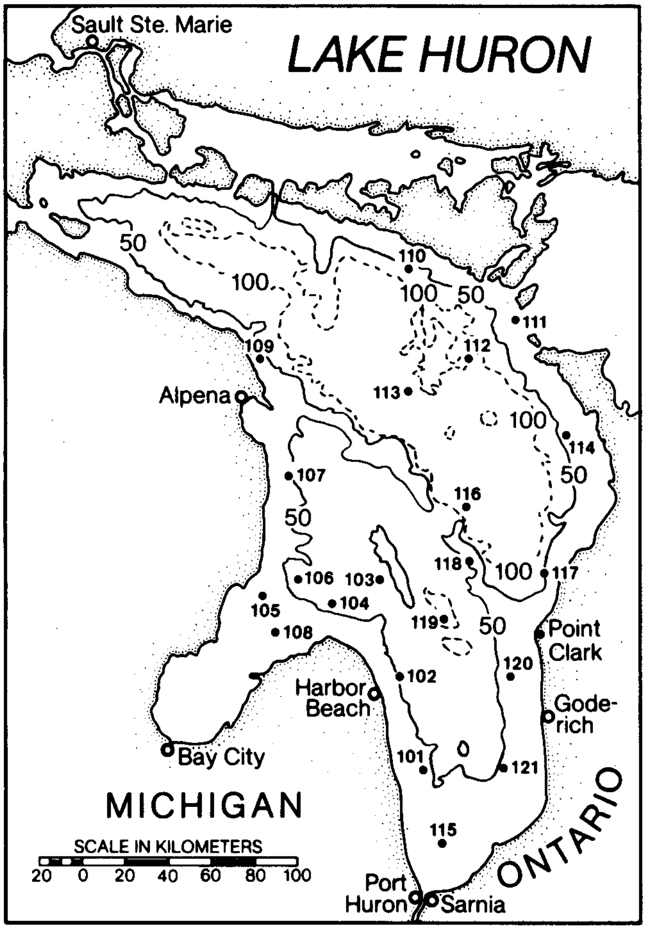

FIG. 1. Location of map showing meter mooring sites and Lake Huron bathymetry. Only the 50- and 100-m contours are shown as the bottom in the deep northeastern basin is very irregular, exceeding depths of 15 m in over 30% of its area.

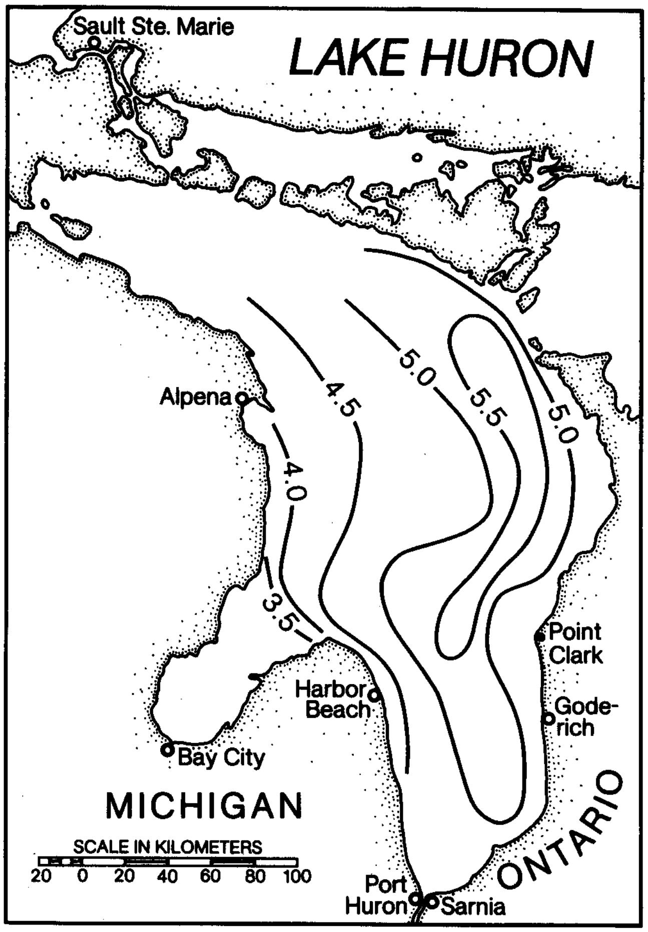

FIG. 2. Mean monthly water temperatures (° C) from available 15-, 25-, and 50-m data during December 1974.

averaged above 4° C (Figure 2). Continued cooling through January decreased the monthly mean temperature to less than 4° C, except in the deep northern basin. The coldest areas were along the western shore and Saginaw Bay (Figure 3). February had the largest horizontal temperature gradient (Figure 4); ice extended about 20 km offshore along the western and southern shores and a narrow ice band was present along the eastern shore, while the deep northern basin was still 3° C. In March, temperatures in the southern basin and nearshore regions remained near 0° C, while the northern basin cooled to about 2° C (Figure 5). In April, warming began in the shallow areas, and the northern basin cooled slightly from the previous month's temperature; hence, the horizontal gradients were very small (Figure 6). During May (not shown), only the moorings on the western third of the lake had not been retrieved. Nearshore heating accelerated, and several areas averaged above 4° C for the first 20 days of the month.

The average monthly 1974–75 winter lake temperatures at depths of 15 and 25 m and the surface temperatures given by Richards and Irbe (1969), presented in Table 1, differ by less the 1° C.

The horizontal variation in temperature generally coincided with the lake bathymetry. Nearshore areas and the shallower southern basin cooled more rapidly in the fall than the deep central region and warmed more rapidly in spring. The warm core surrounded by colder, less dense water can be viewed as being partly maintained by the strong wind-driven cyclonic circulation pattern observed throughout winter (Saylor and Miller 1979) because the mean cyclonic flows greatly exceed those associated with geostrophy. The central southern basin reached its minimum of 0.2° C by late February, whereas the north central basin did not reach

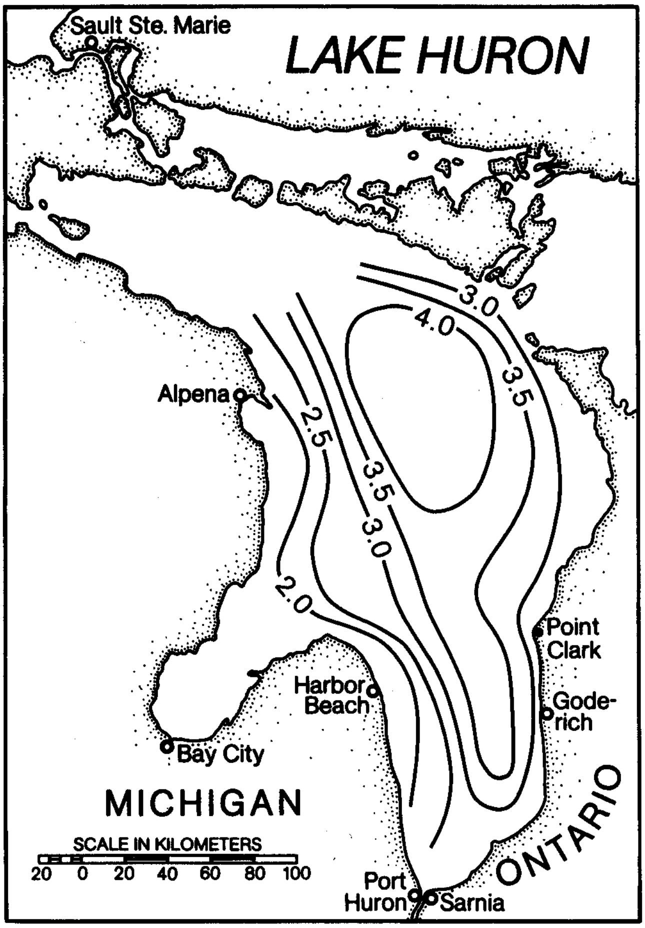

FIG. 3. Mean monthly water temperatures (° C) during January 1975.

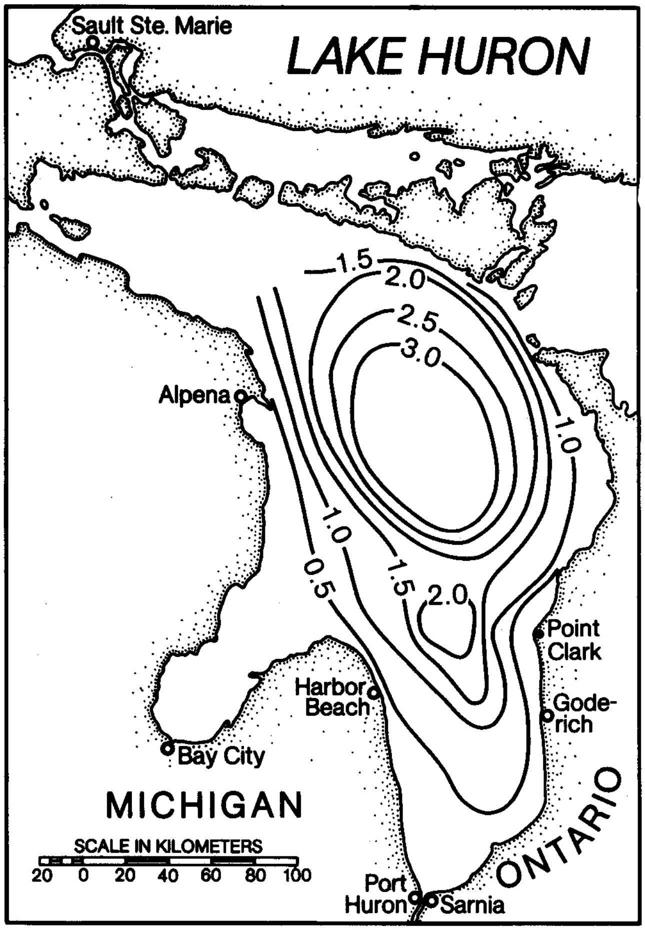

FIG. 4. Mean monthly water temperatures (° C) during February 1975.

its minimum of 1.5° C until early April. The cooling rates from the end of November to the time of the respective minimums were about 1.6° C per month in the southern basin and 1.0° C in the northern basin.

TEMPERATURE TIME SERIES

Temperature data for the deeper moorings show the characteristics of the transition from summer stratification to an isothermal water mass and the development of weak winter stratification. When the instruments were deployed in late November 1974, the southern basin was already isothermal at 7° C. Summer and fall data indicate 4° C water below 50 m (Ayers *et al.* 1956, Pinsak 1970) and 17–20° C water at the surface (Bolsenga 1976). The breakdown of the thermocline occurred prior to meter deployment. Therefore, the bottom water temperature increased by at least 3° C during November. Cooling throughout the water column continued, decreasing to 4° C by mid-January and to near 0° C by 6 April, while the shallow regions (< 50 m) cooled to near 0° C in February. The only observed winter stratification in the southern basin was less than a 1° C gradient between 50 and 94 m below the surface at mooring 119 during mid-March.

Temperatures from the deep northern basin indicated that the depth of the epilimnon was greater than 50 m in late November, with a 1.5–2.0° C gradient at greater depths. Destruction of the summer thermal stratification occurred in mid-December (Figure 7). Strong winds at the beginning of the month, as indicated by the wind speed squared from Bruce Ontario Hydro, accelerated the mixing and by mid-month the water column was isothermal at 4.8° C. At depths greater than 100 m, several warm pulses followed by a return to 4° C preceeded the thermocline disappearance. Noble (1966) observed similar fluctuations at 240 m below the surface in Lake Michigan in mid-

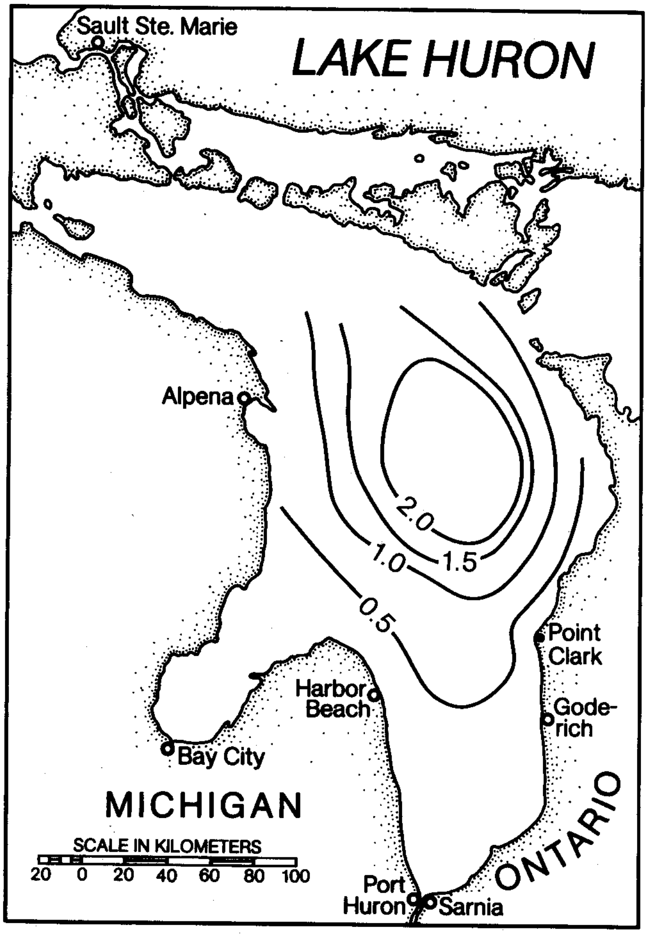

FIG. 5. Mean monthly water temperatures (° C) during March 1975.

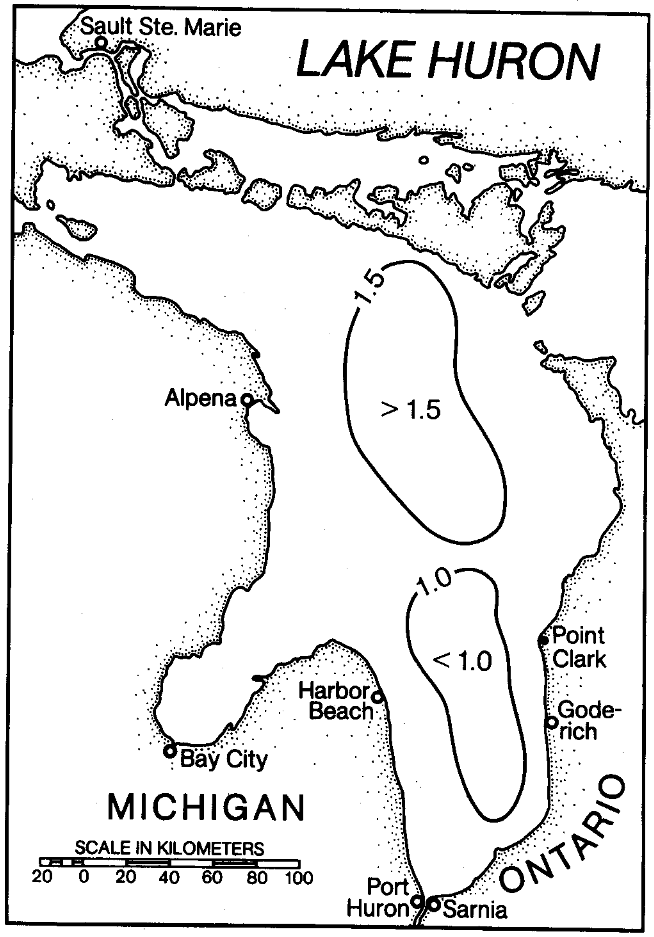

FIG. 6. Mean monthly water temperatures (° C) during April 1975.

TABLE 1. Lake Huron mean monthly water temperatures.

	1974–75		
Month	15 m	25 m	Richards and Irbe (1969)
December	4.6	4.9	5.6°C
January	2.6	2.9	3.3
February	0.8	1.0	1.7
March	0.5	0.6	0.6
April	1.2	1.1	1.1

December and Smith (1973) saw the same phenomenon in Lake Superior indicating that these fluctuations at depth are a regular feature of the fall overturn period in the northern Great Lakes.

A winter thermocline with a maximum temperature difference across it of about 1.5°C developed in the central part of the northern basin during the last 2 weeks in March (Figure 8); the temperature difference was generally less than 0.5°C during April. IFYGL temperature data also show winter stratification developing in Lake Ontario in late February and early March during a period with less than normal wind stress (Marmorino 1978). The occurrence, strength, and duration of winter stratification depend on wind stress and the amount of ice cover. The predominant isothermal character observed in Lake Huron during the 1974–75 winter resulted from near-constant wind stress and minimal ice cover. It may well be argued that since the shallowest thermistor was at a depth of 15 m, the winter stratification would not be observed. This is indeed the case during cold, calm weather. However, calm conditions are rarely observed over the Great Lakes during winter. Results from bathythermograph surveys in Lake Michigan during winter (FWPCA 1967) indicate that the water is, in fact, well mixed from top to bottom so that temperatures at a depth of 15 m are representative of near-surface temperatures. The absence of strati-

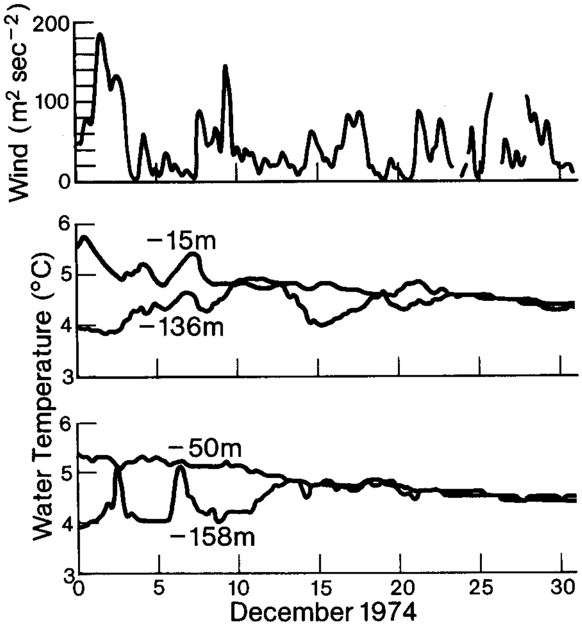

FIG. 7. Hourly wind-speed squared from Bruce Ontario Hydro and hourly water temperatures from depths of 50 m and 158 m at mooring 116 and 15 m and 136 m at mooring 113 during December 1974.

fication between 15 and 50 m during the entire winter was reflected in the nearly constant current speed observed in the upper 50 m throughout the season (Saylor and Miller 1979).

CONCLUSIONS

The 1974–75 winter temperature structure in Lake Huron exhibited monthly isotherms that in general followed the bathymetry of the lake. The shallow regions cooled rapidly, reaching near 0°C by February, while the deep northern area did not reach its minimum of 1.5°C until mid-April. This horizontal temperature gradient between the warm central area in the northern basin and the near 0°C nearshore temperatures is thought to be maintained by the dominant wind-driven cyclonic circulation in the lake (Saylor and Miller 1979).

At depths exceeding 100 m, fall overturn began with a series of warm pulses followed by a return to a stable temperature configuration. As cooling and mixing continued, the northern basin attained an isothermal state at a temperature of about 4.8°C, while the southern basin was isothermal at 7°C in late November at the time of sensor deployment. Hence, the warmest temperatures in the lower layers occur in November-December. The vertical homogeneity of Lake Huron implies that wind-driven mixing extends to the bottom throughout most of the winter, at least until weak winter stratification develops in the deep basins in March.

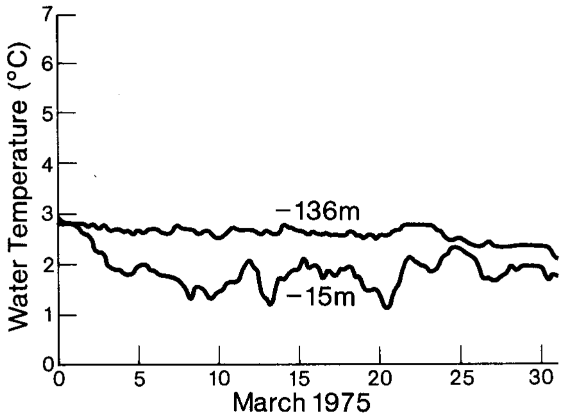

FIG. 8. Mooring 113 hourly water temperatures at 15 m and 136 m below the surface during March 1975.

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