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Studies of Ice Cover on Knob Lake, New Québec

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banlieue de résidence pour gens aisés. Enfin, les Montréalais perpétuent la fonction récréative de North-Hatley mais en la répartissant plus uniformément au cours de l'année.

Jean RAVENEAU

Studies of Ice Cover on Knob Lake,* New Québec

Systematic observations of lake ice cover in the vicinity of Schefferville, Québec, have been made by the staff of the McGill Sub-Arctic Research Laboratory since 1954. A brief examination of the results of this work and of the basic data from Knob Lake for the decade 1954-64 is of some interest, as the meteorology of the central part of the Labrador-Ungava Peninsula was virtually unknown until quite recently. A list of the sources of data from the

* Knob Lake (c. 50°48′N., 60°49′W., and 1,645′ above sea level) has a surface area of 21×10^6 ft.^{2} and a normal pre-melt volume of c. 380×10^6 ft.^{3} with a maximum depth of about 50 ft.

Table* 1. *Ice season data, Knob Lake 1954-55 to 1963-64

A	B	C	D	E	F	G	H
Year	*Number*	*Max. mean Total ice thickness*	*Max. mean White ice thickness*	*Max. mean Black ice thickness*	*Total Snowfall*	*Accumulated freezing degree days*	*Snow per degree day*
		Inches	*Inches*	*Inches*	*Inches*		*Inches*
1954-55	1	37.0	12.0	33.0	124.3	5089	.0244
1955-56	2	35.0	18.0	24.0	134.7	4676	.0284
1956-57	3	44.0	20.0	40.0	99.1	5859	.0169
1957-58	4	41.5	12.0	30.5	111.4	3949	.0282
1958-59	5	44.5	11.5	33.0	128.4	5710	.0224
1959-60	6	46.5	22.0	26.0	139.8	5057	.0276
1960-61	7	47.0	11.0	37.0	86.0	5311	.0162
1961-62	8	42.0	12.5	30.5	113.9	5210	.2190
1962-63	9	47.0	10.5	35.5	100.5	5436	.0185
1963-64	10	48.0	16.0	32.0	108.6	5542	.0196
Mean....................		43.5	15.0	32.0	114.7	5184	.0224
Max. earliest..............		48.0	25.0	40.0	139.8	5859	.0284
Min. latest...............		35.0	10.5	24.0	86.0	3949	.0162
Range....................		13.0	14.5	16.0	53.8	1910	.0122

Cols. C, D, E....highest weekly value of a winter, usually mean of three readings, to nearest half inch.
Col. F..........accumulated Nipher Snowgauge value (water equivalent X 10), July – July.
Col. G..........accumulated with reference to 1st July and 32 degrees F.
Col. H..........F divided by G.
Cols. I, J........anemometers at 33 ft. above ground.

survey and of the main published papers which have resulted from it is appended to this note.

Development of the Survey

The number and the quality of measurements made in the ice survey have increased over the years (Table 1, column P). During the period 1954-56 measurements were few and sporadic, but since then improvements in drilling equipment have allowed weekly measurements. Since 1957 weekly measurements have been made at three sites (East, West and Centre) on Knob Lake and, since 1959, at three sites on Maryjo Lake (Figure 1). During these years of more detailed measurement, it has been usual for the observer to make fre-frequent measurements for comparative purposes at other locations than the regular sites. During the winter of 1963-64, bi-weekly measurements were made at the six regular sites and, at the end of the winter, maps were drawn of the distribution over Knob Lake of the ice-snow cover components studied in the weekly survey : total ice thickness, thickness of black ice and of white ice, and depth of snow and hydrostatic water level in relation to the ice surface. These maps were based on measurements at some 300 drill holes scattered over the lake. At various times since 1954, measurements have been made on a

I	J	K	L	M	N	O	P
Mean wind speed	*Days with gush over 18 mph*	*Date of Freeze-up*	*Date of Break-up*	*Length of ice Season*	*Length of fr. up Season*	*Length of br. up Season*	*Number of Drillings*
mph				*days*	*days*	*days*	
10.2	85		1 June			12	20
11.0	77		15 June			10	9
8.7	70	11 Nov.	20 June	221	18	9	10
11.1	97	3 Nov.	12 June	232	12	19	84
12.7	127	7 Oct.	28 May	233	4	14	70
10.3	75	29 Oct.	1 June	215	6	15	66
10.9	87	3 Nov.	11 June	220	9	16	87
11.7	97	7 Nov.	13 June	218	16	12	87
12.6	120	31 Oct.	18 June	230	5	25	128
12.2	127	2 Nov.	12 June	222	4	32	210
11.0	96	31 Oct.	10 June	224	9	16	78
12.7	127	7 Oct.	28 May	233	18	32	210
8.7	70	11 Nov.	20 June	215	4	9	9
4.0	57	36 days	23 days	18	14	23	201

Col. K..........« freeze-up » means the final, complete, ice cover of a winter.
Col. L...........« break-up » means lake completely ice-free.
Col. M..........L minus K.
Cols. N and O....periods of partial or temporary ice cover preceding freeze-up and break-up.
Col. P...........holes drilled in the course of the routine (weekly) survey only.

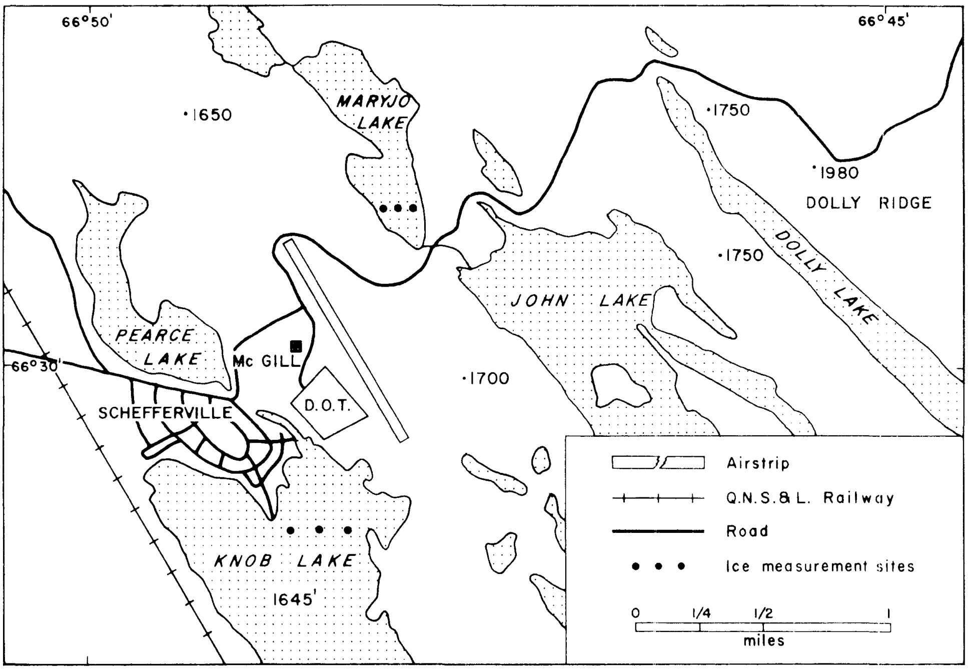


Figure 1 Schefferville area.

From 1:50,000 map sheet no. 23J/15 west Knob Lake

wide range of lakes both close to Schefferville and further afield over the Peninsula.

The basic weekly results are submitted to the Department of Transport as a contribution to its Ice Reconnaissance and they are published in the official compilations. The first detailed publication on the Schefferville work was that of Jones (1958). It included information on lakes in various parts of the Peninsula. Andrews was in charge of the survey in 1959-60, and he analysed data for the period 1957-60 in his papers (Andrews and McCloughan, 1961 ; Andrews, 1962, 1963). He was interested in the growth of the whole ice sheet and in the phenomenon of white ice, especially as a complication in the prediction of ice thickness from meteorological data. His emphasis on the variation in quality and quantity of ice between lakes in the same area and between parts of the same lake stimulated later observers to make check measurements at random locations on both Maryjo and Knob Lakes. Shaw (1963, 1965) and others followed up Andrews' work on white ice. Shaw played an important role in the mapping of the ice-snow cover of Knob Lake in 1964. His observation confirmed Andrew's views on variations within a lake cover. The maps provided important information on the magnitude of such variations at winter's end and gave some perspective to results from the weekly survey sites (Adams and Shaw, 1964).

In recent years efforts have been made to study the initiation and development of the ice cover of Knob Lake in relation to variations in water temperatures. Shaw (1965) measured pre-freeze-up lake temperatures and Mattox (1964) initiated a programme of temperature measurement from a thermocouple profile located in the deepest part of the lake. This work was continued by Barr (1964). These studies and the bathymetric map of Bryan (1964) were important preliminaries to a study of ice cover and the heat budget of Knob Lake.

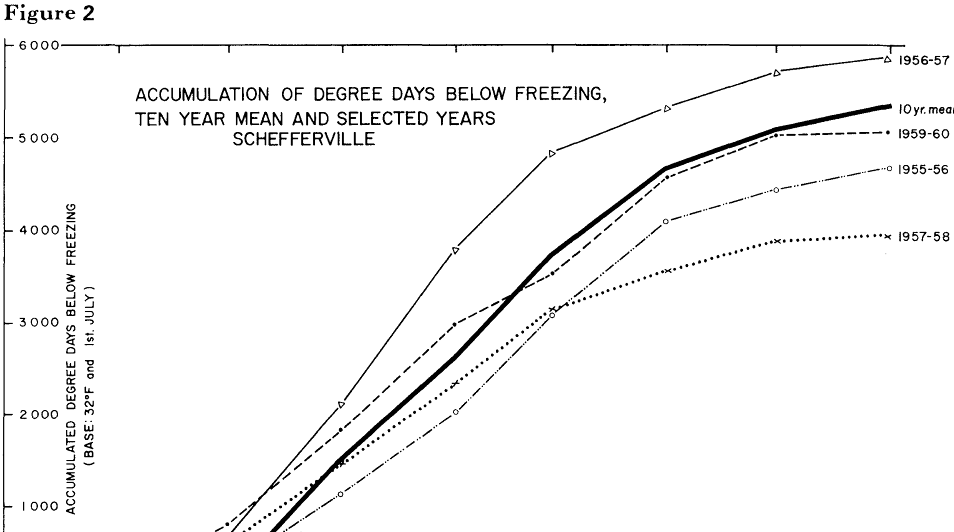
Unusually detailed observations of the ice cover of Knob Lake, with comparative data from nearby lakes, are therefore available for the period 1954-64.

Variations in the Ice Cover of Knob Lake, 1954-55 to 1963-64

Maximum ice thicknesses for each winter, 1954 through 1964, are presented in Table 1, with selected meteorological parameters and pertinent information about each ice season. All meteorological date derive from the Department of Transport (McGill) station at Schefferville, which is located a quarter of a mile north of the lake and some forty feet above it (Figure 1). *Characteristics of selected winters with regard to air temperature and snowfall* — important factors in the development of lake ice — are illustrated by the plots of accumulated degree days below freezing and of accumulated snowfall, in Figures 2 and 3. The wind data in Table 1 (columns I and J) are included as indices of the effectiveness of the snowfall as lake snowcover. Meteorological and ice data presented are too few and too coarse for detailed analysis. However, they demonstrate the overall pattern of lake ice growth in the Schefferville area. Some interesting trends can be seen from an examination of the mean and extreme ice values in relation to the broad effects of temperature, snow and wind.

The greatest total ice thickness (see Figure 4) was achieved in 1963-64, which had an above average accumulation of freezing degree days, a below average snowfall, and above average wind values. By contrast, the ice cover was thinnest in 1955-56, which had the second lowest accumulation of degree days, the second highest snowfall, and average wind values. Significantly, snowfall was relatively high during the coldest months of the latter year (Figures 2 and 3).

Figure 2

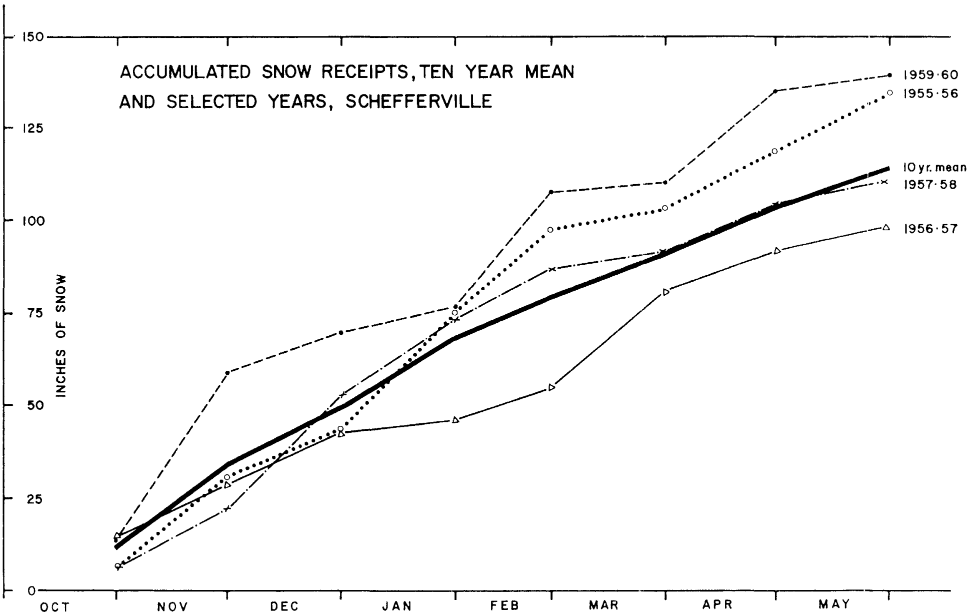


Black ice, which results from the normal freezing of surface water in a lake, was thickest in 1956-57, which had the highest accumulation of degree days below freezing and the second lowest snowfall of the decade, with below average wind speeds and gusting. The winter with least black ice was 1955-56. This was the winter with minimum total ice thickness ; the winter was warm, and there was a good snow cover. A combination of cold and a thin snow cover is clearly favourable to the growth of black ice. The winter of 1956-57 had the second lowest and the highest amounts of snow per freezing degree day respectively (Table 1, column G).

The difference between total ice thickness and black ice thickness is white ice (see Figures 5 and 6), which forms on the surface of the black ice, mainly as a result of flooding. A thick snowcover is the ice sheet and thus favours flooding ; it also retards the normal growth of the ice by insulating it, and less snow is necessary to depress a thin ice cover below the hydrostatic water level. The relation between snowfall and white ice growth is illustrated by events on Knob Lake in 1959-60, the winter which maximum white ice was recorded. There was a slightly below average accumulation of degree days in combination with the highest snowfall of the decade. Also, there was an abnormally high snowfall in the early winter, while the black ice cover was still thin (Figures 3 and 6). Minimum white ice was measured in 1962-63, which had an above average accumulation of degree days and below average snowfall with high gusting winds. Westlake (1964, p. 48) noted that parts of the ice sheet were bare throughout the winter. This combination of degree days and snowfall favours black ice but is not favourable to white ice.

The magnitude of annual variations in the ice cover of Knob Lake has a practical significance for aircraft in the Schefferville area. The maximum total ice thickness measured varied from 35 to 48 inches with a mean of 43 inches. The proportion of white ice present at peak ice development varied from 13% to 57%. Maximum white ice varied from 10.5 to 25 inches (mean 15) and

Figure 3



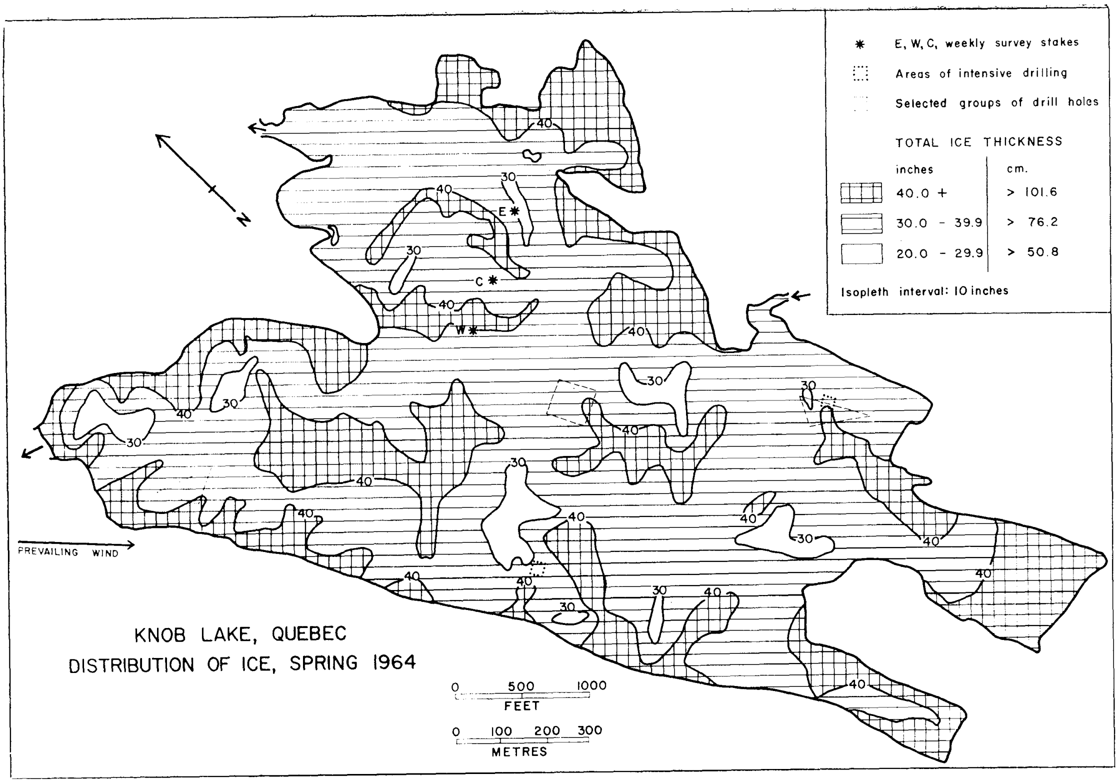
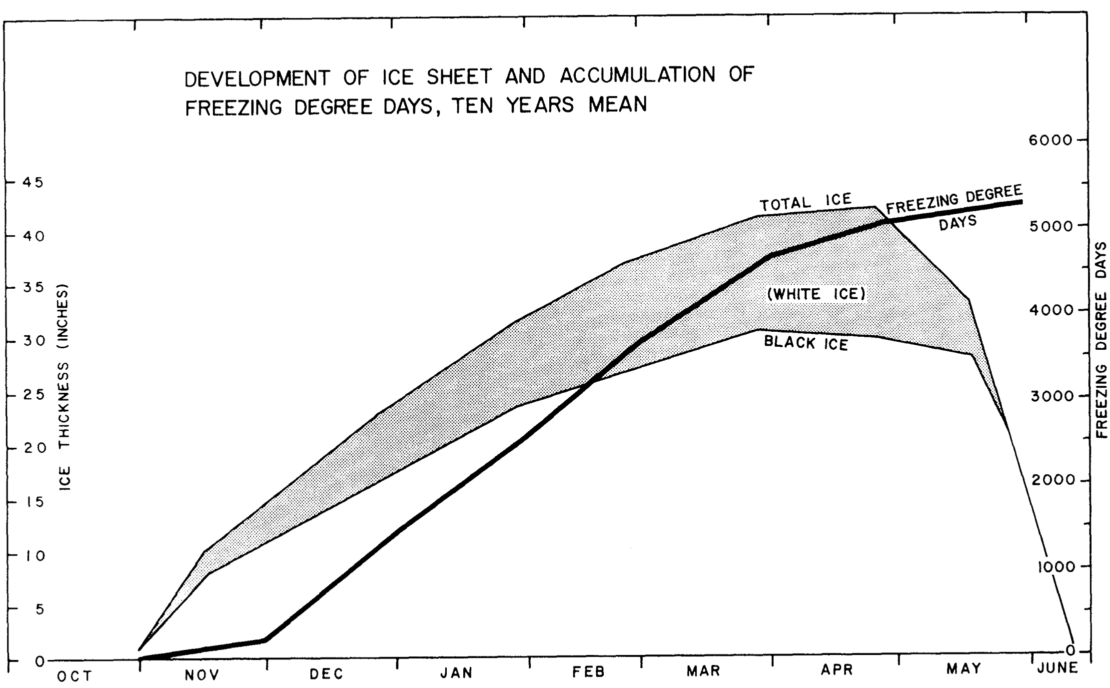


Figure 4

Figure 5



black ice from 24 to 40 inches (mean 32). The relatively larger variations in the white and black components of the ice cover tend to be compensatory. Normally the proportion of white ice in the total ice profile decreases during the mid-winter period of maximum ice growth.

Except for the first there years of the survey, the values discussed above have been means of three measurements at the regular survey locations. Extreme individual values, particularly of white ice, are common and account for differences between the sum of white and black ice values and total ice values in Table 1 (columns D, E, and C). It is felt that the rather limited data available for the early years of the survey do not seriously alter the general pattern of annual difference which has been described. However, it is now clear that the very considerable differences between various parts of the ice cover at any one time, which were postulated by Andrews (1962, p. 339f), do exist The variation in total ice thickness at the end of the 1963-64 winter is shown in Figure 4. The variation in white and black ice was relatively greater (Adams and Shaw, 1964). The extreme range of total ice values measured during the period of the mapping survey was 28 inches. White ice varied from 1 to 24 inches and blakc ice from 13 to 43 inches. The values provided by the weekly sites for the period of the mapping were not exceptional when compared to the lake as a whole, but the amount of white ice was relatively high, suggesting that weekly drilling may have the effect of stimulating white ice growth.

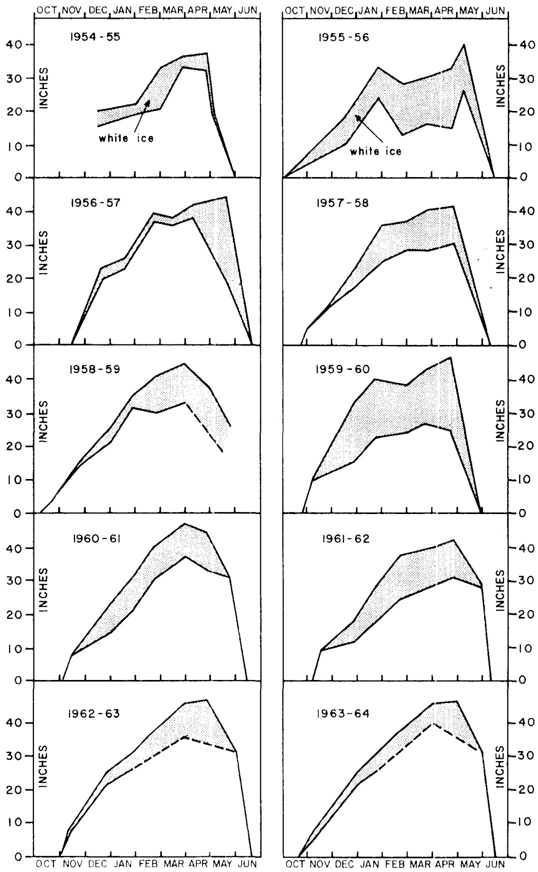


Figure 6 Annual growth of Knob Lake ice cover 1954-55 to 1963-64.

The Annual Pattern of Ice Development

Freeze-up varied from 7th October to 11th November with a mean date of 31st October on Knob Lake during the decade. The average accumulation of degree days below freezing on the freeze-up was 140. On the average, freeze-up was preceded by a period of nine days of partial ice cover, including periods of temporary complete ice cover. The usual pattern of growth which follows freeze-up is a steady increase in black ice thickness, broken by occasional relatively sudden increments of white ice (Figure 6). The nature of white ice formation is described in detail by Shaw (1965). White ice reaches a maximum in the later parts of the winter, February (2 years), March (3 years), April (4 years) or May (1 year). The irregular variations in white ice which appear in

Figure 6 for some of the early years of the survey certainly reflect measurements at random locations rather than at regular survey sites. Increments of white ice can be very local so that there can be considerable variations in its thickness over a lake.

At the end of the winter, the ice sheet first thins as a result of loss of white ice. The white ice begins to disintegrate as soon as the snowcover decreases. In four out of the ten years considered there was no white ice present on the date of the last possible survey. Break-up has been as early as 28th May and as late as 20th June, with a mean date of 10th June (Table 1, column L). Data on the lenght of the end-of-season broken period are perhaps the least reliable of those presented, but the mean of 16 days (Table 1, column O) is a reasonable indication of average conditions.

The length of ice season (Table 1, column M) only varied 18 days, from 215 to 233 days, during the decade. This is a reflection of the relatively small variations in freezing degree totals and snowfall during the period.

Concluding Remarks

The first decade of ice survey on Knob Lake has produced an unusually detailed record of ice cover. It is clear, however, that if the survey is to develop, further efforts have to be made to place the weekly survey measurements in perspective with regard to the whole ice sheet. In an area where white ice is always an important part of the ice cover, any measuring site is likely to provide atypical results for some periods during a winter so that overall growth of the ice sheet can only be followed from many widely spread measurements. Also, in an area where the ice is subject to periodic flooding, the value of measuring ice thickness by drilling should be assessed carefully.

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Availability of ice survey data and reports from the Schefferville area, New Québec, 1954-64. (Notes and basic data for all years on file at the McGill Sub-Arctic Research Laboratory, Schefferville.)

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Fentes de gel fossiles, dans le comté de l'Islet

De nombreuses fentes de gel et diverses formes de cryoturbation fossiles ont été rapportées pour la première fois au Québec, il y a un an (DIONNE, J.-C. 1965, 1966). Ces formes avaient été observées dans la région appalachienne à l'est de Rivière-du-Loup, dans un secteur compris entre les latitudes nord 48°50′ et 47°26′. À l'automne 1966, de nouvelles fentes ont été découvertes dans le comté de l'Islet, à quelques 80 km de Québec, dans un secteur légèrement plus méridional que le précédent, c'est-à-dire entre 47°16′ et 47° de latitude nord.