THE LIMNOLOGY AND FISHERIES

OF PRINCE ALBERT NATIONAL PARK,

SASKATCHEWAN

D. W. Mayhood

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ABSTRACT

The limnology and fisheries of Prince Albert National Park, Saskatchewan, have been summarized from a review of the published and unpublished literature.

The limnological resources of the park consist of 3 large lakes, about 15 intermediate-sized lakes, at least 1500 small lakes and ponds, an unknown number of temporary ponds and pools, and hundreds of miles of permanent and intermittent streams. Water covers, at a conservative estimate, more than 20% of the total area of the park.

The second-largest lake, Waskesiu, is by far the best known. It has two basins with distinctly different physical and biological features; the upper portion being long, narrow and shallow, with slightly warmer summer temperatures and perhaps a slightly greater productivity than the lower lake, which is roundish-lobate, relatively deep and somewhat cooler in the summer than the upper lake. The thermal and dissolved oxygen regimes, along with its high standing crops of plankton and bottom fauna and its high commercial fish yield all mark it as eutrophic.

The physical limnology of several of the other large and intermediate-sized lakes have been characterized in a general way, but there is virtually no biological information available on them. Kingsmere is a large, deep, cold, oligotrophic lake; Crean is a large, moderately deep, probably moderately eutrophic lake; while Namekus is an intermediate-sized, probably eutrophic lake. Halkett is an intermediate, mainly shallow, marl lake with a restricted area of very deep water.

The basic limnological features of the many small lakes and ponds in the southern portion of the park have been inferred from data available

on a group of small lakes taken to be representative of that region. Most are shallow and polymictic, but a small number are relatively deep and exhibit strong thermal stratification with a hypolimnetic oxygen deficiency in summer. These small southern lakes range from brown-water, dilute forest bog ponds to saline parkland lakes, the former being frequent in the Waskesiu Hills and the latter common in two regions of the southern and southwestern portions of the park. The biological communities of these small lakes differ in composition from those in the larger lakes.

Many aspects of the limnology of the park are poorly known. The lakes in the northern half of the park have not been studied, nor have any of the streams or temporary waters of any part of the park. Knowledge of the aquatic biology of the region is restricted for the most part to records of the occurrence of various species, with the exception of a few fish species for which the life histories, or parts thereof, have been worked out. Excluding Waskesiu Lake, the seasonal sequence of change in various physical, chemical and biological features of park waters is largely unknown.

Certain fishery management projects appear to have been successful, or have shown some evidence of initial success. The closure of much of Waskesiu Lake to fishing in the years 1936 to 1939 apparently resulted in improved angling for pike by 1942, and in higher numbers of both pike and walleye in gill net catches of that year in comparison to the years prior to closure. There is also some circumstantial evidence indicating that the walleye stocking program and the manipulation of Mud Creek have been successful in contributing to the walleye and pike populations, respectively, of Waskesiu Lake. Plantings of lake trout and cisco in Halkett Lake also have shown initial success.

Other fishery management programs have failed or have not been evaluated. Attempts to establish smallmouth bass in several lakes were ultimately unsuccessful because low water temperatures in the spring precluded sustained natural reproduction. Similarly, brook trout stocked in Halkett Lake failed to become established. The effectiveness of the commercial fishery as a control on the whitefish population of Waskesiu Lake was never assessed; nor has the effect of sucker removal from the Kingsmere River on the populations of Waskesiu Lake suckers and walleye been examined. Attempts to rehabilitate the Crean Lake lake trout fishery have been unsuccessful so far; however, the most recent activities could not be expected to have any effect for a number of years.

Potential problems in the preservation and management of several lakes have been pointed out. The drainage basins of at least two lakes (Wabeno and Namekus) are being developed in areas beyond the jurisdiction of the park, and are subject to modification as a result of these activities. Halkett Lake appears to be slowly drying up, and there is a possibility that this is a result of man-induced changes in drainage to the lake. It is also suggested that sliding and erosion of the shorelines of both Waskesiu and Crean Lakes is a result of artificial manipulation of the levels of those waters.

The significance of the findings to the interpretation and management of the park has been discussed, and detailed recommendations for further studies of park limnology, together with estimates of the time and money required for their completion have been presented.

ACKNOWLEDGEMENTS

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INTRODUCTION

Prince Albert National Park is a land of lakes: nearly 1200 ponds and lakes have been enumerated in the southern half of the park alone, and it seems likely that the total will reach 1500 to 2000 when accurate maps of the northern portion become available (Mayhood et al. MS 1973). In addition, there are hundreds of miles of permanent and intermittent streams, and uncounted numbers of temporary ponds and pools. Assuming that, in addition to the three large lakes there are 1500 lakes averaging 40.5 ha (100 acres) in area[1], more than 20% of the area of the park is water. Clearly, on the basis of numbers, extent, and variety, the lakes and streams of Prince Albert Park are important features of its landscape.

The lakes of the park all occupy basins in glacial drift, and are a legacy of the Wisconsinan glaciers that receded from this area 11,000 to 11,900 years ago (Prest 1970). Many of the smaller lakes have formed in kettles of various kinds (types 35 to 38 of Hutchinson 1957), or occupy "chance" variations in ground moraine (type 34 of Hutchinson 1957). Others, particularly the larger lakes, probably occupy basins of complex origin. Most of the larger lakes are found in the northern half of the park, while the great majority of the lakes in the south are small.

Park waters lie in either of two of western Canada's major watersheds: the Churchill to the north or the Saskatchewan to the south. Both are part of the larger Hudson Bay watershed. The major drainage basins within the park are illustrated in Figure 1, and their areas are presented in Table 1. Sixty-three percent of the park area lies in the Churchill

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1. based on the mean area of 27 lakes and ponds classified as "small" by Mayhood et al. (MS 1973). Both the estimate of the total number of lakes and their mean area are conservative.

watershed while the remaining thirty-seven percent drains to the Saskatchewan River.

The history of limnological and fisheries investigations in Prince Albert National Park began in 1928. Dr. D. S. Rawson of the University of Saskatchewan was engaged to undertake a limnological survey of the lakes to assess their potential to support sport fisheries, and to make recommendations for their management. This work was summarized in several reports and publications (Rawson MS 1929a and b, 1932, MS 1936, 1938, 1940, MS 1942, 1945). Much of the data collected during this applied research Rawson used in his broader limnological investigations (Rawson 1936, 1939, 1941, 1947, 1951, 1953, 1955, 1958a and b, 1960, 1961; Rawson and Moore 1944). Other biologists have studied Rawson's collections and have published the results of their examinations of park material (Walker 1940, 1953; Kuehne 1941; Brooks 1957; Oliver 1958), while some of Rawson's students conducted their own investigations of the biology of park waters (Campbell MS 1935; Milne MS 1941, 1943; Stevenson MS 1942).

Since the time of Rawson, the Canadian Wildlife Service has conducted limnological and fisheries investigations in Prince Albert National Park. Most of the studies have been directed toward fisheries management (Solman MS 1948, MS 1949, 1950a and b, 1951; Gilmour MS 1950a and b; Cuerrier MS 1950, MS 1951, 1952; Cuerrier and Ward 1951, 1952, 1953; Schultz MS 1954, 1955, 1956; Foskett MS 1961a and b, MS 1962; Hoskins MS 1964; Kilistoff MS 1964; Kooyman MS 1970b, 1971, unreported data; Saunders MS 1972; Hare and Kooyman MS 1973), but there have been some surveys on lakes in the southern portion of the park (Mayhood et al. MS 1971, MS 1973; Mayhood and Kooyman unreported data 1971). Independent studies have been conducted at various times (Rempel 1936, 1950, 1953; Hammer MS 1962, 1964, 1965; Brooks and Kelton 1967; Conroy MS 1968; Kooyman MS 1970a; McLeod MS 1971), and most recently, fishery management projects have been undertaken by the Warden Service of Prince Albert Park (eg; Corrigal MS 1973).

The long history of aquatic research outlined above has resulted in a considerable body of information on the limnology and fisheries of Prince Albert Park that has never been reviewed in detail. Two earlier attempts at synthesis (Andres and Corrigal, no date; Anonymous, no date) are only typed notes on information in National Parks files and were clearly never intended as complete reviews of all published and unpublished data.

The present report summarizes the physical and chemical limnology, aquatic biology and fisheries management of Prince Albert National Park from an examination of the published and unpublished literature on each subject area. The adequacy of the data from a technical point of view is discussed at the end of each section, a discussion of the relevance of the data to the interpretation and management of the park being reserved until the end of the report after all subject areas have been reviewed. Finally, recommendations are made for further work, priorities are assigned, and detailed time and cost estimates for each project are presented in a final section of the report.

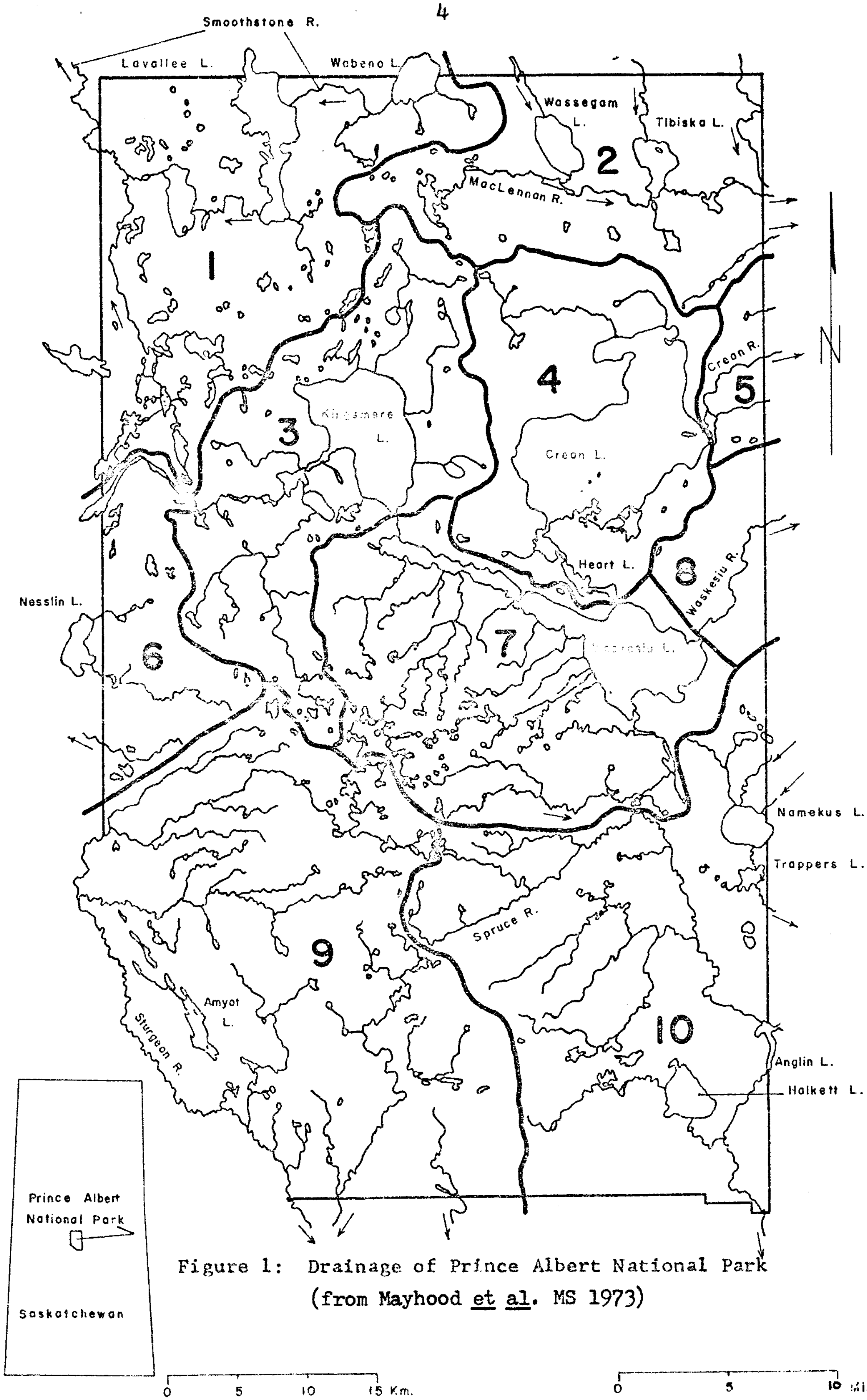


Figure 1: Drainage of Prince Albert National Park (from Mayhood et al. MS 1973)

Table 1: Major drainage basins of Prince Albert National Park

Drainage basin no.	Drainage basin name	Area within park mi^2	Area within park km^2	% total park area	Major watershed
1	Smoothstone	194	502	13	Churchill
2	MacLennan	121	313	8	Churchill
3	Kingsmere	170	440	11	Churchill
4	Crean Lake	147	381	10	Churchill
5	Crean River	20	52	1	Churchill
6	Delaronde	64	166	4	Churchill
7	Waskesiu Lake	192	497	13	Churchill
8	Waskesiu River	33	85	2	Churchill
9	Sturgeon	301	780	20	Saskatchewan
10	Spruce	255	660	18	Saskatchewan

Area of Churchill watershed in park: 2437 km^2 (941 mi^2) -- 63% of park area

Area of Saskatchewan watershed in park: 1440 km^2 (556 mi^2) -- 37% of park area

from Mayhood et al. (MS 1973).

PHYSICAL LIMNOLOGY

Morphometry and Drainage

The basic morphometric characteristics of the major park lakes have been described by Rawson (1936), and are summarized in Tables 2 and 3. The following discussion is based primarily on these data.

Crean Lake, with an area of 104 km^2 (40 mi^2), is the largest lake in the park. Although it has an extensive littoral zone (0 to 5m[1]; 32.6% of of the total area), much of it is quite deep, one-quarter exceeding 20m (66 ft). Its greatest depth is found in a small depression in the south basin (Figure 2). The large size and rounded shape of the lake leaves it exposed to the action of winds. Some of the islands and steep parts of the shoreline show evidence of recent sliding and erosion.

Crean receives water from Waskesiu via the Heart Lakes and a man-made channel, but its natural drainage area is rather small -- less than 3 times the area of the lake alone (Table 1). The lake drains via the Crean and MacLennan Rivers to Montreal Lake east of the park, but a dam built in 1958 (Corrigal MS 1973) presently obstructs the outlet, maintaining the lake somewhat higher than its natural level.

Waskesiu is the second largest of the lakes in the park. It can be considered as two lakes which are almost completely separated by the Narrows. The upper lake is long, narrow and shallow, with many points and small bays protecting it from strong wind action except from along its long north-west, south-east axis. The lower lake is relatively deep and broadly open to the action of the wind (Figures 3 and 4). There is some evidence of recent

1. as defined by Rawson (1936)

Table 2: Morphometric features of some of the major lakes in Prince Albert National Park[1]

Lake	Area km^2	Area mi^2	Length (Approx.) km	Length (Approx.) mi	Width (Approx.) km	Width (Approx.) mi	Depth (m) max.	Depth (m) mean	Volume (m^3 X 10^6)	Shoreline development
Crean	104	40	14.0	9.0	7.2	4.5	27	11.8	1220	2.2
Upper Waskesiu	11.1	4.3	10.4	6.5	1.1	0.7	15.0	7.8	84.0	2.4
Lower Waskesiu	59.0	22.7	14.7	9.2	7.3	4.5	24.0	11.8	686.0	1.7
Waskesiu (total)	70	27	26.0	16.0	4.8	3.0	24	11.1	770	2.6
Kingsmere	47	18	10.0	6.0	4.8	3.0	47	21.2	990	1.3
Namekus	7.3	2.8	3.5	2.2	2.4	1.5	27	11.9	83	1.1
Halkett	10.1	3.9	4.8	3.0	2.7	1.7	52[2]	10.6	157	1.7

1. from Rawson (1936)
2. Kooyman (1971) reports a maximum depth of 180 ft (54.9 m)

Table 3: Relative areas of depth zones (A) and relative volumes of strata (B) as percentages of total area and volume for some major park lakes [1]

Depth (m)	Crean A	Crean B	Waskesiu A	Waskesiu B	Kingsmere A	Kingsmere B	Halkett A	Halkett B
	Percentages							
0-5	32.6	36	19.1	41	16.9	22	49.4	37
5-10	17.0	25	23.4	31	11.0	19	13.9	21
10-15	17.0	17	30.7	19	9.0	16	13.1	15
15-20	10.3	13	19.3	8	7.4	14	7.3	9
20-25	10.2	8	7.5	1	14.5	12	4.3	7
25-30	12.9	1			11.1	9	3.8	5
30-35					18.1	5	3.1	3
35-40					7.9	2	2.6	2
40-45					3.6	1	0.9	1
45-50					0.5	0	1.1	0
50-55							0.1	0

1. from Rawson (1936)

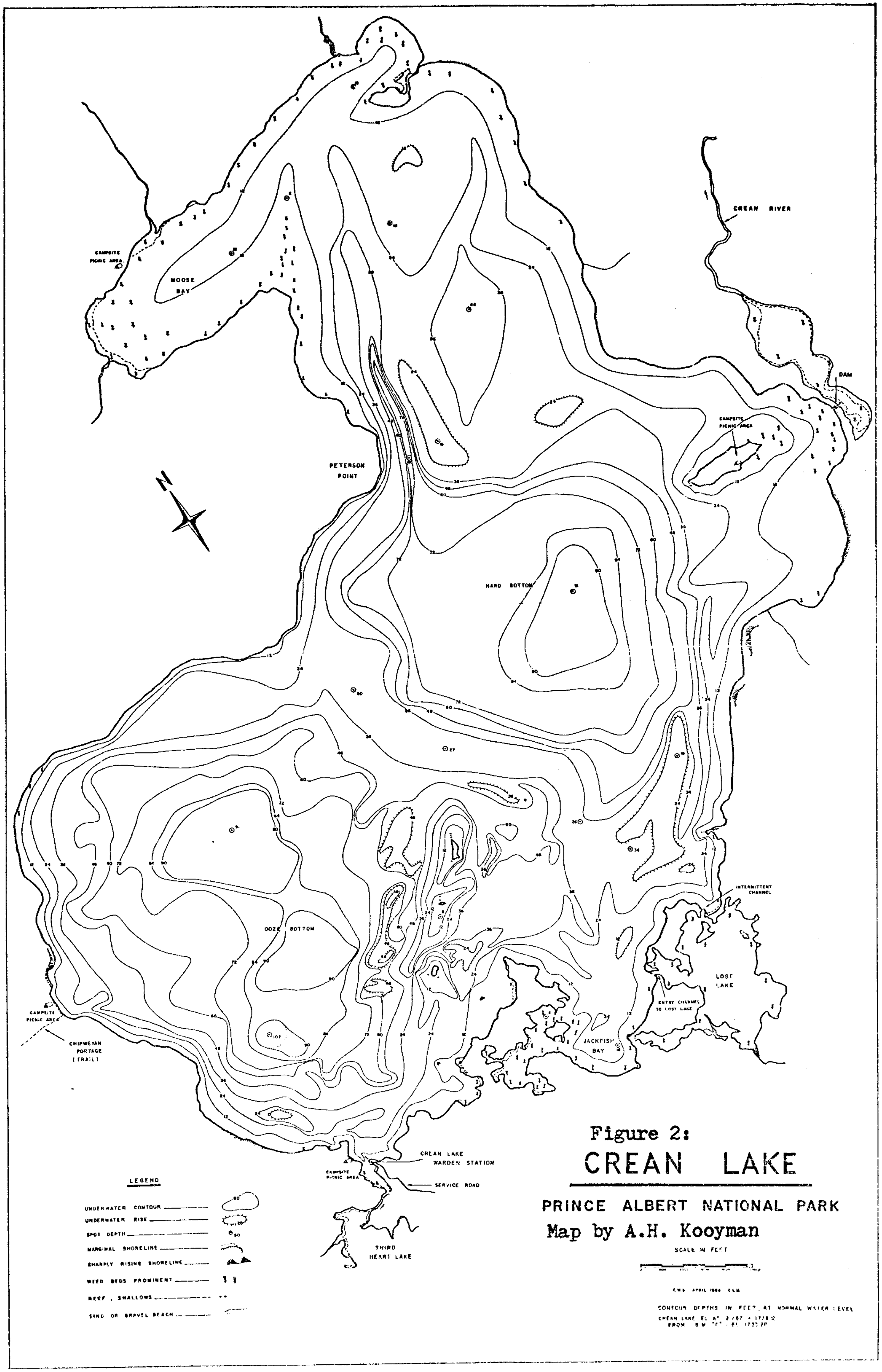


Figure 2:
CREAN LAKE
PRINCE ALBERT NATIONAL PARK
Map by A.H. Kooyman

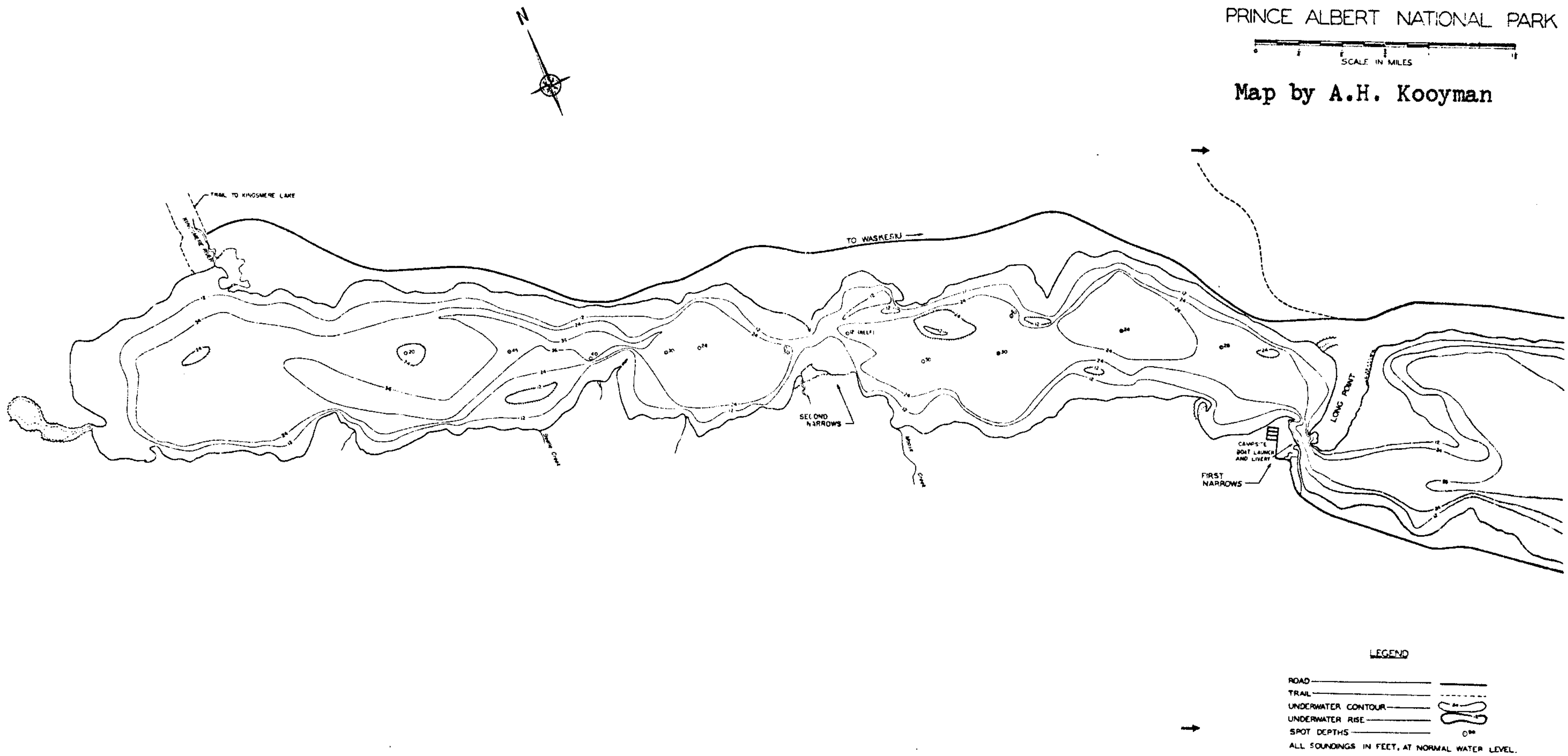
Figure 3:
WASKESIU LAKE
PRINCE ALBERT NATIONAL PARK

Map by A.H. Kooyman

Figure 4:
WASKESIU LAKE

PRINCE ALBERT NATIONAL PARK

Map by A.H. Kooyman



sliding of the steep shore at Prospect Point.

Waskesiu receives water from the largest drainage area of any major lake in the park: 868 km^2 (335 mi^2), or twelve times the area of the lake alone. Its inlet drainage was modified in 1915 by diversion of Beartrap Creek water into the Spruce River, but was restored to its normal state in 1938 (Rogers MS 1941b). A dam on the Kingsmere River, however, still obstructs drainage from Kingsmere Lake into Waskesiu. The outflow of Waskesiu is presently obstructed by a dam placed on the Waskesiu River in 1939 in an attempt to maintain higher water levels in the lake (Rogers MS 1941b). A second outlet has subsequently been dug from Birch Bay to First Heart Lake to supplement Crean Lake water levels. This channel in recent years (1967 to 1972) has been opened in early May, but has become plugged with sand again by mid-June.

The third largest lake in the park is Kingsmere, with an area of 47 km^2 (18 mi^2). It is also one of the deepest: the maximum depth is 47 m (154 ft), and more than one-half of the lake is over 20 m (66 ft) deep. It has a very regular shoreline, with little protection from the wind.

The drainage area of Kingsmere is reasonably large: 394 km^2 (152 mi^2), or more than 8 times the area of the lake alone (Table 1). As mentioned above in connection with Waskesiu Lake, the outlet, the Kingsmere River, is obstructed by a dam.

Namekus is a lake of intermediate size, having an area of 7.7 km^2 (3.0 mi^2)(Mayhood et al. MS 1973), a maximum depth of 27 m (89 ft), and a mean depth of 11.9 m (39 ft). Its low shoreline development index (1.1) reflects its nearly circular shape and very regular shoreline. Long sand beaches form both the west and south-east shores.

Namekus, like certain other park lakes, receives some of its water from outside the park. It drains southward to Trappers Lake via a markedly meandering stream.

Although Halkett Lake with an area of 10.1 km^2 (3.9 mi^2) is of only intermediate size, it is the deepest lake in the park at 54.9 m (180 ft). The deep area is a very small part of the total, however, so that the mean depth of 10.6 m (35 ft) is less than for any of the lakes yet discussed. The entire north part of the lake is very shallow. Gilmour (MS 1950a) felt that Halkett was becoming smaller in area and that much of the north shore had formerly been under water.

Halkett Lake receives water from at least one creek which enters along the west shore. Its outlet, McKenzie Creek, is at most intermittent between the south shore and Lake 207 (Mayhood et al. MS 1973). It was dry throughout the summers of 1971 and 1972.

Limited morphometric and drainage data consisting of area, maximum depth, elevation, drainage classification, and base maps with spot depths are available for more than 50 lakes in the southern half of the park (Mayhood et al. MS 1971, MS 1973; Mayhood and Kooyman unreported data 1971). Most of these lakes have areas of 24 ha (60 acres) or less and a maximum depth of 6m (20 ft) or less. Several have restricted areas of relatively deep water in the form of bottom trenches of holes. Many of the small lakes having no surface outlets appear to gain or lose water by seepage, but some others probably lose water mainly through evaporation.

Thermal Conditions

Thermal conditions in lakes of the park have been investigated by Rawson (MS 1929a, 1936) in detail for Waskesiu Lake, and in less detail for other major lakes. McLeod (MS 1971) has studied temperature conditions at two stations in Waskesiu for 1969, and incidental observations on thermal conditions in park lakes have been recorded by many workers (Rawson MS 1936, 1939, MS 1942, 1945, 1960, 1961; Rawson and Moore 1944; Gilmour MS 1950a; Kooyman MS 1970a; Saunders MS 1972; Mayhood et al. MS 1973; Mayhood and Kooyman unreported data 1971). The discussion to follow is based largely on Rawson (1936) unless indicated otherwise.

The thermal regime of Waskesiu is the best known of any park lake. Ice break-up usually occurs about May 16, and warming of the water takes place rapidly thereafter. Full vernal circulation lasts only about 10 days. In most years thermal stratification is rather weak and is easily disrupted by strong windstorms, but in some years (eg; 1934) a thermocline is maintained throughout the summer. Complete circulation of the lake throughout the open water season has also been observed (eg; 1929). In any case, a long period of autumnal circulation has usually begun before September, and continues until final freeze-up in mid-November.

Rawson emphasized the role of strong windstorms in determining the duration and strength of thermal stratification in Waskesiu Lake. A marked thermocline will form during a period of calm, warm weather, and will be maintained as long as winds are no more than moderate. Strong windstorms, especially if they continue for some days, will disrupt the thermocline even in mid-summer (cf. McLeod MS 1971).

Rawson found the gross heat budget for Waskesiu (base temperature $0^{o}C$) to average 20,300 cal/cm^2 for the seven year period 1928 to 1934, ranging from 19,200 cal/cm^2 to 21,200 cal/cm^2. He calculated the net heat budget for the one year (1934) in which adequate data were available to be 20,500 cal/cm^2. He gave the annual heat budget above $4^{o}C$, a figure of more value in comparative studies, as 15,900 cal/cm^2, and this is the figure reported in later publications (Rawson 1958a, 1960; Hutchinson 1957). The highest recorded mean temperature was given as 18.4°C.

In Kingsmere Lake, the spring ice break-up occurs about May 24, while final freeze-up is not until December 1, and is sometimes as late as December 17. Stratification becomes established in late July or August with a thermocline forming at 10 to 15 m (32.8 to 49.2 ft). Even strong windstorms appear to affect only the upper layer of water.

Rawson gave the annual heat budget of Kingsmere Lake as 26,000 cal/cm^2, and that above 4°C as 20,500 cal/cm^2. The highest recorded mean temperature is 13.0 °C.

Crean Lake has break-up and freeze-up dates similar to those for Waskesiu. This lake usually becomes stratified by late June, with a thermocline about 10 m deep which descends to below 15 m by late August if winds have not disrupted it by then. The gross heat budget of Crean Lake is 21,300 cal/cm^2, and the highest recorded mean temperature is 17.3 °C.

Halkett Lake breaks up about May 13 and marked thermal stratification becomes established by the first part of July. This is maintained throughout the summer, with the thermocline being forced down from about 11 m to 18 m. Fall circulation has often not begun by early September, and freeze-up occurs about November 12. The average gross heat budget for the lake is 16,650 cal/cm^2, and the highest recorded mean temperature is 15.0°C.

Rawson explained the differences in the thermal conditions of the major lakes on the basis of their morphometry, emphasizing that larger relative volume of deep water lead to greater stability of stratification and lower mean temperatures in Kingsmere and Halkett Lakes relative to Crean and Waskesiu, while extensive areas of shallow water in Halkett, Waskesiu and Crean are responsible for their earlier freeze-up and break-up dates relative to Kingsmere Lake.

Observations on the thermal conditions in other lakes of the park have been spotty. Namekus and especially Wassegam apparently stratify fairly strongly in summer, but many of the other lakes such as Amyot, Tibiska, Wabeno, Lavallee, Trappers and the First and Third Heart Lakes probably circulate more or less continuously throughout the open water season (Rawson 1936, Mayhood et al. MS 1973, Mayhood and Kooyman unreported data 1971). The majority of the small lakes in the southern half of the park appear to be polymictic[1] also; however, a small number are sufficiently deep and protected from the wind that they develop a marked stratification (Mayhood et al. MS 1973).

Water Transparency, Turbidity and Colour

None of these features have been studied in any detail, but some incidental observations have been reported.

Secchi disc transparency figures for Waskesiu Lake published by Rawson (1941, 1960, 1961) and by Rawson and Moore (1944) are contradictory. Though the mean Secchi depth has been variously reported as 6.5m, 5.5m, and 3.1 m (21.3 ft, 18.0 ft, and 10.2 ft, respectively), the range of 2.3 m to 4.0 m (7.5 ft to 13.1 ft) given by Rawson (1960) does not include some of these values.

Secchi disc transparencies of other park waters in summer have ranged from 0.3 m (1 ft) to 8.7 m (25 ft), though most seem to be close to 3.0 m (10 ft) (Mayhood et al. MS 1973). Such values could be described as indicating "low to moderate" transparency. Secchi depth exceeds the maximum depth in many of the small lakes, and in the majority of these waters there is light penetration to the bottom over most of their area.

1. in the sense that they mix more or less continuously throughout the summer, as opposed to stratifying and mixing several times in a year.

Turbidity and colour data have been recorded for many park lakes (Mayhood et al. MS 1973, Mayhood and Kooyman unreported data 1971). Summer turbidity is generally low, only rarely exceeding 5 Jackson turbidity units. Colour is more variable, ranging from 0 to 130 Hazen units (that is, from "clear" through green to a strong red-orange "tea" colour). The larger lakes have little or no water colour, but many of the smaller lakes have high colour values which have tentatively been attributed to the products of plant decomposition.

Discussion

Our knowledge of the morphometry of the larger park lakes has been provided largely by Rawson (1936), who had to use less accurate techniques than are available today. He determined spot depths at 130 to 900 stations per lake with a tarred cotton sounding line, locating his stations by sighting by eye, timing an outboard motor, and taking bearings with a compass. His data are probably accurate enough for many puposes; however, it would be better to use morphometric measurements made on modern maps. Kooyman's maps (eg; Figures 2, 3 and 4) were drawn from sounding charts made with electronic sounders, and though superior to those of Rawson in bottom and shoreline detail, were plotted on base maps drawn from composite aerial photographs not corrected for near-edge distortion. It is therefore not certain whether morphometric data based on these maps would be any more accurate than those of Rawson (1936). It would be valuable to have Kooyman's maps replotted on more accurate base maps. No bathymetric maps presently exist for some other major lakes such as Halkett, Namekus or Kingsmere. Such maps are necessary if their limnology is to be studied in any detail.

Morphometric data on the smaller park lakes that have been studied so far are deficient with respect to mean depth and volume. Except for those waters that are (or will be) developed, this may not be particularly serious. The many small lakes are of interest as a group which is representative of many other unexamined lakes in the park, and for such a purpose mean depths and volumes estimated using the methods of Neumann (1959) should prove satisfactory. For the small lakes that are (or will be) developed, each specific lake is of interest. Accurate bathymetric maps for these waters are basic to any detailed study of their limnology -- as might be required for an environmental impact assessment, for example.

Gilmour's (MS 1950a) view that Halkett Lake had decreased in area since the time of Rawson (ie; prior to 1940) is supported by differences in the shape of the lake on recent topographic maps when compared to that shown on older maps. A map plotted using 1939 data (Prince Albert National Park -- Geological Survey of Canada) shows a shallow, northward-extending bay on the north shore which is very reduced in the most recent topographic map (73 G/9 Ed. 1 MCE Ser. A 742 -- 1963 data). The islands are larger in the newer map also.

There are bare clay scars on the steep shorelines of Crean Lake, its islands, and Prospect Point on Waskesiu Lake, which are evidence of recent sliding at those points. Such shoreline modification commonly accompanies water level manipulation in reservoirs (see Neel 1963). It is possible that the damming of the outlets and the subsequent rise in the water levels of these lakes is at least in part responsible for these slides.

The fact that several of the lakes have parts of their drainage basins outside the park (eg; Namekus, Wabeno, Wassegam and Tibiska) makes them subject to modification from developments in areas beyond the jurisdiction of the park. In particular, Namekus receives water from McPhee Lake, which is presently being developed as a resort; and the northern part of the Wabeno Lake drainage basin is within an area presently being logged. There are scant limnological data available for these waters, which makes detection of any man-caused changes difficult if not impossible.

Rawson (1936) provided a good explanation of the control of most thermal conditions in the major lakes by the morphometry of the lakes and their susceptibility to wind stress. He did not adequately account for the differences in their heat budgets, however. Gorham (1964) has found a strong positive correlation between the heat budgets of temperate lakes and their volume. This relationship appears to hold for Kingsmere, Waskesiu and Halkett Lakes, where Kingsmere has the largest heat budget and the greatest volume of these three lakes, while Halkett, with the least volume, has the smallest heat budget. Crean Lake, however, has the greatest volume of any lake in the park, but its heat budget is much less than that of Kingsmere. Gorham (1964) also found that lakes having a high area to depth ratio tend to have lower heat budgets than those with low area to depth ratios. Crean, with an area more than twice that of Kingsmere and a mean depth about one-half that of Kingsmere clearly has a higher area to depth ratio than does Kingsmere Lake. It is thus possible that the unexpectedly low heat budget for Crean Lake is a result of the broad, shallow nature of its basin.

<u>Summary and Conclusion</u>

The morphometric data available on the larger, more accessible lakes of Prince Albert National Park (Waskesiu, Crean, Kingsmere, Namekus and Halkett) and on most of the smaller lakes that have been examined in the southern part of the park are adequate for a general characterization of these lakes. If detailed studies of their limnology are to be done, more accurate morphometric data will be necessary. Bathymetric maps are available only for Waskesiu, Crean and the Heart Lakes, and outline maps with some spot depths exist for many small southern lakes.

Except in the case of Waskesiu, data on the thermal features of the lakes studied so far are adequate only for a general characterization of those waters. The temperature regime of Waskesiu through the open water season is well documented, but few data are available for this or any other lake in the park for the winter months.

There is a possibility that the manipulation of water levels in Waskesiu and Crean Lakes is causing damage to the shorelines of these lakes. At least two lakes are presently susceptible to modification by developments outside the park because parts of their drainage basins beyond the park boundary are being modified.

There is evidence of a decrease in the area of Halkett Lake since the 1930's.

CHEMICAL LIMNOLOGY

Dissolved Oxygen

Dissolved oxygen has been studied in detail only in Waskesiu Lake. Rawson (1936) found that the oxygen levels in the deep water generally depend on the strength and duration of thermal stratification, which is a variable feature in Waskesiu. In 1929 when the lake did not stratify all summer, bottom dissolved oxygen values were close to, but always lower than, those in the surface waters. In 1934 when strong thermal stratification persisted throughout most of July and August, the dissolved oxygen in the bottom water during those months remained very close to zero. In most years, dissolved oxygen content declined during periods when the lake was stratified, but rose sharply when stratification was disrupted by windstorms (cf. McLeod MS 1971). Low bottom oxygen values were observed in the lake in winter, but the frequency of such occurrences is unknown since winter records exist for only one year. On the basis of oxygen deficit calculations, Rawson classified this lake as eutrophic.

Rawson (1936) also discussed dissolved oxygen concentrations in some other major lakes of the park, but presented fewer data on them. Bottom oxygen concentrations in Kingsmere Lake are apparently always high, having never been known to drop below 3.8 cc/l (5.4 mg/l). Rawson classified this lake as clearly oligotrophic on the basis of oxygen deficit calculations. The average dissolved oxygen content of Crean Lake bottom waters is about the same as that for Waskesiu; however, concentrations in Crean Lake have not been known to reach the very low levels sometimes attained in Waskesiu. Halkett Lake bottom oxygen concentrations average the lowest of any of these lakes.

Incidental observations on the dissolved oxygen conditions in the above lakes have been reported by several investigators (Rawson MS 1929a, 1960, 1961; Rawson and Moore 1944; Gilmour MS 1950a; Kooyman MS 1970a; McLeod MS 1971; Mayhood et al. MS 1973), but they do not alter the general descriptions outlined herein.

Some determinations of the dissolved oxygen content in many of the small lakes in the southern half of the park have been made, but none have been studied in detail (Mayhood et al. MS 1971, MS 1973; Mayhood and Kooyman unreported data 1971). These lakes have high dissolved oxygen concentrations in the surface waters in summer, and those that circulate to the bottom continuously throughout the open water season (the majority) presumably have high concentrations throughout the water column. A few of these lakes, those that are relatively deep, have a very pronounced hypolimnetic oxygen deficiency in summer. One of these, a lake of about 40 ha (100 acres) and over 15 m (49.2 ft) deep, in August 1972 had no oxygen from 9 m (30 ft) down, although the concentration at 7.6 m (25 ft) was reasonably high at 4 mg/l.

pH

In Waskesiu Lake, the pH of the surface waters averages 8.2, although values as low as 7.8 have been obtained when a surface runoff layer of water influenced the reading, and values as high as 8.4 have been recorded. The pH of the bottom water in this lake ranges from 7.8 to 8.1, and is always lower than the pH at the surface except during times of complete circulation. The lowest values occur during summer stagnation, while the highest are associated with the fall overturn (Rawson 1936). Incidental observations by others are in agreement with these general conditions (Rawson and Moore

1944; Rawson 1960, 1961; Gilmour MS 1950a; Mayhood and Kooyman unreported data 1971).

The pH conditions in Crean, Kingsmere and Namekus Lakes are similar to those in Waskesiu, the surface pH not exceeding 8.7 and the lowest recorded value for the bottom water being 7.2 (Rawson 1936, Rawson and Moore 1944, Gilmour MS 1950a, Mayhood _et al_. MS 1973, Mayhood and Kooyman unreported data 1971). The pH of the surface waters in several small lakes in the southern part of the park is higher, values of 8.8 to as high as 9.4 being not uncommon. Surface pH values as low as 7.6 have been found in two lakes in the Waskesiu Hills (Mayhood _et al_. MS 1973).

Total Dissolved Solids

Total dissolved solids (TDS) of Waskesiu Lake water determined on samples evaporated at 110 °C or 105 °C have been variously reported as 199 ppm, 181 ppm, 224 ppm (Rawson 1936), 201 ppm (Rawson 1941), 188 ppm (Rawson 1951, 1960, 1961; Ryder 1965), and 167 ppm (Hammer 1964, 1965). TDS determined on samples evaporated at 180 °C has been reported as 170 ppm, 171 ppm, 178 ppm (Rawson and Moore 1944) and 191 ppm (Mendis 1956); and the sum of constituents (total dissolved solids calculated from a complete analysis) has been given as 167 ppm (Rawson and Moore 1944), 180 ppm apparently including SiO_2 (Hammer 1964), and about 160 ppm (Mayhood and Kooyman unreported data 1971). Other values have been reported without specification of the methods used. Thus Kuehne (1941) reported a value for total solids as 178 ppm, and Stevenson (MS 1942), 210 ppm.

Some changes in the TDS of Waskesiu Lake have been pointed out before. Rawson (1951) noted that it increased from about 180 ppm to 200 ppm during the drought years of the 1930's when the lake had little or no outflow.

Mendis (1956) reported that the TDS of Waskesiu increased 7.3% in the period from 1938-40 to 1955 -- from 178 ppm to 191 ppm. The data of Rawson (1958b) and Hammer (1965) indicate that such trends have been short-lived, and that since the 1930's the TDS (by evaporation) of Waskesiu Lake has tended to remain within the range of 170 ppm to 200 ppm.

Other major lakes are less well known with respect to their total dissolved solids. No determination has been reported for Crean Lake, and but two determinations are known for Kingsmere Lake: 169 ppm (Rawson 1951) and 159.6 ppm (Mayhood and Kooyman unreported data 1971). The former value was probably determined by evaporation and would be expected to be higher than the latter, which was calculated as the sum of constituents. Total solids of Namekus Lake waters have been recorded as 200 ppm -- or 180 ppm by calculation (Rawson and Moore 1944), 217 ppm (Hammer 1964, 1965), 178.5 ppm (Mayhood and Kooyman unreported data 1971), and 167.4 ppm for 1972 (Mayhood et al. MS 1973). In comparing the values and considering the likely variability of determinations in various years, there appears to have been no consistent change in TDS from 1938 to 1972 in this lake.

In contrast to Waskesiu and Namekus Lakes, Halkett has apparently increased in TDS fairly continuously since the 1930's. Rawson (1936) gave the total dissolved solids (evaporated at 110 °C) as 276.1 ppm for 1934. This later rose to 283 ppm (Kuehne 1941), 283 ppm evaporated at 180 °C (Rawson and Moore 1944) in 1938, then to 335 ppm at 180 °C in 1955 (Mendis 1956), and finally to "about 400 ppm" (Rawson 1958b). The total dissolved solids as sum of constituents has risen from 263 ppm in 1938 (Rawson and Moore 1944) to 323 ppm in 1971 (Mayhood and Kooyman unreported data 1971) and 327.4 ppm in 1972 (Mayhood et al. MS 1973).

Total dissolved solids of small lakes in the southern part of the park have been determined by Hammer (1964, 1965), Mayhood et al. (MS 1973), and Mayhood and Kooyman (unreported data 1971). Values for sum of constituents range from 39.0 ppm to over 1500 ppm. Six of the lakes examined so far are saline according to the criterion of Northcote and Larkin (1963), who regard waters as saline if their TDS is 500 ppm or greater; but 19 lakes are saline if Rawson and Moore's (1944) limit (TDS $\geqslant$ 300 ppm) is accepted. At the other extreme, 4 lakes are known to have total dissolved solids less than 100 ppm, and could be considered quite dilute. The remainder of the lakes, about one-half of those examined so far, fall within the range of 100 to 300 ppm total dissolved solids.

Major Constituents

Total hardness, usually measured in parts per million as $CaCO_3$, is a measure of the alkaline earth (mainly calcium and magnesium) content of the water. For Waskesiu Lake, available values for total hardness range from 145.1 ppm to 165.5 ppm (Rawson 1936, Mayhood and Kooyman unreported data 1971). The available information on calcium and magnesium concentrations in Waskesiu Lake indicate that calcium averages about 37 ppm and magnesium averages about 15 ppm, with little year to year variation (Rawson 1936, Rawson and Moore 1944, Mayhood and Kooyman unreported data 1971).

The two other major cations, sodium and potassium, have been reported together in some publications. The 1934 sodium + potassium figures for Waskesiu (Rawson 1936) range from 12.9 to 15.1 ppm and are about twice the 1938 figure of 6.5 ppm reported by Rawson and Moore (1944). Mayhood and Kooyman (unreported data 1971) have found a mean sodium concentration of 5.6 ppm and a mean potassium concentration of 3.0 ppm, the sum comparing more closely to the 1938 value. Although there appears to have been nearly a 50% drop in sodium + potassium concentration since 1934, within-year variations in these constituents of similar magnitude have been observed during the open water season in other lakes of the park (Mayhood et al. MS 1973).

The cationic composition of Waskesiu Lake water on the basis of equivalent weights is $Ca > Mg > Na > K$, or in terms of percentage of cations, $Ca \simeq 50\%$, $Mg \simeq 40\%$, $Na \simeq 7\%$, $K \simeq 2\%$, and other $\simeq 1\%$ (Mayhood and Kooyman unreported data 1971).

Total alkalinity as $CaCO_3$ is a measure of the carbonate content in these waters. Available data for Waskesiu Lake indicate a range in total alkalinity from 147 to 158 ppm. A phenolphthalein alkalinity of less than 1 ppm has also been detected at times (Rawson 1936, Mayhood and Kooyman unreported data 1971).

Sulphate concentration in Waskesiu is quite variable, but is generally not more than 10 ppm (Rawson 1936, Rawson and Moore 1944, Mayhood and Kooyman unreported data 1971). Chloride averaged 6.4 ppm in 1934 (Rawson 1936), but was only 1.3 ppm in 1938 (Rawson and Moore 1944) and 1971 (Mayhood and Kooyman unreported data 1971).

The composition of anions in Waskesiu Lake water on the basis of equivalent weights is $HCO_3 > SO_4 > CO_3 \simeq Cl$, or in percentage terms, $HCO_3 \simeq 95\%$, $SO_4 \simeq 3\%$, $CO_3 \simeq 1\%$, $Cl \simeq 1\%$ (Mayhood and Kooyman unreported data 1971).

Less information is available on the major ion composition of the water of the other major lakes. No data are available for Crean Lake. Unreported data of Mayhood and Kooyman for 1971 indicates that the major ion composition of Kingsmere water is nearly identical to that of Waskesiu, as is that of Namekus (Rawson and Moore 1944, Hammer 1964, Mayhood et al.

MS 1973, Mayhood and Kooyman unreported data 1971). For the latter lake, there appears to have been no significant change in composition over the period 1938 to 1972.

In contrast to the previously mentioned lakes, Halkett has shown a continuous change in the ionic composition of its waters since 1934. Calcium concentrations have decreased slightly from 36.8 ppm in that year, through 31.1 ppm in 1938 and 29.6 ppm in 1971, to 27.5 ppm in 1972. This has been accompanied by increases in the concentrations of magnesium, sodium + potassium, carbonate and sulphate ions. There has been no consistent change in bicarbonate concentration since 1934, nor in the concentration of chloride ion since 1938. The latter did drop markedly from 10.0 ppm in 1934 to 1.0 ppm in 1938 (Rawson 1936, Rawson and Moore 1944, Mayhood et al. MS 1973, Mayhood and Kooyman unreported data 1971).

The chemical composition of many of the small standing waters in the southern part of the park has been examined by Mayhood et al. (MS 1971, MS 1973), and by Mayhood and Kooyman (unreported data 1971). The ionic composition is quite variable, with the most dilute lakes being calcium bicarbonate type and the most saline being magnesium sulphate type. On the average, the cations are codominated by calcium and magnesium, and the anions are dominated by bicarbonate. Sodium, potassium and chloride are generally low, even in the most saline lakes.

Minor Constituents and Silica

Minor chemical constituents of Prince Albert National Park waters have not been studied in detail, although incidental observations have been made in many waters. Rawson (1936) and Rawson and Moore (1944) have reported values for $Fe_2O_3 + Al_2O_3$ for Waskesiu, Namekus and Halkett Lakes. These values never exceeded 2.8 ppm. Mayhood et al. (MS 1973) and Mayhood and Kooyman (unreported data 1971) have recorded values for copper, iron, manganese, lead, zinc, fluorine, total Kjeldahl nitrogen, nitrate +nitrite nitrogen, ortho-, inorganic, and total phosphate, and total organic and inorganic carbon for the surface waters of many small lakes in the southern half of the park. With few exceptions, the concentrations of these constituents were low; frequently they were at undetectable levels.

Silica values for park lakes have been determined by Rawson (1936), Rawson and Moore (1944), Mayhood et al. (MS 1973) and Mayhood and Kooyman (unreported data 1971). Silica concentrations even within lakes are quite variable. Among all the park lakes, silica ranged from nearly 0 ppm to more that 15 ppm, and averaged about 4 ppm.

Seasonal and Depth Differences in Water Chemistry

With the exception of dissolved oxygen and pH (discussed above in their respective sections), these aspects of water chemistry have been relatively neglected for Prince Albert Park waters. Mayhood et al. (MS 1973) found that in four relatively shallow lakes, samples taken from under the ice near the end of winter (April) had much higher concentrations of almost all constituents than had any of the summer samples. For example, winter sums of constituents were two or more times the summer values as a result of much higher calcium and bicarbonate concentrations in the winter samples. These higher winter values were probably caused by concentration by freezing of much of the lake water, and by dissolution from the macrophytes and bottom muds under the low-oxygen reducing conditions under the ice.

With regard to differences in water chemistry with depth, Mayhood et al. (MS 1973) found measurable chemical differences between surface and deep waters in all thermally stratified lakes examined. The deep waters tended to be higher most notably in sums of constituents and all major ions except carbonate, while they were lower in carbonate and pH. Increases in sums of constituents between surface and bottom waters of up to 50% were noted.

Discussion

The values for bottom oxygen given by Rawson (1936) should not be considered as being representative of the hypolimnia of the lakes. His determinations were made on samples taken only 20 cm (7.9 in) above the bottom, and as he noted for Waskesiu Lake, the near-bottom water layer (1 m above the bottom to the mud surface) is often a "microstratum" of very low dissolved oxygen. If proper account is not taken of this fact, his data for Halkett Lake, for instance, would lead one to think that the hypolimnion is very low in oxygen in mid-summer, when in fact other data (Mayhood et al. MS 1973, Mayhood and Kooyman unreported data 1971) show that hypolimnetic oxygen is high. For this reason, information on oxygen concentrations at several depths in addition to surface and bottom is desirable. Unfortunately, Rawson (1936) published data only for one year and only for Waskesiu Lake.

In past studies, total dissolved solids has usually been determined on samples evaporated at a specified temperature; usually 110 to 105 °C. the most recent investigations, however, have used sum of constituents as a measure of TDS. Such a procedure results in consistently lower values than those produced by the evaporation method, because it does not include the non-ionized constituents. For the purposes of studying changes in the TDS since the 1930's, it thus would be of value to have data on the TDS by evaporation for recent times in addition to the sum of constituents.

In comparing Rawson's chemical analyses with more recent results, it has been assumed that his methods were as accurate as present methods are, and that his samples were taken from the surface waters of the lakes during the open water season. In fact, the former assumption is likely to be only approximately true, especially for the determinations of the various ions. The latter assumption seems reasonable, since it is clear from Rawson's writings that he did little winter work in the park; and when only occasional samples are taken for chemical analysis, surface samples are the most logical choice for comparisons of water chemistry from lake to lake. The fact that Halkett Lake water analyses showed consistent trends in chemical composition over a 40 year period when several analyses were considered was taken as adequate evidence of chemical change.

The changes in the water chemistry of Halkett Lake have accompanied apparent changes in water level and area of that lake (see note in morphometry and drainage section). The fact that the total concentration of dissolved substances has apparently increased in a consistent manner suggests that the lake is losing water mainly by evaporation rather than by seepage (there is no overflow). This increase in TDS reflects large increases in all major constituents except calcium, bicarbonate and chloride ions. A hypothesis that the former two constituents have reached saturation as a result of of evaporative concentration and precipitate out of solution as the concentration continues to increase is supported by the occurrence of a whitish, flocculent, apparently inorganic marl-like precipitate on the surface of the bottom muds. The decline in chloride ion, however, between 1934 and 1938 cannot be accounted for in a similar manner, since its compounds with the major cations are all highly soluble in water.

It may be that the changes in Halkett Lake are entirely the result of natural processes; but the possibility that they have been caused by human interference should be investigated. The changes described above are consistent with the diversion or blockage of a major tributary of the lake.

The saline lakes of the park have been found in two regions: in the Sturgeon River region and south and west of Halkett Lake. The most dilute lakes have been found in the Waskesiu Hills. These differences in the distribution of lake types may reflect differences in the lithology of these regions and/or differences in the mode of water loss in the lakes.

Summary and Conclusion

The dissolved oxygen regime of Waskesiu Lake and its variability from year to year has been documented for the open water season, but there is little information on dissolved oxygen conditions in Waskesiu or any other park lake in winter. There is only a general knowledge of the dissolved oxygen regime and its yearly variability in the other major lakes for the open water period. Summer oxygen conditions in the smaller, shallower lakes can be inferred from the few data available on a representative group of these waters, but oxygen relations in the small, relatively deep, thermally stratified lakes are poorly known.

The data presently available on the major and minor constituents of Prince Albert National Park waters have given us an idea of the range of chemical types of lakes in the southern half of the park. There is a general lack of information on the seasonal changes and the year to year variability of the lakes, however. This is true for the larger, developed lakes as well as the smaller, more remote waters.

Halkett Lake, one of only three waters for which water chemistry data are available for a long period of time, shows evidence of a continuous increase in total dissolved solids since the 1930's. The waters of Waskesiu and Namekus Lakes have not changed in a consistent way over the same period.

AQUATIC BIOLOGY

Plankton

a. Quantity

The only investigation of total plankton quantities in park waters was reported by Rawson (MS 1929a) for Waskesiu Lake. He determined plankton volume and nitrogen content weekly at one station throughout the summer, and found that plankton volume was greater in the 0 to 5 m (0 to 16.4 ft) layer than in lower layers. Both plankton volume and nitrogen content showed large variations through the summer. Unfortunately, Rawson did not relate his figures to water volume or surface area, so his data cannot be compared to later figures. In later publications, Rawson used a variety of values for net plankton quantity (# 20 mesh net) in Waskesiu, including 91.6 kg dry weight/ha (Rawson 1941), 90.5 kg dry weight per hectare (Rawson 1953, 1955, 1960, 1961), and 56.5 kg organic matter/ha (Rawson 1953, 1955).

McLeod (MS 1971) found that the numbers of most zooplankton species were higher in upper Waskesiu than in lower Waskesiu Lake, and that most populations peaked somewhat earlier in upper Waskesiu. He attributed these differences to the slightly higher temperatures that prevail in the upper lake.

Plankton quantities have not been assessed for other park lakes.

b. Composition

Composition of the phytoplankton of Prince Albert Park waters has been examined primarily by Kuehne (1941) in his survey of the phytoplankton of southern Saskatchewan. He identified algae collected throughout the summer from 1928 to 1931 in Waskesiu Lake, and algae in fewer samples from Bagwa, Crean, Halkett, Kingsmere, Lavallee, Shady, Tibiska and Wabeno Lakes, and Beartrap and Moose Creeks. In all, he recorded 153 species from the park: 40 Cyanophyta, 66 Chlorophyta, 39 Bacillariophyceae and 8 species in miscellaneous groups. One hundred-sixteen of these species occur in Waskesiu Lake.

Mayhood et al. (MS 1973) in a survey of many southern park lakes, noted that chlorophytes, though present in the plankton of most of the lakes, are seldom common; that cyanophytes and chrysophytes (particularly diatoms) are the most abundant groups, and that the dinophycean Ceratium hirundinella is the most common species in these lakes. It was also found that diatoms were rare in the plankton of small lakes although they were an important component of large lake phytoplankton.

Algal blooms have been recorded on some of the lakes in the park. Rawson (1960) noted that Waskesiu Lake produced "moderate" algal blooms. Kuehne (1941) reported that blooms in the "Narrows" (the upper lake) consisted mainly of Anabaena, Aphanizomenon, and Microcystis. Hammer (1964, 1965) recorded the bloom species Anabaena flos-aquae, Aphanizomenon flos-aquae, Lyngbya birgei, and Microcystis aeruginosa from the lake, but did not observe a water bloom. Hammer did, however, note a bloom of Aphanizomenon flos-aquae in Shady Lake, and Kuehne (1941) reported a bloom of Anabaena spp., Microsystis and Aphanizomenon in lower Moose Creek[1].

Rawson (MS 1929a) followed the changes in the composition and abundance of Waskesiu Lake zooplankton for 1928, and McLeod (MS 1971) did the same for 1969. Brooks (1957) identified species of the zooplanktonic genus Daphnia in Rawson's samples from four park lakes. A survey of the zooplankton of many (mainly small) lakes in the park has been undertaken by Mayhood et al. (MS 1971, MS 1973), and by Mayhood and Kooyman (unreported

1. Dr. Hammer undoubtedly gives further details of blooms in park lakes in his thesis (Hammer MS 1962), which was not examined in this review.

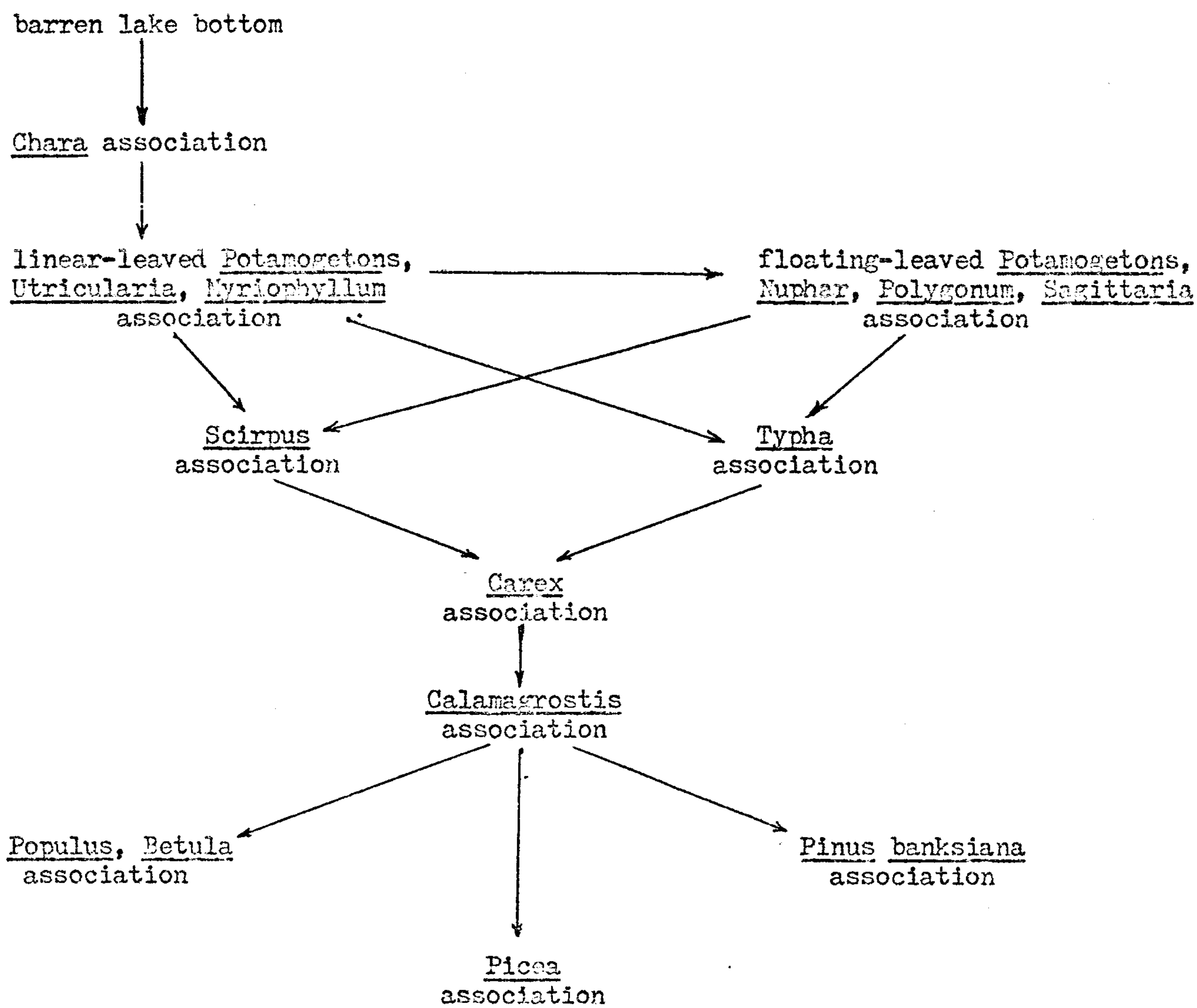
data 1971). The most widespread rotifers in the lakes studied so far are Keratella cochlearis, Polyarthra, Asplanchna, and Keratella quadrata, while Kellicottia longispina, Trichocerca (multicrinis?) and Filinia are also common. Several species of Cladocera and Copepoda seem to be limited to the small lakes in the park, while other species are apparently found only in the larger lakes.

Considering only the Rotifera and the Crustacea, the numerically most important groups, there have been 61 zooplanktonic species reported from park waters. Of these, 20 are Rotifera, 31 are Cladocera, 7 are Calanoida, 7 are Cyclopoida and 2 are Harpacticoida. In addition to these, members of several other groups have occasionally been recorded from plankton samples, including Protozoa, Turbellaria, Gastrotricha, Nematoda, Bryozoa (floatoblasts), Oligochaeta, Hydracarina, Ostracoda, Amphipoda, Ephemeroptera, Zygoptera, Heteroptera, Coleoptera and Diptera (especially the larvae of Chaoborus and Tendipedidae).

Aquatic Macrophytes

Records of the aquatic macrophytes of Prince Albert Park have been provided by Rawson (MS 1929a), Stevenson (MS 1942), Rawson and Moore (1944), Breitung (1957), Mayhood et al. (MS 1971) and Saunders (in Mayhood et al. MS 1973). More than 127 aquatic and semi-aquatic species have been identified from park waters. Saunders found the following plants to be the most commonly occurring aquatic macrophytes in the southern half of the park. In taxonomic order, they are Chara globularis, C. vulgaris, Drepanocladus aduncus, Equisetum fluviatile, Typha latifolia, Sparganium multipedunculatum, Potamogeton (foliosus?), P. gramineus, P. natans, P. pectinatus, P. richardsonii, P. zosteriformis, Sagittaria cuneata, Calamagrostis canadensis, Carex aquatilis, Carex lacustris, Carex lasiocarpa, Eleocharis acicularis, Eleocharis palustris, Scirpus lacustris group (S. acutus?), Calla palustris, Hippurus vulgaris, Myriophyllum exalbescens, and Utricularia vulgaris. Saunders has also provided an outline of the succession sequence of plant associations from deep water to above the high-water line for Prince Albert Park lakes (Figure 5). No quantitative data on the aquatic macrophytes are available, other than general comments on relative abundance in the above-noted papers.

Figure 5: Typical sequence of succession of plant associations in waters of Prince Albert National Park (from Saunders, in Mayhood et al. MS 1973)



Littoral Fauna

a. Quantity

Stevenson (MS 1942) has provided a quantitative study of the littoral fauna of Waskesiu Lake. He found the mean number of organisms in the littoral zone of the entire lake to be $1314/m^2$ ($122/ft^2$), with peak numbers being found in the 0.5 to 1.5 m (1.6 to 4.9 ft) depth zone. Chara beds were found to be the habitat harbouring the greatest number of organisms, while bare sand and gravel bottom held the least. In terms of weight, the quantity of littoral fauna in the lake averaged 12.1 kg dry weight/ha (10.8 lb/acre), with a peak in the 0.5 to 1.5 m (1.6 to 4.9 ft) zone. The upper lake had a higher standing crop of littoral animals than did the lower lake.

No studies of the total quantities of littoral fauna in other park lakes have been reported.

b. Composition

The composition of the littoral fauna of park lakes has been studied mainly by Stevenson (MS 1942) for Waskesiu Lake, and by Saunders (in Mayhood et al. MS 1973) for 15 small lakes located mainly in the southern part of the park. Preliminary or incidental observations on the littoral fauna of Waskesiu have been made by Rawson (MS 1929a) and Rawson and Moore (1944), while specific groups have been reported on by Walker (1940, 1953: Odonata), Milne (MS 1941, 1943: Trichoptera), Rempel (1936, 1950, 1953: Diptera), Oliver (1958: Hirudinea), Conroy (MS 1968: Hydracarina), and Brooks and Kelton (1967: Heteroptera).

The Tendipedidae form the most abundant group in the littoral fauna of Waskesiu Lake, followed by the Amphipoda and Sphaeriidae. In terms of weight, however, Trichoptera are the largest group, followed by

Ephemeroptera, Amphipoda and Tendipedidae (Stevenson MS 1942).

The samples of Saunders (in Mayhood et al. MS 1973) are not directly comparable to those of Stevenson because they were taken in a much different way. Stevenson's sampling method captured many animals on or in the mud and vegetation, while Saunders' methods sampled the mud only inadvertently. The samples of Hare, however, were taken with an Ekman dredge and are more comparable to Stevenson's method. They indicate that as in Waskesiu, Tendipedidae are the most abundant and Amphipoda the next most abundant groups in the smaller lakes. Sphaeriidae are much less abundant in the littoral zone of the small lakes than they are in Waskesiu Lake.

The reports on specific groups of littoral animals, with the exception of Milne (MS 1941, 1943) have been limited to distribution records. Milne's studies, however, were directed toward elucidating the ecology of many species of Trichoptera in Waskesiu Lake, Waskesiu River and Mud Creek. He found that in the lake, Trichoptera larvae were most abundant at a depth of 2.5 m (8.2 ft). At shallower depths than this, he believed that wave action limited abundance, while at depths below 8 m (26.2 ft) a lack of plants was responsible for larval scarcity. Wave action and depth were felt to act through their influence on food, oxygen and case-building materials. Nearly one-half of the Trichoptera larvae in Waskesiu Lake were the species *Molanna flavicornis*.

Discussions of the distribution of various littoral species within the park are provided by Rawson (MS 1929a), Stevenson (MS 1942), Milne (MS 1941, 1943), and Hare and Saunders (in Mayhood et al. MS 1973).

Benthic Fauna

a. Quantity

In Waskesiu Lake, Rawson (MS 1929a) found the average standing crop of benthic organisms in water over 4.6 m (15 ft) deep to be 15.4 kg/ha (13.7 lb/acre) on a dry weight basis. The average standing crop in the upper lake (36.8 kg/ha, or 32.7 lb/acre) was considerably greater than that of the lower lake (9.3 kg/ha, or 8.3 lb/acre). The average number of organisms for the entire lake was $655/m^2$ ($60.8/ft^2$). Rawson noted that although the average weight per unit area is about what could be expected in a lake of such depth and area, the numbers of bottom organisms is very low, indicating a preponderance of large individuals in the fauna.

In one publication, Rawson (1939) used the standing crop value for the entire lake as given above, but in subsequent papers he gave a variety of figures quite different from those already cited. Two of these papers (Rawson 1941, 1955) give the value for the entire lake as 24.7 kg dry weight per hectare (22.0 lb/acre). Another two publications (Rawson 1960, 1961) report the value as 24.6 kg/ha (21.9 lb/acre), which is the same value that Rawson and Moore (1944) provide as the average standing crop of bottom organisms for the upper lake alone. Furthermore, Rawson (1960) gives the average number of bottom organisms as $837/m^2$ ($77.8/ft^2$) for the entire lake: much larger than his earliest value of $655/m^2$, but considerably smaller than the $1364/m^2$ ($127/ft^2$) given in Rawson and Moore (1944) for the upper lake alone. Since Rawson did not attempt to explain these discrepancies in any of his reports or publications and did not provide detailed information on his methods of calculation, it has not been possible to resolve these differences.

There are apparently no quantitative data on the benthic fauna of other major lakes of the park.

Quantities of bottom fauna in 15 smaller park lakes have been assessed by Hare (in Mayhood et al. MS 1973). His data suggest that within the range of salinity found so far in the park, the standing crop (in terms of "preserved wet weight per sample") of bottom fauna is highest in the most saline lakes and lowest in the most dilute lakes.

b. Composition

In his initial survey of the benthic fauna of Waskesiu Lake, Rawson (MS 1929a) noted that larval Tendipedidae ("Chironomus plumosus") constituted 85% of the benthic fauna by numbers and 94.8% by weight. The remainder was made up of Oligochaeta, Sphaeriidae, Ephemeroptera, Gastropoda, Ostracoda and Chaoborus. In a much later paper, (Rawson 1960), he reported that tendipedids constituted 66% of the bottom fauna, with the remainder consisting of Oligochaeta (5%), Amphipoda (4%), Sphaeriidae (1%), and 24% undisclosed. It has not been possible to explain the discrepancies in the above data, since Rawson did not describe his methods in detail.

No data on the composition of the benthic fauna in other major lakes of the park are presently available.

Hare (in Mayhood et al. MS 1973) has provided the numbers of each major group of organisms collected in dredge samples from each of 15 small lakes. These data show that on the basis of numbers, Diptera larvae and pupae (mainly Tendipedidae) comprise 58% of the bottom fauna, Amphipoda 25%, Mollusca (mainly Sphaeriidae) make up 7%. Since the 15 lakes that Hare investigated usually had very extensive littoral zones which in several cases represented the only bottom zone, his results are best considered as representative of the "bottom" fauna of those lakes.

Incidental notes on certain organisms in the benthic fauna of park lakes are provided by Rawson and Moore (1944) and Hare (in Mayhood et al. MS 1973).

Fish

Rawson (1960, 1961) reported an average catch of 119 fish per "standard net"[1] in Waskesiu Lake, averaging 61 kg (134 lb) per net. He reported a 10 - year average commercial fish yield of 7.8 kg/ha/yr for the same lake.

No similar quantitative data have been reported for other lakes in the park.

Table 4 lists the twenty-three species of fish that have been reported from Prince Albert National Park (Schultz 1956, Kooyman MS 1970a, Banks and Mayhood in Mayhood et al. MS 1973). Of these, the most familiar or abundant are lake trout, cisco, lake whitefish, white sucker, northern pike, yellow perch, walleye, spottail shiner, fathead minnow, Iowa darter, brook stickleback and ninespine stickleback. The others appear to be rather rare, or common only in certain waters. One (smallmouth bass) was an apparently unsuccessful introduction into Waskesiu, Shady and the Heart Lakes (Rawson MS 1936, MS 1942, 1945, Marshall and Johnson 1971), and another (brook trout) was an unsuccessful introduction into Halkett Lake (Schultz 1956, Kooyman MS 1970b).

The biology of some of these species in Waskesiu Lake has received special attention from Rawson (1932: pike), Campbell (MS 1935: white sucker), Kooyman (MS 1970a: cisco), and McLeod (MS 1971: cisco). Some of these and other species have been the subject of fishery management programs discussed in the next section. The fishes important in the angling or former commercial fisheries are discussed in detail below.

1. 300 yd of 1.5, 2, 3, 4, 5, 5.5 inch mesh for 24 hr

Table 4: Fish species reported from Prince Albert National Park. Nomenclature is that of Scott and Crossman (1973) unless noted otherwise. Introduced species are marked with an asterisk.

Cisco *Coregonus artedii* "complex" (Kooyman MS 1970a)

Lake whitefish *Coregonus clupeaformis* (Mitchill)

Brook trout *Salvelinus fontinalis* (Mitchill)*

Lake trout *Salvelinus namaycush* (Walbaum)

Longnose sucker *Catostomus catostomus* (Forster)

White sucker *Catostomus commersoni* (Lacepede)

Blacknose shiner *Notropis heterolepis* Eigenmann and Eigenmann

Spottail shiner *Notropis hudsonius* (Clinton)

Fathead minnow *Pimephales promelas* Rafinesque

Northern redbelly dace *Chrosomus eos* Cope

Finescale dace *Chrosomus neogaeus* (Cope)

Longnose dace *Rhinichthyes cataractae* (Valenciennes)

Pearl dace *Semotilus margarita* (Cope)

Northern pike *Esox lucius* Linnaeus

Burbot *Lota lota* (Linnaeus)

Trout-perch *Percopsis omiscomaycus* (Walbaum)

Smallmouth bass *Micropterus dolomieui* Lacepede *

Iowa darter *Etheostoma exile* (Girard)

Yellow perch *Perca flavescens* (Mitchill)

Walleye *Stizostedion vitreum* (Mitchill)

Slimy sculpin *Cottus cognatus* Richardson

Brook stickleback *Culaea inconstans* (Kirtland)

Ninespine stickleback *Pungitius pungitius* (Linnaeus)

Compiled from Schultz (1956), Kooyman (MS 1970a) and Banks and Mayhood (in Mayhood *et al.* MS 1973).

Information on other species is very limited, consisting mainly of distribution records, or notes on occasional collections. The recent book by Scott and Crossman (1973) discusses each species within the broader framework of Canada, while Atton (MS 1963) provides keys and a check-list of Saskatchewan species.

a. Northern Pike

Waskesiu Lake pike have been found to utilize "South Bay Lake" (ie, Lake 1051 of Mayhood et al. MS 1973), Amiskowan Lake, Mud Creek, small bays of upper Waskesiu, a small lake off the extreme west end of upper Waskesiu, and the Waskesiu River as spawning areas (Rawson 1932; Gilmour MS 1950a; Schultz MS 1954, 1955; Hoskins MS 1964). Lake 1051, however, is no longer connected to Waskesiu and is not now used by pike for spawning. Spawning migrations in Mud Creek have numbered 5000 to 6000 fish (Schultz MS 1954, 1955). Beaver dams on this creek have been accused of blocking the pike spawning run in some years (Rogers MS 1941a; Schultz MS 1954, 1955), and low water has curtailed spawning in other years (eg; 1963, Hoskins 1963 correspondence).

Spawning takes place in late April to early May at water temperatures of about 13 °C (55.4 °F) in shallow, weedy areas, especially among sedge hummocks (Rawson 1932). Yolk sac fry about 9 mm in length first appear in Mud Creek in the latter half of May after about 15 days of development in the egg stage. They grow rapidly, reaching 30 to 35 mm (1.18 to 1.38 in) by early June (Rawson 1932). These fry have sometimes been trapped behind beaver dams in Mud Creek and have suffocated over the winter (Hoskins MS 1964), although in at least one year they have survived after having grown at a high rate during the previous summer (Schultz MS 1954, 1955).

Rawson (1932) reported that female pike in Waskesiu Lake first spawn in either their third of fourth year, but males do not spawn until their fourth year. Schultz, however, found that pike in Waskesiu did not mature until their fourth year, and in most cases not until their fifth. Schultz also reported that females and males of the same age were about the same length and weight. Rawson (1932) and Hare and Kooyman (MS 1973) found adult females to be consistently larger than males. After the fry stage, the pike of the 1953 population that Schultz studied had a similar rate of growth to those in the population studied by Rawson, but the absolute sizes of each age group were larger (Schultz MS 1954, 1955). Schultz attributed this difference to a higher growth rate in the fry stage for the 1953 fish.

The pike fry of Waskesiu were found to feed primarily on Cladocera, tendipedid larvae and other insects (Rawson 1932), while larger pike ate fish almost exclusively; particularly ciscoes and perch (Rawson 1932, Hare and Kooyman MS 1973).

Rawson (MS 1929a, 1932) reported that pike were abundant and angling was excellent for this species in Waskesiu Lake in the years 1928 to 1931, but that by 1934 gill net and anglers catches had declined markedly (Rawson MS 1942, 1945), an event he attributed to overexploitation of the stock by angling. Three-quarters of the lake was closed to angling from 1936 to 1939, and higher angling and gill net catches were reported in 1942 (Rawson MS 1942, 1945). Hare and Kooyman (MS 1973) reported that the pike population of Waskesiu Lake increased considerably from 1966 and 1967 to 1972, and attributed this change to increased spawning success in the Mud Creek watershed as a result of certain fishery management practices there.

The pike of other park lakes have received practically no attention, data on their occurrence, length, weight, and stomach contents being reported as incidental information only (Rawson MS 1929a, Gilmour MS 1950a, Banks and Mayhood in Mayhood *et al.* MS 1973).

b. Walleye

Waskesiu Lake walleye are known to have ascended Mud Creek in large numbers in the past, presumably for the purpose of spawning (Schultz MS 1954, 1955). More recent information, however, indicates that this run has declined dramatically (Hoskins MS 1964, Kooyman unreported data). Another moderately large run is known to occur in the Kingsmere River (Kooyman MS 1970b, Saunders MS 1972), and walleye in spawning condition have been found at the Narrows in fairly large numbers (J. Kilistoff personal communication), although attempts to confirm this finding for 1972 were unsuccessful (Hare and Kooyman MS 1973). Other spawning areas for Waskesiu walleye are presently unknown.

Saunders (MS 1972) found that the 1972 spawning run in the Kingsmere River consisted of 2000 walleye, with a male to female ratio of 1:1. There was a three to four day peak in the run in early May when water temperatures ranged from 3.3 to 10.0 °C (38 to 50°F). Actual spawning was observed only once, but preliminary courtship was observed several times. The small number of walleye eggs found in the river disappeared rapidly, which Saunders attributed to the combined action of egg predation by whitefish (see notes on this species to follow) and washing away by the propwash of boats using the river.

Saunders (MS 1972) also found evidence of walleye spawning in Amiskowan Lake in the form of many walleye fry and fingerlings which he caught at the outlet. Using data on the growth of walleye fry in the Heart Lake hatchery and in Amiskowan Lake itself, he estimated that the Mud Creek spawning run of 1972 must have occurred in late April, one to two weeks before that in the Kingsmere River.

Walleye fry less than 30 mm (1.18 in) in length feed mainly on

Copepoda and Cladocera, while those larger than this apparently feed on insects, although the data on this are inconclusive (Saunders MS 1972). Larger walleye feed almost exclusively on fish, particularly perch and sticklebacks (Hare and Kooyman MS 1973).

The data of Hare and Kooyman (MS 1973) reveal that the walleye in Waskesiu Lake are not sexually mature until their sixth year (that is, age 5+). They found no males older than 10 years, but females reached an age of 14 years. The most numerous age groups in their catches were age 6+, 7+ and 8+, but in 1966 the most numerous were 8+, 9+ and 10+. They attributed this change to an increase in the number of young fish in the population.

Rawson (MS 1942, 1945) reported a very great increase in gill net catches of walleye in 1942 over those in 1928 to 1934, and attributed the difference to an increase in the population size. Hare and Kooyman (MS 1973) reported that gill net catches of walleye increased slightly from 1966 to 1972, and were slightly higher than those of Rawson (MS 1942, 1945) for 1928 to 1934.

Information on walleye in other park lakes is very limited. There is a large run of walleye into the Heart Lakes from Crean Lake in late April to early May, and trap records of the run are available for the period 1967 to 1973. Incidental observations on walleye in Waskesiu Lake and other park waters are given by Rawson (MS 1929a), Gilmour (MS 1950a), Cuerrier (MS 1950), Banks and Mayhood (in Mayhood et al. MS 1973), and Clayton, Tretiak and Kooyman (1971).

c. Lake Trout

Lake trout have been studied primarily in Crean Lake. Spawning takes place in mid-September over rocky reefs, one of the better-known ones being at the south end of the lake near the warden's cabin (Solman MS 1948, Corrigal MS 1973). Other than this, nothing is known of their life history in this lake.

Rawson (MS 1929a) noted that lake trout were very abundant in Crean in the years up to and including 1928. Solman (MS 1948) reported that angling catches had begun to decline by 1939 or 1940, although commercial fishing and angling for this species had been excellent as late as 1926 for the former and 1933 for the latter. Angling catches dwindled to only 2 lake trout in 1948. In 9 gill net sets that year, Solman was able to catch only 4 lake trout. He suggested that the progressively larger and older fish being caught indicated an "aging, unbalanced population", but noted that fairly large concentrations of trout were reported over the spawning reefs during the fall of 1948. Cuerrier (MS 1950) was able to catch 29 lake trout by gill netting in 1949; however, virtually all of them were taken in one set over one reef at the onset of the spawning season.

Lake trout in other lakes of the park are even less well known. Rawson (MS 1929a) believed that they were present in large numbers in Kingsmere Lake in 1928, and reported that they spawn in mid-September there. Lake trout in Wassegam were reported as being plentiful by Gilmour (MS 1950b) and Cuerrier (MS 1951, 1952). Khan and Qadri (1971) concluded that lake trout from the "Lake Waskesiu locality", as part of the Hudson Bay drainage species group, originated from a Mississippi glacial refugium.

d. White Sucker

This species has been studied chiefly by Campbell (MS 1935) in Waskesiu Lake. The following discussion is based primarily on his study.

White suckers spawn in several of the small streams that enter Waskesiu Lake, migrating upstream in Late April and early May for this purpose. They may also spawn in the lake (ripe fish have been collected in the lake in early June) but this has not been observed directly. Substantial numbers of females have been collected from the lake from June to as late as August in which spawning has not occurred and in which the eggs were being resorbed.

Males first spawn at the age of 6 or 7 years, and females at 7 or 8 years. The sex ratio in the spawning run was roughly 1:1 in Campbell's study.

The eggs are washed downstream by the current after they are released by the female, and collect in backwaters over silt deposits. There they hatch into fry which gradually move downstream to the lake, where they school in large numbers in the shallow inshore waters. They remain in shallow water until the end of the second or the beginning of the third growing season, then move farther out into the lake. The larger suckers are common in depths up to 18 m (59 ft), but there are few below 21 m (69 ft) in Waskesiu.

Campbell found the most important food items of suckers in Waskesiu to be tendipedid larvae and pupae (48% of the diet) and molluscs (17% of the diet). Trichoptera, Ephemeroptera, and Chaoborus together made up 11% and Amphipoda 6% of the total diet. Suckers 25 cm (9.8 in) or longer ate greater proportions of tendipedids and amphipods, and lesser proportions of molluscs and entomostraca than did smaller suckers.

Campbell found no evidence of egg predation by suckers in his study, even though he examined the guts of many suckers collected in streams where fish were spawning. Similarly, Saunders (MS 1972) found only a very few eggs in the guts of suckers taken from the Kingsmere River during walleye spawning time.

Rawson (MS 1942) reported that the population of suckers in the total gill net catch had not decreased from 1928 to 1942. Hare and Kooyman (MS 1973) reported that the proportion of suckers in 1972 gill net catches was about twice that found by Rawson (MS 1942). A decrease in the catch from 1966 to 1972 was also noted, which Hare and Kooyman suggested may have been the result of a sucker removal program in the Kingsmere River in 1968 and 1969.

Incidental observations on suckers in Waskesiu and other lakes of the park are reported by Rawson (MS 1929a), Cuerrier (MS 1950), Gilmour (MS 1950a), Schultz (MS 1954, 1955), Hoskins (MS 1964) and Banks and Mayhood (in Mayhood *et al.* MS 1973).

e. Cisco

Aspects of the biology of the cisco have been investigated by Kooyman (MS 1970a) and McLeod (MS 1971) in Waskesiu Lake. Although it was originally believed that there were two species in this lake (Rawson MS 1929a, 1947; Dymond and Pritchard 1930)[1], the work of Kooyman (MS 1970a) suggests that the two apparent types are really one species in the *Coregonus artedii* "complex".

Only one spawning area for the Waskesiu population is presently known: in the Waskesiu River upstream from the dam. Spawning takes place here from October to December (Kooyman MS 1970a).

McLeod (MS 1971) found that smaller ciscoes consumed mostly zooplankton and selected certain groups on the basis of size. Larger ciscoes consumed larger food items such as insect pupae and fish in addition to zooplankton.

1. Koelz (1931) reported only one species from this lake based on the examination of only 3 specimens.

Although the fish were both diurnal and nocturnal feeders, they had one or two peak feeding times per 24 hour period.

Hare and Kooyman (MS 1973) reported that ciscoes had undergone wide fluctuations in abundance in the past 40 years, on the basis of a comparison of their gill net data with that of Rawson (MS 1942, 1945).

Incidental observations on ciscoes in Waskesiu and other park lakes have been provided by Rawson (MS 1929a), Cuerrier (MS 1950), Gilmour (MS 1950a), Clayton Franzin and Tretiak (1973), and Banks and Mayhood (in Mayhood et al. MS 1973).

f. Lake Whitefish

Whitefish were the subject of a commercial fishery in Waskesiu in the years leading up to the establishment of Prince Albert Park (Rawson MS 1929a), and for many years thereafter (Cuerrier in correspondence).

Rawson reported that Waskesiu Lake whitefish attained weights of 3 to 4 lb (1.4 to 1.8 kg), although they were slightly smaller than those in Kingsmere Lake. He felt that the 1921 to 1927 commercial catch records indicated that the whitefish were abundant in Waskesiu, Kingsmere, and Crean Lakes.

Rawson (MS 1929a) found that tendipedids composed the greatest proportion of the diet and that sphaeriids were next in importance. In Kingsmere, whitefish caught in shallow water had fed largely on amphipods and snails, while in deepwater catches whitefish stomach contents were similar to those of Waskesiu whitefish. Hare and Kooyman (MS 1973) report similar contents of whitefish stomachs in their 1972 samples. Saunders (MS 1972), however, found this species in the Kingsmere River during the walleye spawning run to be feeding almost exclusively on walleye eggs.

Incidental observations on whitefish in Waskesiu Lake and other park waters are provided by Rawson and Moore (1944), Rawson (1945, 1960), Cuerrier (MS 1950), Gilmour (MS 1950a), and Banks and Mayhood (in Mayhood *et al.* MS 1973).

Discussion

The total quantities of net plankton, bottom fauna, and fish in Waskesiu Lake are all consistently high relative to those in other western Canadian or north temperate lakes. Plankton standing crop is among the highest of 26 western Canadian lakes discussed by Rawson (1953, 1960, 1961), being exceeded only by that in the Saskatchewan lakes Churchill, Big and Little Peter Pond, Ile a la Crosse, and Last Mountain. Bottom fauna standing crop in Waskesiu is higher than that of all but 2 of 20 large Canadian lakes examined by Rawson (1955, 1960, 1961), and the former commercial fish production of the lake is second only to that of Lake Erie in the group of 34 north temperate lakes discussed by Ryder (1965). Rawson (1953, 1955, 1960, 1961) attributed these high crops to the low mean depth and relatively high total dissolved solids of the lake.

The data required for a similar comparison for other park lakes have not been reported.

The large discrepancy between Rawson's earliest assessment of bottom fauna standing crop in Waskesiu (Rawson MS 1929a) and that reported in his later publications (Rawson 1960, 1961) cannot be satisfactorily explained on the basis of the available evidence. It may be that the later values were calculated on the basis of more data than were available for the earlier estimate. It does not appear that Rawson simply added Stevenson's (MS 1942) estimates of littoral fauna standing crop to the early benthic standing crop figure to arrive at a value for total "bottom fauna", since the result would have been much lower than that given in the later publications.

It is noteworthy that the data on plankton, benthic fauna and littoral fauna for Waskesiu Lake all show greater standing crops of these groups in the upper lake than in the lower lake. Since the species involved are the same in both parts of the lake and are subject to broadly similar physical conditions, these differences must reflect a higher biological production in the upper lake. This higher production is probably related to the shallower nature and slightly higher summer temperatures of the upper lake relative to the lower.

The Canadian Oceanographic Identification Centre (MS 1972) has reported on its examinations of plankton samples collected from Prince Albert National Park waters in 1971. Mayhood (in Mayhood and Kooyman unreported data 1971) was unable to confirm the occurrence of several species reported by the COIC in a re-examination of the same samples, even when the species had been described as being "abundant" in a particular sample. In addition, several species not reported from particular samples were frequently found. The present author therefore feels that the COIC findings are unreliable, and has not included them in the section on zooplankton composition.

Except for certain groups, the benthic and littoral organisms found in park waters are very poorly known taxonomically. The Odonata, Trichoptera, Culicidae, Hirudinea, Hydracarina, Heteroptera, Mollusca and some members of the Coleoptera have been identified to species in one or more studies, but organisms in other bottom or littoral dwelling groups have been identified no further than order or even phylum. The reason for this lies in the enormous diversity of species known to occur in the littoral and benthic zones, the lack of adequate keys and taxonomic treatments of most of the groups found in western Canada, and the consequent highly specialized knowledge required to identify the animals to the species level.

The ecology and life history of the various exploited fish species in park waters is not adequately known. In Waskesiu Lake there has been no comprhensive study of the walleye, and Rawson's (1932) original study of the pike, although supplemented by the studies of Schultz (MS 1954, 1955), Hoskins (MS 1964) and Kooyman (MS 1970b and unreported data), has been made obsolete by changes in the spawning grounds of, and angling pressure on, this fish. In other heavily fished lakes there is essentially no life history or ecology information on even the exploited species. Such data are essential to a sound fishery management program. At the same time, more information on the unexploited fishes is required to evaluate their role in the ecology of park waters.

Rawson (MS 1942, 1945) assessed changes in the population sizes of Waskesiu Lake fishes on the basis of their percentage composition of gill net catches. This procedure is theoretically unsound, since the proportion of the catch comprised of any one species is dependent on the number of each other species in the catch. Thus, a drop in the percentage of the catch made up of walleye, for instance, could be due to an increase in one or more other species in the catch rather than to a decrease in the abundance of walleye. Hare and Kooyman (MS 1973) overcame this problem by comparing the number of fish caught per standard gill net set.

The data from these two studies were used to calculated the numbers of fish per 100 yd of net in an attempt to determine if there had been changes in the abundance of particular species since Rawson's time (Table 5). Although there are apparently large differences in the catches made by the two sets of investigators, these are explainable on the basis

Table 5: Number of fish caught per 100 yards of gill net set in Waskesiu Lake, Prince Albert National Park, 1928 to 1972. Data from Rawson (MS 1942) and Hare and Kooyman (MS 1973). Number of yards per set figures for 1966, 1967 and 1972 from Kooyman (personal communication).

Year	1928-30	1932-33	1934	1942	1966	1967	1972
Yards/set	$\pm$ 200	$\pm$ 200	$\pm$200	180	125	125	125
No. of sets	24	20	33	20	14	18	13
Total yards of net	4800	4000	6600	3600	1750	2250	1625
Fish caught/100 yd							
Pike	4.9	1.4	0.8	3.5	1.1	1.0	7.5
Walleye	2.2	1.8	1.7	20.6	3.7	5.7	5.4
White sucker	8.2	4.0	4.0	12.1	35.6	49.8	24.1
Cisco	21.9	8.4	9.6	3.6	61.5	71.7	14.5
Whitefish	2.8	1.4	2.0	1.1	2.9	1.6	1.2
Perch	13.3	10.8	12.8	3.9	51.8	35.5	47.9
Total	54.0	29.8	31.5	42.6	153.1	167.0	102.5

of the two to three times greater efficiency of the nylon nets used by Hare and Kooyman in relation to the cotton and/or linen nets that must have been used by Rawson (Lawler 1950, Hewson 1951, Atton 1955, Pycha 1962). These data thus cannot be used as evidence of changes in the abundance of the fish species in Waskesiu Lake.

Even within each study, differences in these catch per unit effort data do not necessarily reflect differences in species abundance. Such conclusions could be justified only if the netting had been done with similar equipment, for similar lengths of time, during similar times of the year, and at similar locations in all the habitat types within the lake. Rawson (MS 1942) and Hare and Kooyman (MS 1973) both present evidence that some of these requirements were not met.

Summary and Conclusion

Studies completed to date on the plankton of Prince Albert Park lakes have identified many, perhaps most, of the planktonic species that occur in park waters, and have provided an estimate of the commonness or rarity of each species. They have not indicated the seasonal or year to year variability in the plankton composition of any lake, nor have they been quantitative.

Studies completed to date have identified many, perhaps most, of the aquatic macrophytes that occur in Prince Albert Park waters, and have provided some estimate of their relative abundance. There have been no quantitative studies attempted.

The benthic and littoral organisms found in park waters are poorly known taxonomically: the animals have been identifed no further than order in most studies. There have been only two truly quantitative studies, and these have been restricted to Waskesiu Lake. There have been no studies of the seasonal or year to year variability of the littoral or benthic fauna of any lake in the park. Also, there have been no studies of the "Aufwuchs"[1] per se, although certain species from that community type have been collected in the course of other investigations.

The life histories of the northern pike and the common sucker in Waskesiu Lake have been worked out, although the studies on the former may have been rendered obsolete by changes in spawning habitat and angling pressure. The life history of the walleye in Waskesiu has received some study, but is still incompletely known. The life histories of other fish species known to occur in the park have not been worked out for any park waters.

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1. the communities of organisms attached to, or moving upon, a submersed substrate, but which do not penetrate into it (Reid 1961).

FISHERIES MANAGEMENT

Crean Lake

Fishery management activities in Crean Lake have been directed toward rehabilitation of the lake trout sport fishery which collapsed in the 1940's (Solman MS 1948). The investigations of Solman and of Cuerrier (MS 1950) suggested that the trout population was made up almost entirely of old fish. Opinions on the cause of the decline of the fishery were numerous, and included

- overfishing by the commercial fishery of 1943-45 (Solman MS 1948, Kooyman MS 1970b)
- lack of skill on the part of anglers (Cuerrier MS 1950)
- increases in the number of whitefish (which ate the trout eggs) and of walleye (which ate the fry) (Cuerrier MS 1951)
- increases in whitefish and suckers which ate the trout eggs Corrigal (MS 1973)
- a decrease in lake level which adversely affected spawning (Cuerrier MS 1951, Kooyman MS 1970b)
- an increase in lake level which allowed filling in of crevices in the spawning reefs, and greater egg predation by suckers and whitefish (Corrigal MS 1973)

Although any of these hypotheses might well be true, none were adequately tested.

Nearly 3000 adult lake trout were transferred from Wassegam Lake, and 5400 yearlings were planted in various years from 1951 to 1968, in an attempt to balance the population (Cuerrier MS 1951, 1952; Kilistoff MS 1964; Kooyman MS 1970b). Most recently, an attempt to improve one of the spawning reefs with fresh crushed rock has been made (Corrigal MS 1973). There is presently no evidence of improved angling for trout, although the more recent activities would not be expected to have any noticeable effect for a number of years (Kooyman MS 1970b).

No other serious attempt has been made to manage fish stocks in this lake, although a token 900,000 walleye sac fry were planted in 1967 to 1968.

Waskesiu Lake

Initial fishery management activities concentrated on attempts to introduce smallmouth bass into this lake (Rawson MS 1929a and b, MS 1936, 1938, 1940, MS 1942, 1945, 1947; Rogers MS 1941c); however, later angling results and investigations indicated that the introduction had failed -- probably because of spring temperatures that were too low for continued successful spawning (Solman MS 1949; Kooyman MS 1970b, 1971; Marshall and Johnson 1971).

A commercial whitefish fishery operated on Waskesiu Lake after the formation of the park as part of a program recommended by Rawson (MS 1929a and b). This enterprise apparently removed 13,636 to 22,727 kg (30,000 to 50,000 lb) of whitefish per year (Cuerrier 1957 correspondence). Rawson had recommended the fishery to make "this excellent food fish" available to park visitors, to make use of the large tendipedid production of the lake, and to keep whitefish, suckers and burbot from increasing in numbers when the "game" fish (pike and walleye) were exploited. Cuerrier (1957 correspondence) objected to the fishery on the grounds that the relationship between the game fish and the whitefish is not well enough known, that whitefish could be a forage species for game fish, that the removal of 30,000 to 50,000 lb of whitefish would in any case have little effect on the population, and that the netting would capture game fish that would be of greater benefit to anglers. The commercial fishery was subsequently discontinued.

Pike have also been the subject of management activities in Waskesiu Lake. A dramatic decline in angling success for this species by the mid-1930's had been forecast by Rawson (MS 1929a and b, 1932) and had become apparent by 1934 (Rawson MS 1942, 1945). Rawson attributed the decline to overexploitation and wasteful fishing practices. His recommendations that anglers be educated to conserve fish, that minimum size limits be imposed to ensure that each fish was able to spawn at least twice, that the season remain closed until at least May 15 each year to protect fish on their spwning grounds, and that possession limits be reduced (Rawson MS 1929a and b, 1932) had apparently not been acted upon by 1946 (Solman 1946 correspondence). Three-quarters of the lake was closed to angling from 1936 to 1939, and angling for pike had improved by 1942 (Rawson MS 1942, 1945).

Obstruction of the Mud Creek spawning run by beaver dams in various years since the early 1940's has frequently been dealt with by removal of the beaver and the dams (eg; Rogers MS 1941a; Schultz MS 1954, 1955). Whether spawning in this creek is essential to the maintainance of the the pike population of Waskesiu, and whether manipulation of the beaver population is a legitimate fishery management practice in a National Park has been the subject of considerable debate in National Parks correspondence for many years. With regard to the former question, observations on the numbers of young pike migrating downstream in Mud Creek in various years (Schultz MS 1954, 1955; Kooyman MS 1970b) show that this stream is capable of contributing many thousands of young pike to Waskesiu Lake. In addition, Hare and Kooyman (MS 1973) reported collecting many more pike in 1972 than in the late 1960's, and noted that the 1965, 1966 and 1967 year classes were the most abundant. A special effort was made during those years to ensure that pike were able to migrate up Mud Creek to spawn; thus there is some circumstantial evidence that the Mud Creek spawning ground is important for the maintenance of the pike population at a high level. In any case, the practice of facilitating the spawning migration by removing beaver dams from Mud Creek has been discontinued.

The walleye of Waskesiu Lake have only recently been the subject of fishery management projects. Information on the size of the walleye spawning run in Mud Creek shows that, although at least 2300 walleye had migrated upstream in 1953 (Schultz MS 1954, 1955), the run had declined to nil in 1963 and had remained very low until at least 1967 (Kooyman unreported data). Hare and Kooyman (MS 1973) reported that the abundance of walleye was very low (based on their percentage composition of gill net catches), and that angling was poor judging from creel census results. An extensive fry planting program was undertaken beginning in 1965 in an attempt to supplement the natural walleye stock in the lake (Kooyman MS 1970b), spawn being taken from walleye of Crean and the Heart Lakes for this purpose. At the same time, spawn was recovered from the Kingsmere River run and reared artificially in an attempt to salvage the eggs from destruction by boat disturbance and suspected fish predation (Kooyman MS 1970b).

Attempts to monitor the success of the plantings have been unsuccessful for the most part, although a certain amount of circumstantial evidence suggests that the stocking may be having some effect. Fry planted in the lake have disappeared from meter net catches within days after stocking, but this may well be the result of inadequate sampling methods rather than a real mortality of fry. Considerable night seining in 1970, 1971 and 1972 produced small numbers (50 to 60) of walleye fingerlings, whereas extensive seining in 1967 and 1968 failed to produce even a single specimen (Kooyman unreported data). Also, gill netting in 1972 produced some young (age 4+ and lower) walleye. Such young fish had been virtually absent from samples collected in 1966 to 1969 (Hare and Kooyman MS 1973).

An attempt was made in 1968 and 1969 to eliminate suspected predation of walleye eggs by suckers in the Kingsmere River, by removing 23,000 suckers from the spring run (Kooyman MS 1970b, Hare and Kooyman MS 1973). The success of this project is unknown, but this removal may be responsible for lower catches of white suckers in the 1972 gill net samples relative to catches in 1966 and 1967 (Hare and Kooyman MS 1973).

Other Lakes

The Heart Lakes received considerable attention with regard to the establishment of a smallmouth bass population (Rawson MS 1936, MS 1942, 1945, 1947) but this attempt, as in Waskesiu, failed because of low temperatures during the spring spawning period (Solman MS 1949, Kooyman MS 1970b, Marshall and Johnson 1971). Walleye eggs have been collected in the Heart Lake - Crean Lake channel since 1967 and have been used in the stocking of Waskesiu and several other park lakes, plus some lakes outside the park.

Plantings of brook trout (*Salvelinus fontinalis*) and walleye in Halkett Lake in the 1950's have not been successful (Schultz 1956, Kooyman MS 1970b), but plantings of lake trout and cisco in 1966, 1968 and 1969 have shown initial success (Kooyman MS 1970b).

Namekus Lake received small numbers of walleye fry in 1969. The success of this planting is not yet known (Kooyman MS 1970b).

A small number of walleye fry have been planted in Kingsmere Lake in recent years, but no intensive management of the fishery of that lake has been attempted (Kooyman unreported data).

Creel Census

Some form of angler harvest survey has been in operation, with short-term interruptions, since 1940 (Solman 1951). It originally involved the voluntary provision by the angler of data on the number, weight, length, and species of fish caught, the number of hours spent angling and the number of anglers in the party. An interview type survey was initiated by A. H. Kooyman in 1967 and operated until 1971. The results of some of these surveys have been reported (Solman 1950; Cuerrier and Ward 1951, 1952, 1953; Foskett MS 1961a and b, MS 1962), but long-term changes revealed by these figures have not been analysed.

Discussion

The fishery figures for Crean Lake discussed by Solman (MS 1948) suggest, but by no means conclusively show, that the lake trout fishery declined as a result of commercial over-fishing. In spite of the attempts to increase the number of spawning adults (Cuerrier MS 1951, 1952; Kilistoff MS 1964; Kooyman MS 1970b), and in spite of very limited angling pressure, the sport fishery has remained depressed. The most recent transplant project could have no effect on angling success for a number of years, in view of the slow growth and maturation rates characteristic of lake trout (Kooyman MS 1970b). It is also possible that the depressed sport fishery is the result of the few anglers fishing for lake trout in recent years, or the result of a real failure of the trout population to increase. Further work would be required to determine which of these potential explanations is true.

Although there is some circumstantial evidence that the stocking of walleye fry in Waskesiu Lake is contributing to the walleye population, there is presently no way of evaluating the results of past stockings conclusively. This is because there is no means of distinguishing the "Heart - Crean" walleyes which were planted as fry from the native "Waskesiu" walleyes. The present halt in stocking will enable investigators to judge if the year class abundance of walleyes in "stocked" years is greater than in "unstocked" years. An unusual abundance of "stocked year" fish in the population would constitute further evidence for the success of the stocking program.

The gill net catch data reported by Hare and Kooyman (MS 1973) for 1972 provide circumstantial evidence of this type for the success of the pike management program (see page 58 for a discussion of this point). For the reasons already discussed in the previous section (page 52), their observation that gill net catches of pike in 1972 were greater than in the late 1960's need not reflect differences in the size of the pike population, the possibility that the relative abundance of the year classes in the catch was strongly influenced by net selection cannot be ruled out, and it is quite possible that natural reproduction was just naturally high in 1965, 1966 and 1967 independently of the management activities in Mud Creek. More detailed experimental work is required to determine if facilitation of the pike spawning run in Mud Creek has been, or can be, an effective management method and whether such action is required to maintain the pike population in the face of angling pressure and the loss of other spawning habitat in Lake 1051.

The original type of "voluntary" creel census used in Prince Albert Park suffered from the disadvantage that there was no way of guaranteeing the accuracy or uniformity of collection of the data. Under the system it was possible and even likely that anglers would fail to report nil catches, that they would measure the fish improperly, that they would not report released fish, and that they would generally provide unreliable data. The institution of an interview type creel census by Kooyman should have overcome a considerable amount of the bias inherent in the older system.

Summary and Conclusion

Fishery management projects on Crean Lake have not yet been successful in improving angling for lake trout.

Studies on pike and walleye spawning in Mud Creek have shown that this stream is capable of supplying many thousands of fingerling pike and hundreds of walleye fingerlings to Waskesiu Lake, but have not demonstrated that spawning in Mud Creek is essential to the maintenance of the populations in the face of angling pressure and (in the case of pike) the loss of former spawning grounds in Lake 1051.

There is some circumstantial evidence that the walleye fry stocking program in Waskesiu Lake has been successful in contributing fingerling and older fish to the population, but further study is required to verify this.

The stocking of lake trout and cisco in Halkett Lake has shown initial success.

Two attempts to introduce exotic species into the park have failed: the introduction of smallmouth bass into Waskesiu, Shady and the Heart Lakes, and the introduction of brook trout into Halkett Lake.

GENERAL DISCUSSION AND CONCLUSION

The work completed to date has provided a general characterization of some of the larger lakes, and of the small lakes in the southern portion of Prince Albert National Park.

Of all the lakes, Waskesiu is the best known. It is a large lake having two distinct basins. The upper lake is long, narrow and shallow, breaks up and freezes up earlier, tends to be warmer in summer, and has a somewhat higher biological productivity than the lower lake, which is roundish-lobate, relatively deep, and cool in the summer. Thermal stratification in both parts of the lake is unstable, being easily disrupted by strong windstorms, and bottom dissolved oxygen reaches very low levels during periods of prolonged stratification. The thermal and dissolved oxygen regimes, along with the high standing crops of plankton and bottom fauna and the former high commercial fish yield all mark the lake as eutrophic.

Crean Lake resembles Waskesiu, but is larger and has a greater proportion of deep water that lends greater stability to thermal stratification. Dissolved oxygen in the bottom water can reach low levels during stratification, but has never been known to be as low as has sometimes been observed in Waskesiu. The existence of extensive areas of deep water in Crean Lake, coupled with adequate levels of oxygen in the hypolimnion, are important factors which have allowed the existence of a natural lake trout population in the lake. Even though lake trout have ready access to Waskesiu Lake via the Kingsmere River from Kingsmere Lake, the small area of deep, cool water available, and the very low dissolved oxygen levels in Waskesiu have mitigated against the establishment of a lake trout population.

Kingsmere Lake differs from Waskesiu and Crean in being very much deeper over a large proportion of its area. This large proportion of deep water makes Kingsmere a cold, oligotrophic lake. Thermal stratification is stable throughout the summer, but dissolved oxygen levels in the hypolimnion are always high. The combination of a large, cool hypolimnion with high dissolved oxygen provide ideal conditions for the natural population of lake trout in the lake.

Halkett Lake is mainly shallow, but a restricted area of very deep water makes it the deepest lake in the park. Thermal stratification is stable throughout the summer, and dissolved oxygen in the hypolimnion is moderately high. This lake is decreasing in size apparently through evaporation, which has resulted in a progressive increase in its salinity, changes in the chemical composition of the water, and perhaps deposition of marl on its bottom muds.

Namekus Lake is similar to Waskesiu, but is considerably smaller and relatively deeper. It probably has a stable thermocline and low dissolved oxygen in the hypolimnion in summer.

The majority of the lakes in the southern portion of the park are shallow, polymictic, warm and well-oxygenated in the summer and have light penetration to the bottom over most of their areas. Ice cover and snow prevent photosynthesis in winter, and decomposition leads to pronounced deoxygenation of the water. Concentration of constituents by freezing of a considerable proportion of the water, groundwater flow, and dissolution of chemicals from the bottom mud under strong reducing conditions probably account for the much higher concentrations of dissolved substances in winter than in summer in these lakes.

A few of the small lakes are relatively deep and develop in some cases a pronounced thermocline and a severe hypolimnetic oxygen deficiency in summer. Winter conditions in these lakes are unknown, but it seems likely that oxygen depletion would be less severe, and dissolved solids concentration less pronounced than in the shallow lakes.

The bottom fauna and plankton of the small lakes differ in composition from those in the larger lakes, and it is likely that the composition of the communities in the saline lakes differ from dilute lake communities. For example, certain aquatic macrophytes found in the dilute lakes have not been found in the saline lakes, and vice versa.

The outline of the limnology of the park presented by this report could be used as the basis of an interpretive program that would emphasize the relationships within the aquatic habitats and their relationships to the other aspects of the park. For example, such a program might consider what processes formed the lake basins, and how the shape of the basins so formed has influenced the thermal and chemical features and the biological communities of the lakes. Waskesiu, because it has been well-studied and offers the opportunity to illustrate several limnological principles by comparing and contrasting the upper and lower portions of the lake, would make a good subject for the program. The very different natures of the saline and dilute lakes, the small shallow and small deep lakes, and the other large lakes could then be illustrated.

This review has pointed out some potential problems in the preservation and management of the park. It has been pointed out that both Namekus and Wabeno Lakes could be affected by activities in that part of their drainage basins that lie outside the park. In the case of Namekus Lake, resort development on McPhee Lake outside the park is the potential problem.

Steps should be taken to ensure that flow from McPhee Lake to Namekus is not blocked off, and that any exotic fish species planted in McPhee cannot move into the park. In the case of Wabeno Lake, steps should be taken to prevent logging of the drainage basin outside the park. Aside from the damage to the aesthetic value of the northern shore, a decline in water quality is likely to result from logging operations. If the area must be logged, its effects on the lake should be monitored.

Another management problem concerns the sliding of the shorelines of Waskesiu and Crean Lakes. The possibility that artificial manipulation of the water levels in these lakes is responsible for the damage should be investigated, and steps should be taken to prevent further damage if the sliding is determined to be due to human interference.

The apparent slow drying up of Halkett Lake constitutes a third management problem. An attempt to verify this contention should be made. If the lake is in fact decreasing in size, the possibility that human interference is responsible should be considered. One possibility is that the logging companies operating in the area before the park was established may have diverted a major tributary to the lake.

Limnologically speaking, Prince Albert Park is a transition area. It lies in the "forest zone of freshwater lakes" (Northcote and Larkin 1963), between the dilute lakes of the Canadian Shield and the highly saline waters of the parkland. It is of scientific interest as a region in which large numbers of lakes characteristic of the zone are protected from human modification. From a purely scientific point of view, therefore, it is important to have baseline data on all types of aquatic habitats in the park against which changes in waters both within the park and beyond its boundaries can be measured. Such baseline data are of further importance as a basis for the proper interpretation and management of the park.

Considered in these terms, our knowledge of the limnology of the park is far from adequate. There have been no studies of the running waters, temporary waters, or northern lakes. There is little information on the biological communities of Kingsmere, Crean, Namekus, Halkett or the Heart Lakes. Finally, the seasonal and year-to-year variation in the waters is unknown (with the exception of Waskesiu Lake, for which some data are available).

Further work on the management of the sport fisheries of the park is also required. The causes for the continued depression of the lake trout fishery in Crean Lake are unknown and should be determined before any further attempts are made to rehabilitate it. The preliminary indications of the success of the walleye and pike management programs in Waskesiu Lake require verification. Similarly, the success of the lake trout and cisco stockings in Halkett Lake should be determined. Perhaps most important of all, angling success in the heavily fished lakes, and the fish populations themselves, should be monitored.

RECOMMENDATIONS

Basic Limnology

1. Lake, stream and temporary waters survey: A survey of various streams and temporary waters representative of all types found in the park should be made. The survey should attempt to define the variety of temporary and running water habitats and their communities found within the park. At least a few of these waters should be studied more intensively throughout the year to determine the nature of any seasonal changes that may occur. At the same time, a similar survey of the northern lakes should be made, and again, at least some of these plus a few southern lakes should be studied more intensively throughout the year.

A study of this type would require at least a year and a half. Many of the streams and temporary ponds in the southern portion of the park would be accessible by road or trail, but the northern lakes and streams would require aircraft transportation. Projected expenses are:

Biologist (salary)	$21000
Technician (salary)	10500
Field expenses (assumes 150 field days each for 2 people @ $20 per person/day)	6000
Technical, secretarial, identification assistance	3000
Transportation (Aircraft, vehicle, boats)	4500
Total	$45000

2. Biological surveys of the "major" lakes: A thorough biological survey of Halkett, Namekus, Heart, Crean and Kingsmere Lakes should be conducted. The aim of the survey should be to outline both quantitatively and qualitatively the planktonic, benthic, littoral and fish communities

of the lakes throughout the entire year. Such a survey would serve as a detailed baseline study against which changes in the lakes (all of which are likely to receive considerable usage) could be assessed. The proposed study would require at least 18 months to complete. Projected expenses are:

Biologist (salary)	$21000
Technician (salary)	10500
Field expenses (150 field days each for 2 people) (@ $20/person/day)	6000
Technical, secretarial, identification assistance	3000
Transportation (vehicle, boats)	3000
Total	$43500

Special Studies

1. Crean Lake lake trout study: A preliminary study of the Crean lake trout population should be undertaken to determine if there is significant natural reproduction in the lake, and if there is any evidence of significant predation by other fish on the eggs and young. The study would involve a gill netting survey, examination of the gut contents of potential predators on the spawning reefs during the spawning and incubation periods, and direct observations on spawning and egg incubation. The study would require one year to complete. Projected costs are:

Biologist (salary)	$14000
Student assistant (wages)	2500
Field expenses (100 field days each for 2 people) (@ $20/person/day)	4000
Technical, secretarial assistance	1500
Transportation (vehicle, boats)	2000
Total	$24000

2. Wabeno and Namekus Lakes study: An attempt should be made to determine whether present development of the watersheds of these lakes outside the park are now, or will be in the future, modifying the physical, chemical or biological features of the lakes or their inlet streams. The initial stage of the investigation would involve only the verification that the problem exists, and would require some preliminary examination of the areas in the field, inquiries of provincial government officials, and perhaps some preliminary sampling and analysis. A report should be prepared on the preliminary examination in which specific recommendations for further action would be made. It is anticipated that this initial investigation should cost no more than $5000.

3. Halkett Lake study: The contention that Halkett Lake is decreasing in size should be verified by field observations and/or air photo interpretation, and an attempt should be made to determine if any tributaries to the lake have been blocked or diverted. A report on this preliminary study should make specific recommendations for further action, if any is required. The initial investigation should cost no more than $5000.

4. Shoreline study, Waskesiu and Crean Lakes: The possibility that water level manipulation in these lakes, or some other human phenomenon, is responsible for the sliding of the shorelines at several points should be investigated. Initially, this would only require the examination of the areas in the field by a specialist, perhaps a soils engineer, who would make recommendations for further action if necessary. This initial phase of the investigation should cost no more than $5000.

Routine Studies

Two ongoing routine studies should be undertaken to form the basis for the sound management of the sport fisheries of park lakes.

1. <u>Creel census</u>: An interview-type creel census (angler harvest survey) should be re-instituted. The survey would provide essential information on angling success and on the exploited portion of the fish populations in the heavily-fished lakes (Waskesiu, Kingsmere, Crean, Lost, Bagwa, Lily, the Heart Lakes, Namekus, Halkett). The data collected by A.H. Kooyman should be used to develop a less intensive unbiased sampling procedure which could provide adequate data using only one or two interviewers to cover all the lakes. This initial step of setting up the sampling pattern would require about 8 months, and its projected costs are:

Biologist (salary)	\$9500
Technical, secretarial assistance, computer time, etc.	3000
Total	\$12500

Once the sampling system was set up, the costs would involve the wages of one or two student interviewers for the fishing season, their expenses, and the analysis and write-up time of a biologist every year.

Biologist (salary)	\$2500
Interviewers (wages for one)	2500
Secretarial assistance	500
Interviewer expenses (130 days) (\$20/day)	2600
Total (per year)	\$8100

2. <u>Periodic fish population surveys</u>: Periodic surveys of the fish populations in the heavily fished lakes should be initiated. It is probably not feasible to make regular estimates of population size, but it is possible to use standardized sampling techniques to monitor changes in fish abundance. Such a program would involve making a series of standardized gill net sets in summer every three years. This program,

besides monitoring fish abundance, would also provide essential information on year class abundance, growth rates, food consumed, spawning success, fish condition and parasite load. These data could be used in conjunction with the crrel census information to assess the effects of angling on the populations. The project would require one year to complete each time it was done. Projected costs are:

Biologist (salary)	$14000
Technician (salary)	7000
Field expenses (100 days for 2 people @ $20/day/person)	4000
Secretarial assistance	1000
Travel (vehicle, boat)	2000
Total	$28000

Notes on the recommendations: Costs are based on Federal Government rates of pay for an experienced biologist, inexperienced technician, and Government-sanctioned field expenses of $12.50 per day plus accommodation. It is assumed that all equipment is provided, and transportation is rented. Consultant's fees will probably be 1.5 to 2.5 times the above estimates to provide their profit and cover unanticipated expenses. In some cases, costs could be reduced by combining projects. For instance, it would be possible to combine the Crean lake trout study with a periodic survey of the fish populations in the lake.

The projects should have the following order of priority (in decreasing order): Wabeno and Namekus study, Halkett Lake study, shoreline study (Waskesiu and Crean), creel census, Crean Lake trout study, fish population surveys, major lakes biological survey, lake, stream and temporary waters survey. Those projects involving known or potential problems have been given the highest priority.

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<u>Note</u>: References marked with an asterisk (*) do not specifically refer to the park.