THE BURROWING MAYFLIES OF LAKE WINNIPEG, MANITOBA, CANADA

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Introduction

The following study was part of a joint investigation by staff of the Freshwater Institute, Fisheries Research Board of Canada, to study the chemical limnology, phytoplankton, primary production, zooplankton and zoobenthos, of Lake Winnipeg. The lake, which is a remnant of Glacial Lake Agassiz, according to BRUNSKILL (1973), has a surface area of 23,750 km^2, mean depth of 10.6 m, maximum depth of 32 m, secchi disc visibility of 5–50 cm in the south basin and 1–3 m in the north basin, is essentially isothermal during the open water period and receives a very high nutrient loading from the rivers which enter it. BRUNSKILL (1973) reports 5,000 metric tons of phosphorus and 62,000 tons of nitrogen were being added annually to lake over the period, 1968–1970. However, at least in the south basin, primary production appears to be limited by turbidity rather than nutrient supply.

The burrowing mayflies of Lake Winnipeg have received a considerable amount of attention over the years, mainly because they are an important item in the diet of the commercial fish in the lake. BAJKOV (1930) studied the relationship between substrate types and fauna of the lake and recorded *Hexagenia limbata* as accounting for 10% of the fauna in the "mud bottom areas". NEAVE (1932, 1934) carried out an extensive study of the mayflies over the period 1927–1932. Manitoba Provincial Government biologists, in investigations of the mayflies of the south basin of the lake in the 1960's, have reported a serious decline in the *Hexagenia* populations over the period 1963–67, a decline not attributable to pollution effects from the Red and Winnipeg rivers (J. A. CROWE, personal communication).

Methods

During the open water season of 1969 the benthos of Lake Winnipeg was sampled at up to sixty stations. Sampling was carried out in June, early July, late July, September, early October and late in October. At each station visited, attempts were made to take three tall, six inch Birge-Ekman grabs. Where the substrate was too coarse or too hard the samples were taken using a Ponar grab. Samples were sieved through a 200 μ mesh sieve when possible but when sandy substrates were encountered a 400 μ mesh sieve was used. All samples were preserved in 4–10% formalin and sorted to order using the low power of a dissecting microscope. Subsequent sorting to species was carried out where possible and measurements made of either total body length or the length of some chitinised body part from which estimates of body length could be made. For the burrowing mayflies, total body length was measured as the distance between the front of the frontal process and the base of the cerci. Density

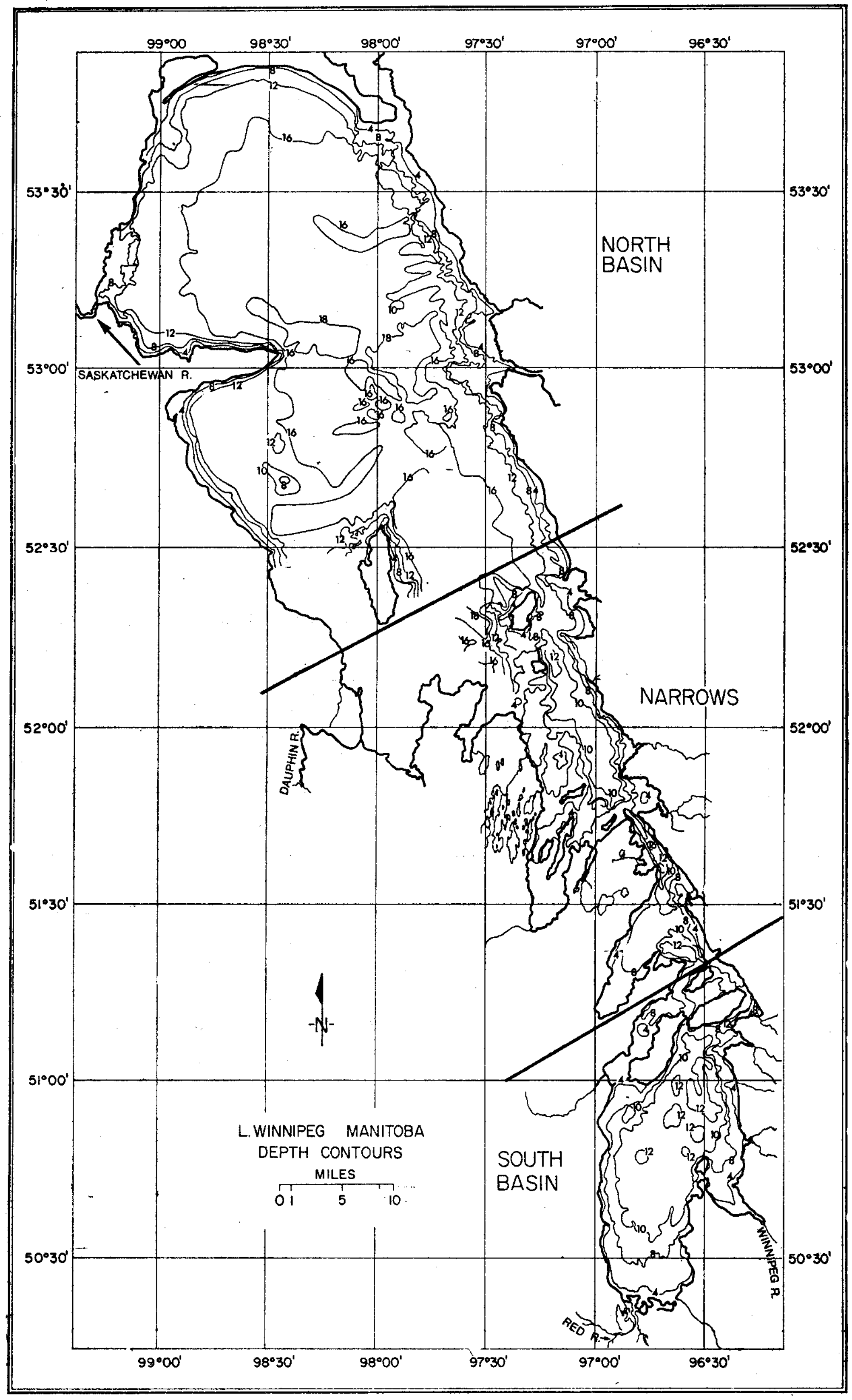

Fig. 1. Map of Lake Winnipeg showing depth contours (partly taken from Canadian Hydrographic Service maps 6240 and 6241, with additions by G. J. Brunskill)

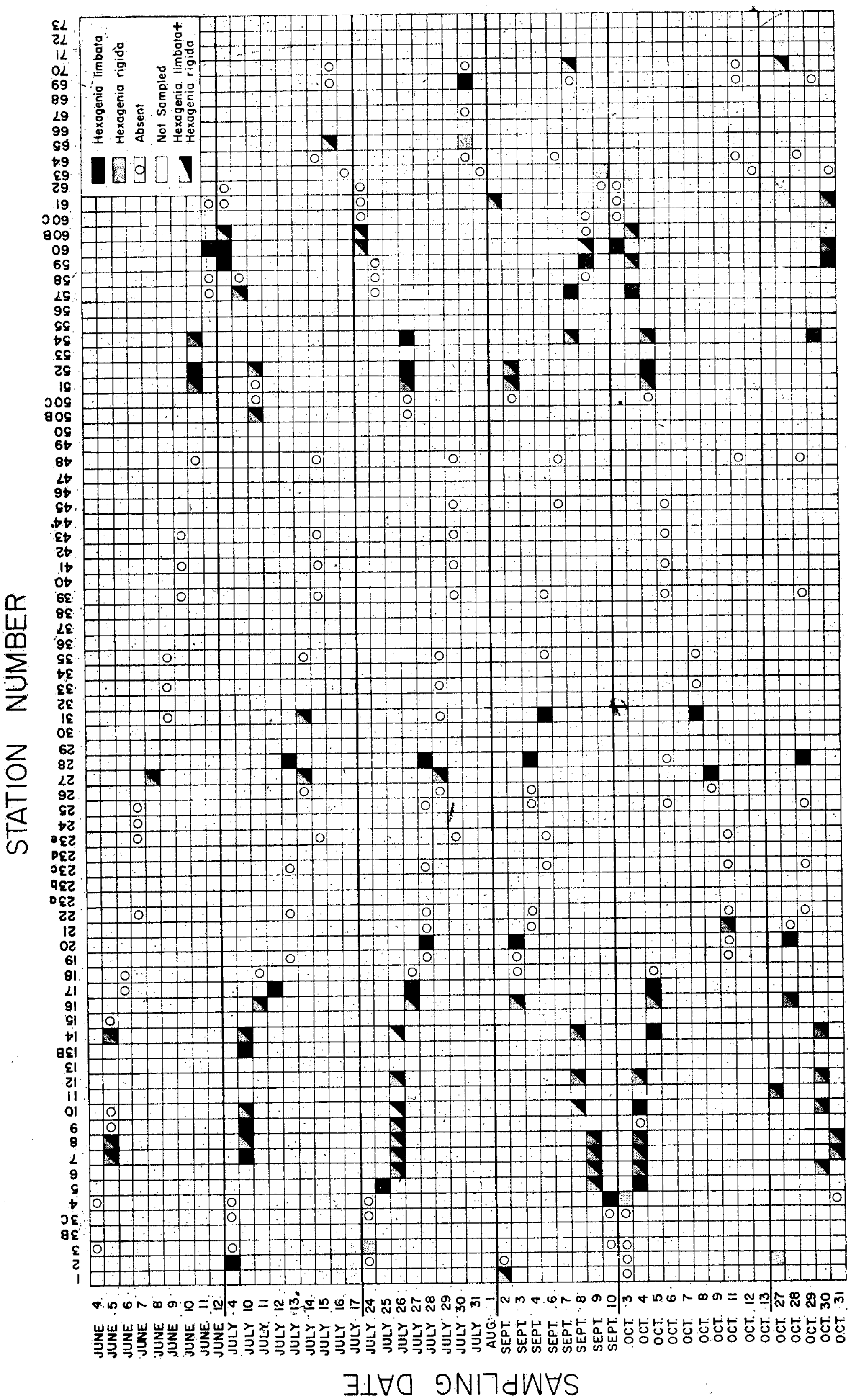

Fig. 2. Distribution of *H. limbata* and *H. rigida* at the various stations through the summer, 1969

calculations (number/m²) were calculated by multiplying the mean number of each species in the three grabs by 44.44 in the case of the Ekman samples, and by 18.94 for the Ponar samples.

For the life cycle studies the lake was divided into three areas: the north basin, the central basin or Narrows, and the south basin (Fig. 1). Within each of these areas the nymphs from each sampling period were arranged in order according to length, ranging from shortest to longest, and the cumulative numbers plotted against the size. Insufficient numbers of *Ephemera simulans* were collected to do more than record their presence, and the small numbers of *Hexagenia rigida* encountered in the north basin precluded any life cycle studies.

Light traps were set while the ship was anchored at night. The efficiency of these traps varied considerably with factors such as the amount of wind and moonlight.

Results

Over the summer 1,043 *H. limbata* and 240 *H. rigida* nymphs were collected, giving a numerical ratio of approximately 4:1 (compared with NEAVE'S (1932) ratio of 7:1). Both species appear to have very similar depth and substrate preferences (Fig. 2).

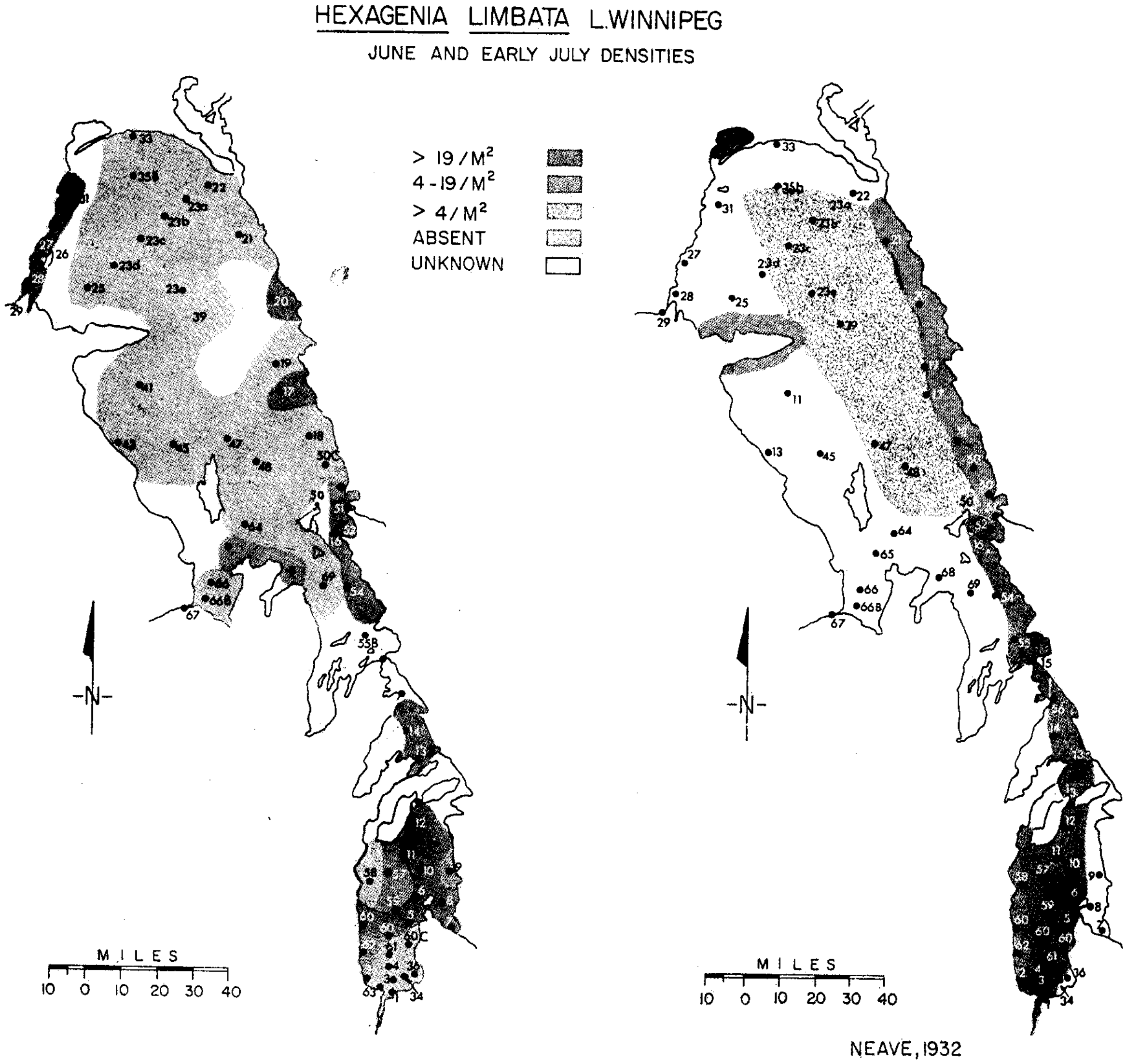

Fig. 3. Comparison of the density distribution in Lake Winnipeg of *H. limbata* in June and early July 1969 with NEAVE'S (1932) figure

Comparison of the density distribution of *H. limbata* during June and early July with that given by NEAVE (1932) for the same time period in 1929 and 1930 (Fig. 3) clearly shows a distinct reduction in numbers in parts of the south basin. The northwest and southeast areas of the basin seem now to have become completely unsuitable for this species and the areas adjacent to them show a considerable reduction in density. The Narrows seem to have changed very little since NEAVE's time, while the north basin perhaps shows a small increase in *H. limbata* density.

In the case of *H. rigida* an even more drastic change appears to have occurred. NEAVE's distribution map indicates 5–15,000,000 nymphs per sq. mile (4–19 per m^2) over all of the south basin, with the exception of the extreme eastern part, which he did not sample. The distribution map for the summer of 1969 (Fig. 4) indicates that this species is now totally absent from a large part of the basin and has increased its density considerably over most of the remaining half (mean $60/m^2$). Little change in the north basin and Narrows area seems to have occurred since NEAVE's time. The highest densities found during the June and early July period were $385/m^2$ for *H. limbata* and $89/m^2$ for *H. rigida*, both densities occurring at station 27 in the northwest part of the north basin.

The generation time for both *H. limbata* and *rigida* is given by NEAVE (1932) as two years. Fig. 5 shows the length distribution, in the north basin, of *H. limbata*. A two year generation time (A_1 generation), with an emergence each year is clearly indicated, however the occurence of large

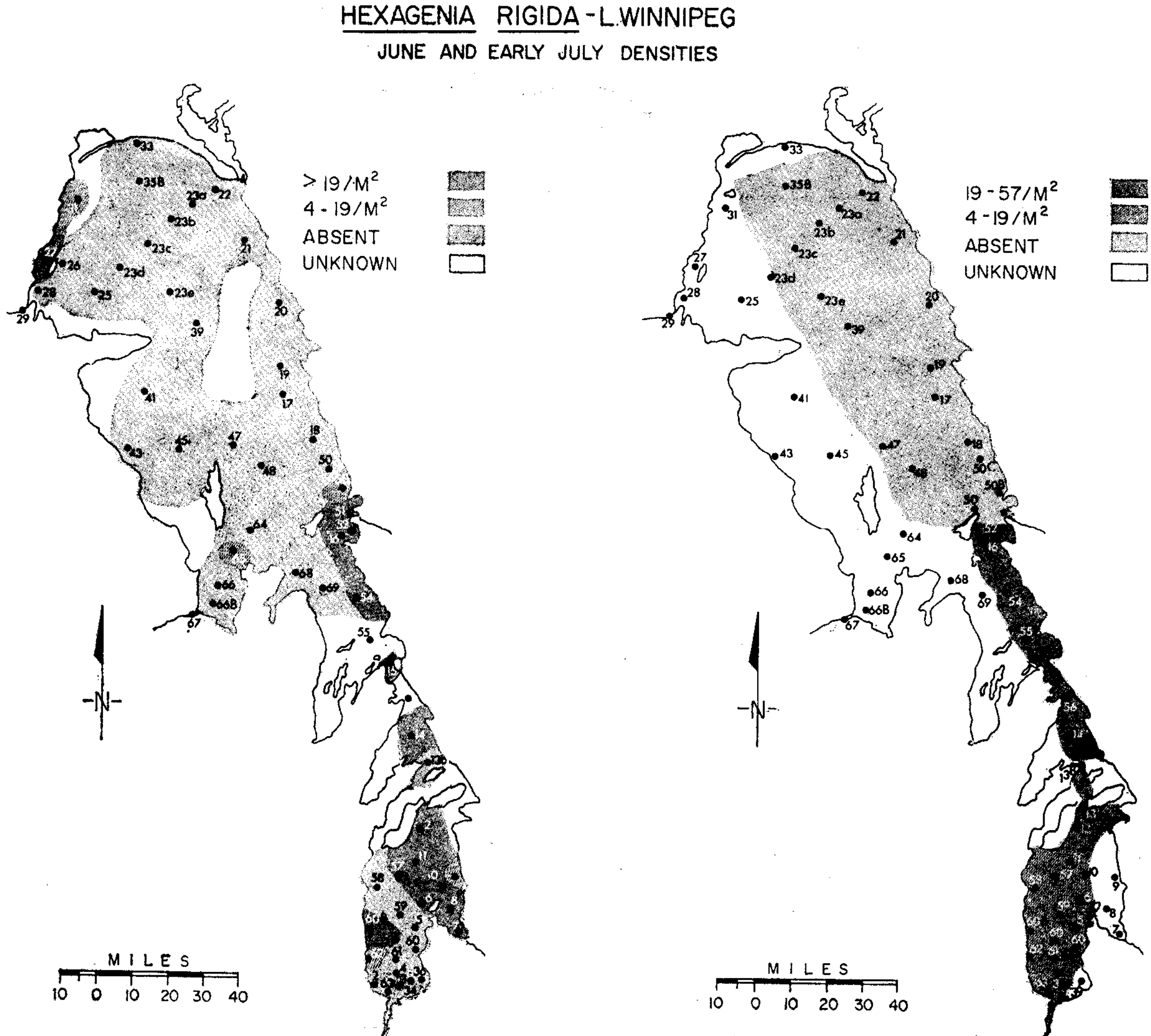

Fig 4. Comparison of the density distribution in Lake Winnipeg of *H. rigida* in June and early July, 1969 with NEAVE's (1932) figure

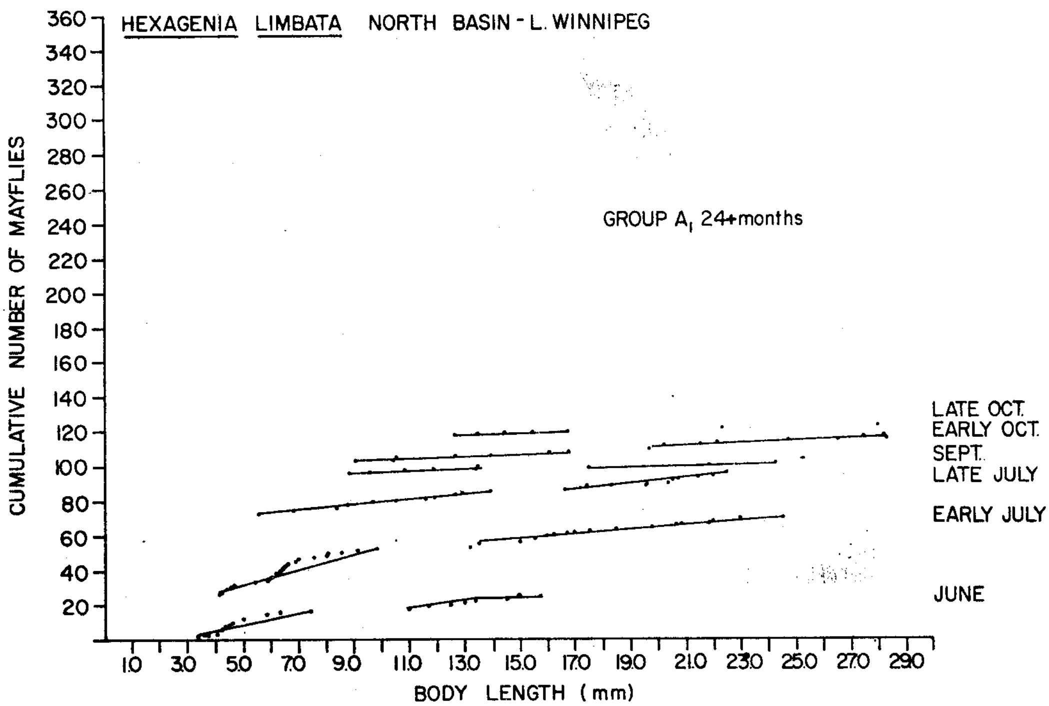

Fig. 5. Size distribution of *H. limbata* over the summer, 1969 in the north basin of Lake Winnipeg

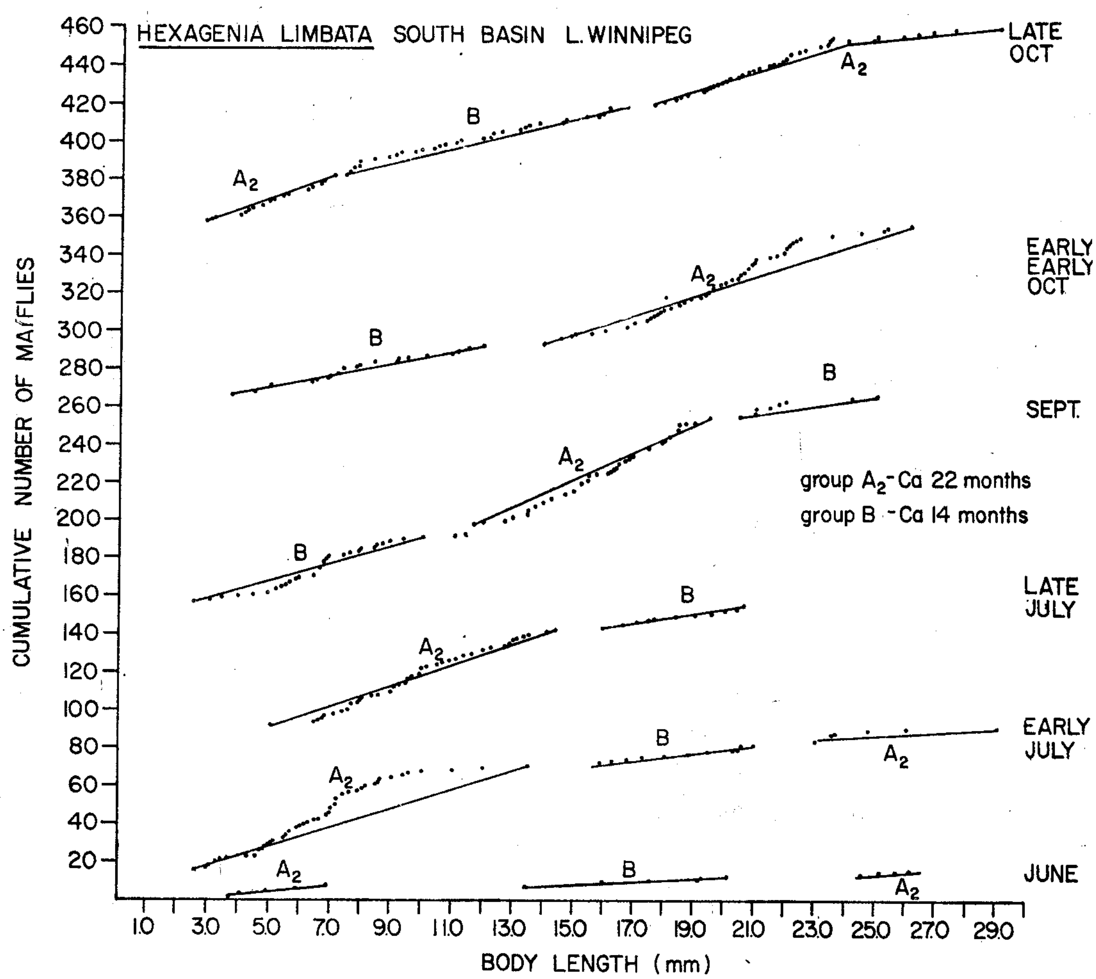

Fig. 6. Size distribution of *H. limbata* over the summer, 1969 in the south basin of Lake Winnipeg

nymphs in early October would seem to indicate that not all the nymphs can complete their life in this time. The size distribution of the nymphs of this species in the south basin shows a very different pattern (Fig. 6). Three distinct groupings are present in four out of six sampling periods and young nymphs are present throughout most of the summer. This would seem to indicate two alternating generations, one of 14 months duration (B) and one of 22 months duration (A_2). The A_2 generation imagines laying eggs early in the summer, thus giving an opportunity for these eggs (B generation) to hatch and the nymphs to grow considerably over their first summer, complete their growth and emerge late in their second summer. The eggs from the B generation (which will form the A_2 generation), although some hatch late in their first summer, seem not to develop until early the following summer, achieve most of their growth the second summer and emerge early in their third summer thus giving rise to the B generation. The situation in the Narrows (Fig. 7) appears to be much more complex: As in the south basin young nymphs appear to be present over most of the summer, but distinct size groupings are not always obvious and three groups are present when only two would be expected if a similar situation to that in the south basin occurred. Plotting of the size ranges from both the north and south basins onto this figure accounts for most of the anomalies and it would therefore seem likely that this population has all three generation times.

H. rigida length distribution in the south basin (Fig. 8) and the Narrows (Fig. 9) show similar patterns to those for *H. limbata* in the south basin. Thus alternating 22/14 month life cycles seem to occur in this species also. The north basin samples produced an insufficient number of specimens to graph.

The results from the light traps at the various stations throughout the summer are too sporadic to do more than record the presence of *Hexagenia* imagines from early July until early September. Two other species *Ephoron album* and *Ephemera simulans* were also taken commonly in these traps. *E. simulans*, in Manitoba appears to be more of a stream species but does occur in the littoral zones of lakes (FLANNAGAN and LAWLER, 1972). In Lake Winnipeg nymphs were only collected at one station. This was probably due to our inability to sample shallow water because of the draught of the ship. *Ephoron album* was not collected in the grab samples.

Discussion

The results presented in this paper deal only with one openwater season and should, therefore, be treated with caution. They do, however, substantiate the reports by the Biologists of the Manitoba Provincial Government (Jo-Anne CROWE, personal communication) that there has been a serious decline in *Hexagenia* populations in the south basin of the lake in the past decade.

From Figures 6 and 8, it would appear that a much larger area of the south basin has become unsuitable for *H. rigida* than for *H. limbata*, however, more detailed study reveals that, in the areas where they are present, densities of *H. rigida* show a decided increase while those of *H. limbata* densities have remained the same or decreased since NEAVE'S (1932) paper. This shift in proportion since 1929–30–1969 is also indicated by the change in ratio of *H. limbata*: *H. rigida* from 7 : 1 to 4 : 1 respectively.

The decline in the numbers of nymphs of the two *Hexagenia* species is probably not due to increasing pollution in the south basin of the Lake. Our 1969 investigations, together with those of the Provincial Government (J. A. CROWE, personal communication) suggest that this decline is probably due to a change in one or more natural factors, such as increased sedimentation or poor mating conditions. Figure 9 shows the steady increase in lake water levels since NEAVE'S time. This increase in water height has been accompanied by severe erosion of the very extensive sand beaches in the northwest, south and southeast parts of the basin. It seems likely that the sand from these beaches has been deposited further out in the lake thereby limiting suitable habitat for the species, and it is, therefore, not unlikely that it is a factor contributing to the decline of the mayfly populations of this basin.

HUDSON and SWANSON (1972) have shown that *H. limbata* undergoes alternate 13–14 and 22 month life cycles in Lewis and Clark Lake on the border between South Dakota and Nebraska, U.S.A. CRONK (1932), however, suggested a two year life cycle for Shakespeare Lake, Ontario, a more northerly lake. HUNT (1953) has shown experimentally that temperature is a major factor controlling the length of the life cycle and has suggested that the maximum potential length of life of *H. limbata* is probably less than 3 years. Since both alternating 22/14 month and a 2 year life cycle are present in Lake Winnipeg in the south and north basins respectively, it would be reasonable to assume that the north basin is

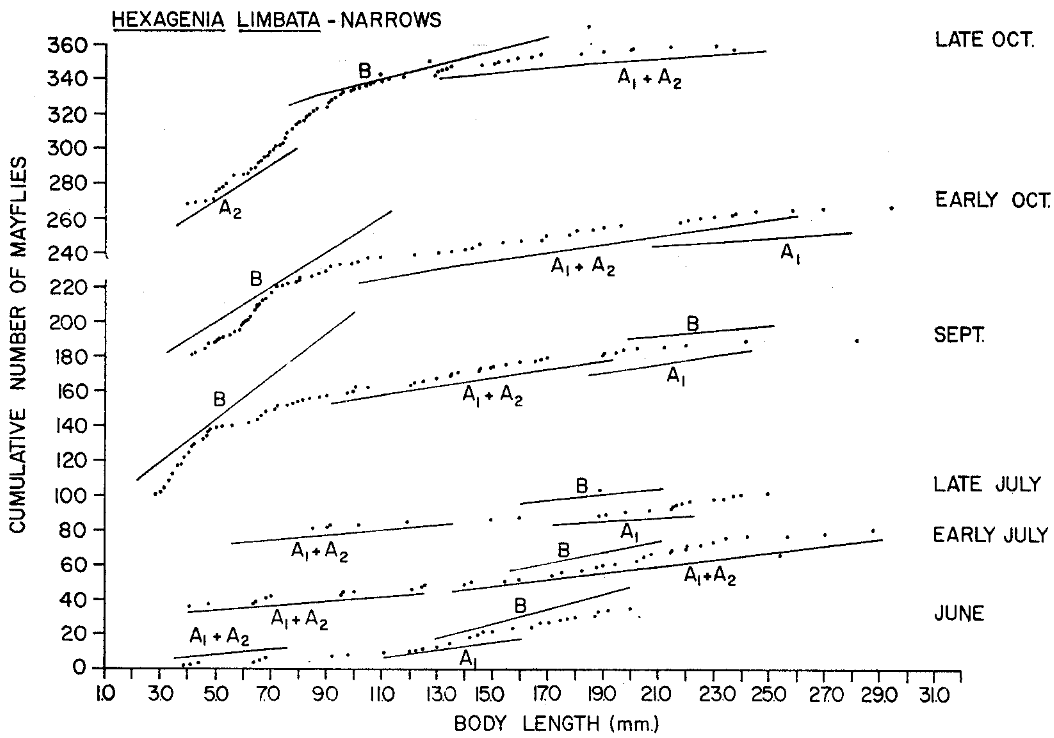

Fig. 7. Size distribution of *H. limbata* over the summer, 1969 in the Narrows, Lake Winnipeg

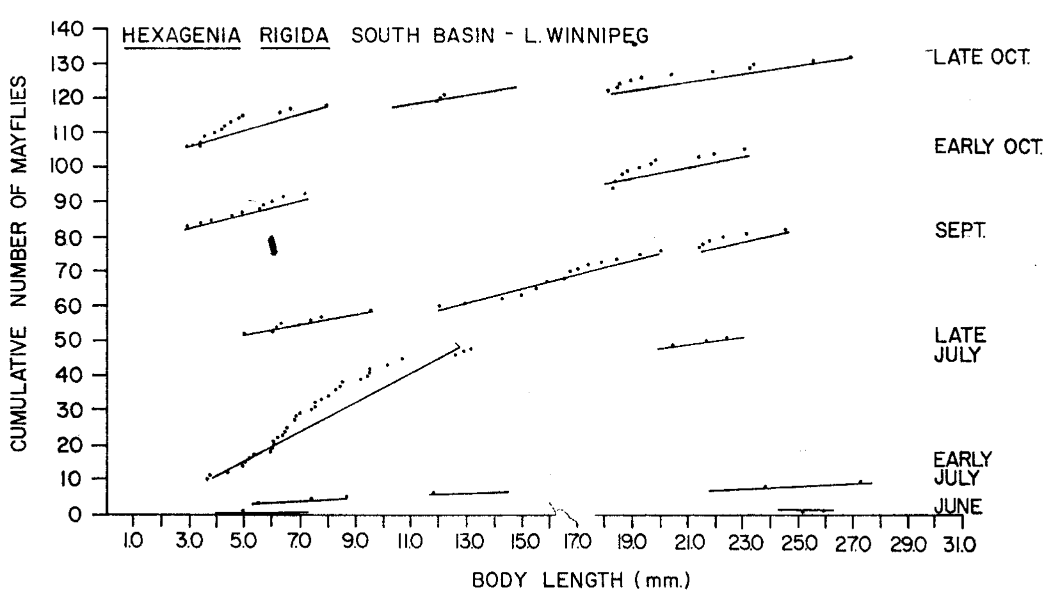

Fig. 8. Size distribution of *H. rigida* over the summer, 1969 in the south baisn of Lake Winnipeg

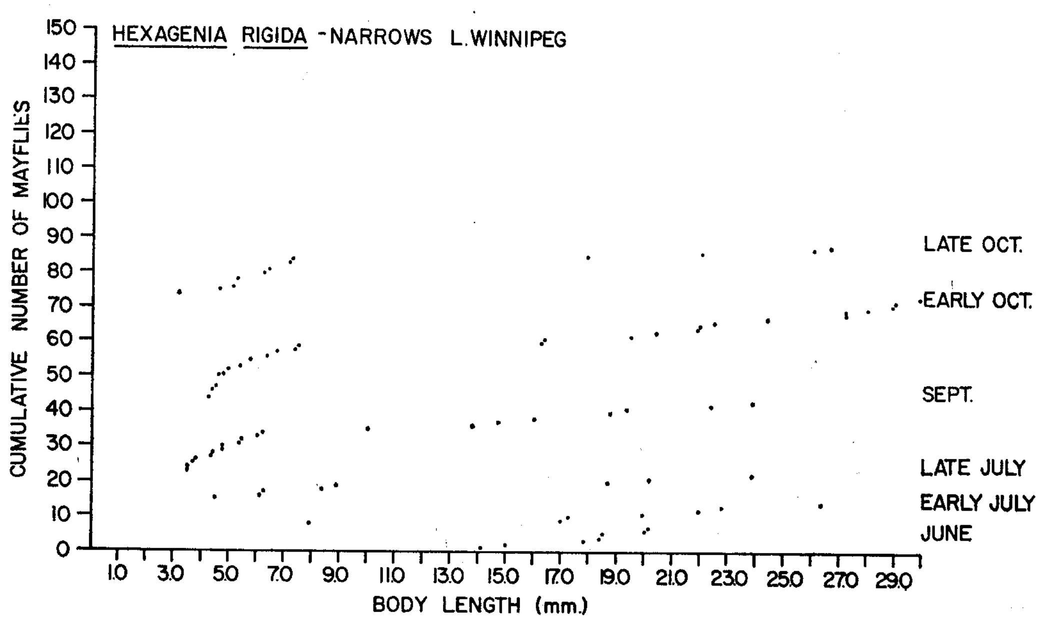

Fig. 9. Size distribution of *H. rigida* over the summer, 1969 in the Narrows, Lake Winnipeg

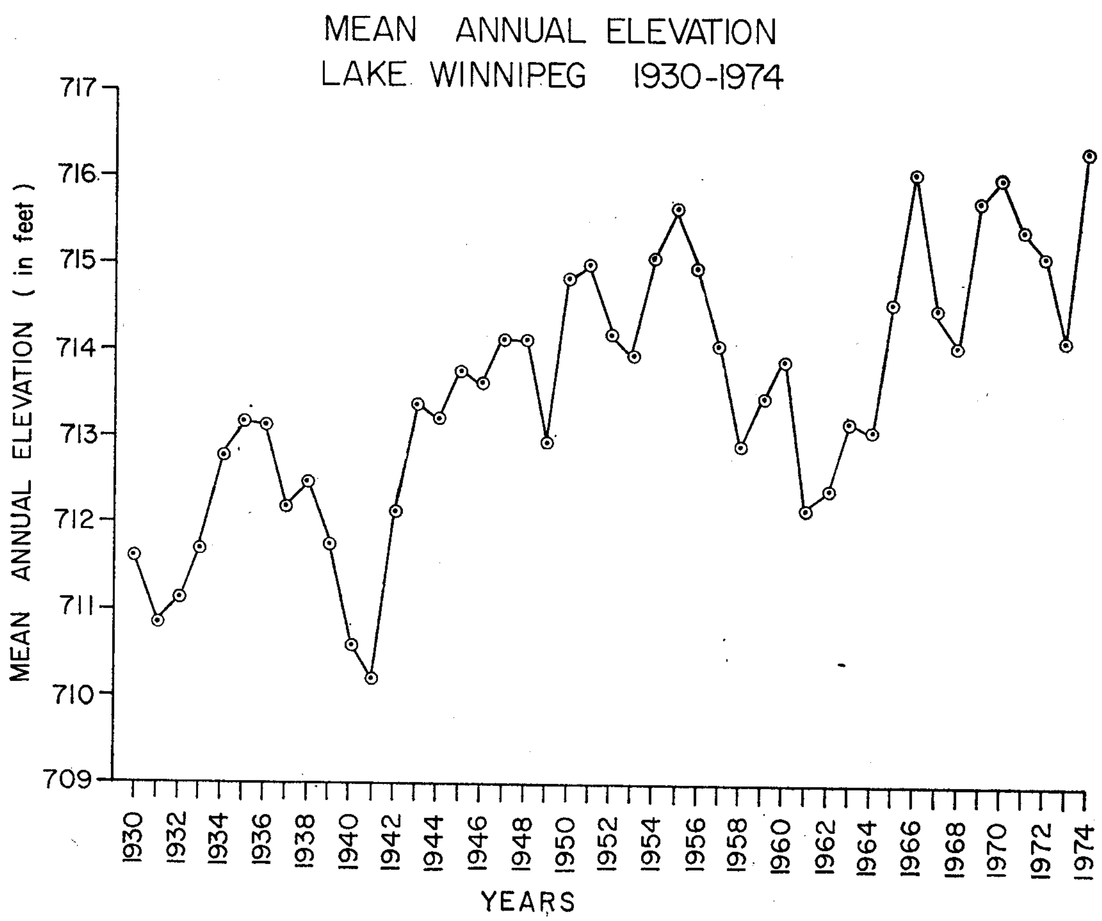

Fig. 10. Water levels, Lake Winnipeg 1930–1974 (from information supplied by Water Surveys, Canada)

considerably colder. This is in fact the case, bottom water temperatures during early July and sampling dates indicate a mean temperature of 12°C in the north and 15.4°C in the south basin. This temperature difference is even evident in the surface waters — the mean surface water temperature for the first three cruises are: north basin, 14.2°C and south basin 17.0°C (BRUNSKILL G. J., personal communication).

The Narrows area of the lake, unlike the stations in the other two basins which have relatively constant depths, has stations which are relatively deep and with fast flowing water [for example, all of the water which enters the south basin of the lake has to flow north through the very narrow channel at station 15 (Fig. 3)] and stations which are quite shallow. It is possible that the rather confused situation with regard to generation time in this area, is related to one of these two factors. That is, it may be due to either a methodological error caused by lumping samples from the very shallow and very deep stations together, or it may be caused by a physical transfer of nymphs from the south basin into the Narrows by the strong northerly flow of water.

Conclusion

If 1969 was a typical year, and from the other evidence it appears to have been, then there has been a significant decrease in the populations of *Hexagenia* of the south basin of Lake Winnipeg together with a shift in the relative abundance of *H. limbata* and *rigida* since 1930.

Two generation types are present in the lake, one of 14 months alternating with 22 months and the other of 2 years.

Further, longer term research is required to investigate the possibility of the high water influencing the densities of *Hexagenia* and to define more accurately the generation time in the Narrows area.

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SUMMARY

The burrowing mayflies of Lake Winnipeg, Manitoba, Canada

During the open water season of 1969, some sixty sampling sites throughout Lake Winnipeg were sampled six times. Attempts were made to take three Birge-Ekman or Ponar grab samples at the various stations during each sampling period. Three species of burrowing mayflies were collected in the bottom samples and a fourth, *Ephoron album* (SAY), was taken in light traps set while the ship was anchored, at night. On the three species taken in the grab samples *Ephemera simulans* WALKER occurred only very rarely, presumably because this species inhabits the sandy substrates common in the shallow water areas of the lake-areas too shallow to be sampled from a large ship. The remaining two species *Hexagenia limbata* (SERVILLE) and *H. rigida* MCDUNNOUGH were common throughout most of the south and central basins of the Lake and were restricted to the inshore areas of the north basin.

Comparison of the distribution of these two species in 1969 with that recorded by NEAVE (1932) for the period 1927–32 indicates that the western and perhaps eastern side of the south basin have become unsuitable for supporting nymphs of *Hexagenia.*

Studies of the life cycles of the two species indicate a two year life cycle for *H. limbata* in the north basin, an alternating 22 month, 14 month life cycle for both species in the south basin, and a rather confused picture in the central basin or Narrows possibly due to either the fact the Narrows contained both deep water and shallow areas or the presence of both kinds of like cycle.

REFERENCES

BAJKOV A. (1930). Biological conditions of Manitoban Lakes. *Contr. Can. Biol. and Fish.*, **5** (12) 381–422.

BRUNSKILL G. J. (1973). Rates of supply of Nitrogen and Phosphorus to Lake Winnipeg, Manitoba, Canada. *Verh. Int. Ver. Limnol.* **18**: 1755–59.

CRONK M. W. (1932). The bottom fauna of Shakespeare Island Lake, Ontario. Univ. Toronto Studies, Biol. 36. *Publ. Ont. Fish. Res. Lab,* **43**:31–65.

FLANNAGAN J. F. and G. H. LAWLER (1972). Emergence of Caddisflies (*Trichoptera*) and Mayflies (*Ephemeroptera*) from Hemming Lake, Manitoba. *Can. Ent.* **104**:173–183.

HUDSON P. L. and G. A. Swanson (1972). Production and Standing crop of *Hexagenia* (*Ephemeroptera*) in a Large Reservoir. *Stud. Nat. Sci.* (Portales, N. M.) **1** (4):1–42.

HUNT B. P. (1953). The life History and Economic importance of a Burrowing Mayfly, *Hexagenia limbata*, in Southern Michigan Lakes. Michigan Conserv. Dep. *Bull. Inst. Fish. Res.* **4**:1–151.

NEAVE F. (1932). A study of the Mayflies (*Hexagenia*) of Lake Winnipeg. *Contr. Can. Biol. and Fish.* **7** (15) 177–201.

—. 1934. A contribution of the Aquatic Insect Fauna of Lake Winnipeg. *Int. Rev. ges. Hydrobiol. Hydrograph,* **31**:157–170.