THE ZOOGEOGRAPHY OF
MOSQUITOES IN SASKATCHEWAN
AND THE ADJACENT
NORTHWEST TERRITORIES

PHILIP STEPHEN COREY

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THE ZOOGEOGRAPHY OF MOSQUITOES

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ADJACENT NORTHWEST TERRITORIES

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Philip Stephen Curry

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ABSTRACT

In 1974 and 1975, mosquitoes were collected from eight locations considered representative of three distinct ecological zones in Saskatchewan and Keewatin District, N.W.T. - the grasslands, the boreal forest, and the tundra. The geographic and seasonal distribution of mosquitoes and their habitats are described and notes are given on the 35 species. The environmental conditions that determined species distribution are also discussed and it is suggested that the rate of snowmelt in the spring and the amount of snow or rain determines the date and extent of egg hatching. The temperature of the water and air determines the rate of development of the eggs, larvae and pupae, the rate of ovarian development in the adult females and the general level of activity in adults. Distribution does not appear to be affected by water quality or the presence of parasites and predators. From this information it was possible to forecast mosquito distribution and abundance, especially on a local scale.

ACKNOWLEDGEMENTS

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Chapter 1

INTRODUCTION

Weather and climate are commonly accepted by entomologists as dominant influences on the behaviour, abundance and distribution of insects. The literature on the subject of climate and insects is extremely voluminous, as may be seen by reading most texts on animal ecology, examples being the large works of Andrewartha and Birch (1954) and Krebs (1972). Specific aspects of this field, such as the influence of climate and weather on outbreaks of insect pests have been studied extensively by entomologists at Agriculture Canada (see for example, Burgess, 1974; Taylor, 1975; Fredeen, 1975). With the increasing attention being focused on insect zoogeography (Gressitt, 1958; Krebs, 1972; Provost, 1974) it is now appropriate to consider the relationships between climate and the distribution of a specific insect - the mosquito.

So far as the physical environment is concerned, extension in range of a mosquito species is considered to be limited by two broad categories of controls, geographic barriers[1] and climate restrictions (Ross, 1964). In the case of many mosquito species in southern Canada, geographic barriers have been greatly reduced as a result of man's activities. As a result of forest clearing for agricultural purposes or irrigation developments, many species are no longer limited strictly to their original ranges or to their original balances with the environment (Shemanchuk, 1965, 1969; McLintock and

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[1]Barriers to dispersal caused by mountains, forests, or other physiographic and vegetation formations.

Iversen, 1975). Because of this, climatic and other environmental controls of mosquito distribution have commanded an increasing amount of attention in Canada during the past half-century, particularly for those species found in the northwestern transition forest section and on the tundra (Hocking et. al., 1950; Twinn, 1950; Jenkins, 1958; and Downes, 1964). Investigations in Saskatchewan by Rempel (1953), McLintock and Rempel (1963), McLintock et. al. (1966) and Iversen et. al. (1973) have concentrated almost entirely on the grassland and southern boreal forest species. The northern half of the province, the area within the Canadian Shield, has not been investigated intensively.

Rempel (1953) stated that a knowledge of the species in Saskatchewan would provide a useful extension to the comprehensive studies carried out in the north and in the United States (see for example, Mail, 1934; Barr, 1958).

1.1 ZONATION OF MOSQUITOES IN THE WESTERN INTERIOR AND ADJACENT ARCTIC AREA OF CANADA

Three broad ecological regions can be distinguished within the western interior and adjacent arctic area of Canada - the tundra region, the boreal forest region (including the northwestern transition, northern coniferous, mixed-wood and aspen-grove sections), and the grassland region (Fig. 1.1). Within each region variation in such factors as climate, soils, and hydrology provides numerous habitats which result in distinct combinations of mosquito species with differing environmental tolerances.

In the grassland region knowledge of the geographic and ecological
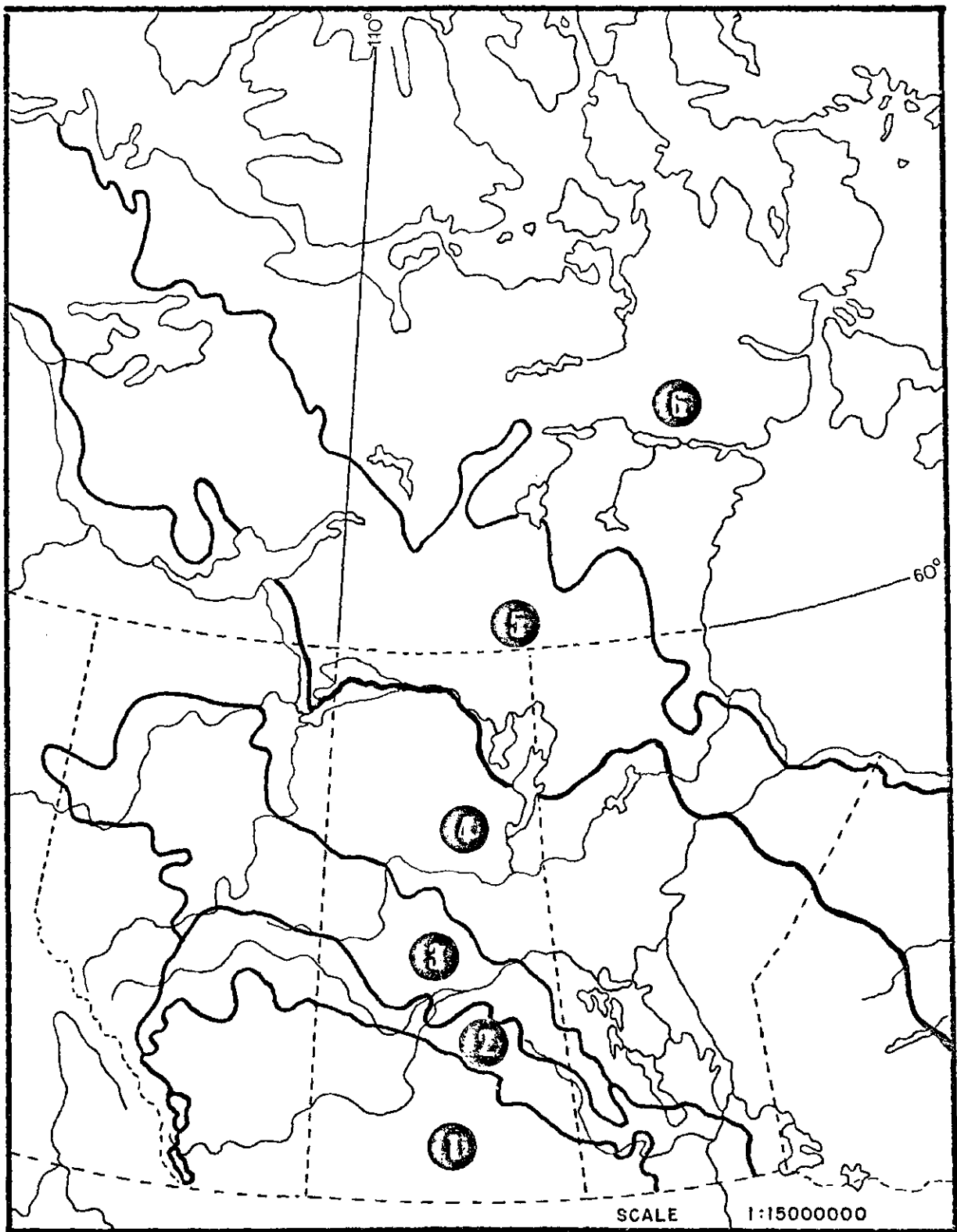
Figure 1.1

    Vegetation zones in the study area (after Rowe, 1971) Grassland region (1);
Boreal forest region, including aspen-grove section (2); mixed-wood section (3);
northern coniferous section (4); northwestern transition section (5); and the
Tundra region (6).

relationships of mosquitoes to the natural environment is somewhat rudimentary. At present only generalities can be stated. The mosquito fauna of the grassland must tolerate dry, continental climatic conditions. Frequently, salt or alkali tolerance is also necessary. Mosquitoes (and many other Diptera as well) are associated directly with sloughs or temporary pools. The aquatic fauna of the sloughs and pools is rich, and includes a good representation of caddisflies (Trichoptera), burrowing mayflies (Ephemeroptera), dragonflies and damselflies (Odonata) and beetles (Coleoptera), in addition to the mosquitoes (Culicidae).

Zonation of mosquito fauna in the grassland region has been demonstrated (Rempel, 1953; McLintock and Rempel, 1963; Happold, 1965). Precise correlation to climatic or other environmental parameters such as soil or vegetation type is, however, lacking. Probably, some of the species characteristic to southern Saskatchewan and Alberta depend on mixed grassland and species penetrating farther north can succeed in a variety of environments. Evidence of a specific mosquito fauna associated with the fescue grassland is less obvious. The aspen-grove section contains, as would be expected, a mixture of grassland and boreal species; so far as is known it does not have an endemic mosquito fauna.

The bogs, fens and marshes throughout the boreal forest region support numerous aquatic insects, especially mosquitoes and blackflies (Simulidae). It has not been demonstrated that there is any

differentiation corresponding to different forest classifications within the boreal region (Jenkins, 1958). Most boreal mosquito species appear to be widespread and at present division into eastern Canadian and western Canadian sections does not seem justified (Freeman, 1952). In terms of a northward extension of mosquito species, a large proportion of boreal-tundra transition mosquito fauna is composed of tolerant boreal zone species, whose range extends northward. While many other aquatic insects are greatly reduced in number as one enters the northern transition area, both blackflies and mosquitoes are present in enormous numbers and considerable variety of species (Twinn et. al., 1948; Hocking et. al., 1950; Freeman, 1952; Hocking and Pickering, 1954).

The mosquito fauna of the tundra region of Keewatin differs strikingly from that of the forested areas to the south. The tundra fauna contains a very high proportion of species confined to it (Freeman, 1952a), though for the most part they belong to more widely distributed genera. The relationship to the arctic mosquito fauna of Europe and Asia is very close, circumpolar species generally outnumbering all others (Gillett, 1972). The fauna as a whole is scanty, but some of the species are very abundant. While division into areas is somewhat tentative, a low-arctic area and high-arctic area may be discerned (Fig. 1.2). The low-arctic area, including arctic Labrador and Quebec, most of Keewatin District and parts of MacKenzie District, has a moderately rich mosquito fauna. As many as ten species are found

Figure 1.2

High and low arctic areas of the Canadian North (after Downes, 1964).

near the southern boundary of this area, and a total of five being reported from more northerly locations (Haufe and Burgess, 1956; Smith, 1970). With this area can be associated Southampton Island, southern Baffin Island and southern Victoria Island. In the high-arctic area, including the Queen Elizabeth Islands, the mosquito fauna consists of only two species (Downes, 1964).

In central Canada the zonal relationships between climate, soils and the distribution of vegetation are displayed clearly from the warm dry grassland in southern Saskatchewan to the cold dry lichen-woodland and tundra of the Keewatin District. To a similar extent, these zonal relationships can also be applied to the mosquito fauna of the area. Rempel (1953) devised a zonal classification for Saskatchewan using a series of distributional lists from different vegetation zones. He examined the mosquito species found in three vegetation zones in the province - prairie grasslands, the aspen-grove region, and the northern mixed-wood forest (Table 1.1). In each zone, several species were listed as being dominant, with numerous other species being listed as common or rare.

Although much overlap does occur, it appears that each major ecological region may have a characteristic group of species confined to it. However, precise correlation to specific environmental parameters is difficult until more zoogeographic investigations have been undertaken throughout the various zones.

Table 1.1   Geographic distribution of Saskatchewan mosquitoes (Rempel, 1953)

REMPEL: MOSQUITOES OF SASKATCHEWAN

TABLE I

GEOGRAPHIC DISTRIBUTION OF SASKATCHEWAN MOSQUITOES

Ecological zone	Species		
	Abundant	Common	Rare
Prairie grasslands. Soil brown, zones 1 and 2. Total summer ppt. 10-12 in.	*A. spencerii* *A. campestris* *A. flavescens*	*A. dorsalis* *A. vexans* *A. nigromaculis* *Culex tarsalis* *Culiseta inornata*	*A. fitchii* *A. increpitus* *A. excrucians* *A. canadensis* *A. cataphylla* *A. sticticus* *A. trisertatus* *Culex restuans* *Culiseta morsitans* *Psorophora signipennis* *Anopheles earlei*
Aspen grove region. Soil black, zones 3 and part 4. Total summer ppt. 12-13 in.	*A. fitchii* *A. campestris* *A. flavescens*	*A. spencerii* *A. vexans* *A. canadensis* *A. cinereus* *A. excrucians* *A. dorsalis*	*A. pionips* *A. communis* *A. riparius* *A. increpitus* *A. impiger* *A. stimulans* *A. cataphylla* *Culex tarsalis* *Culex restuans* *Culiseta inornata* *Anopheles earlei*
Northern coniferous forests. Soil gray zones parts 4 and 5. Total summer ppt. 12-14 in.	*A. intrudens* *A. communis* *A. punctor* *A. pionips*	*A. fitchii* *A. canadensis* *A. excrucians* *A. cinereus* *A. vexans* *A. trichurus*	*A. spencerii* *A. cinereus* *A. riparius* *A. flavescens* *A. cataphylla* *A. impiger* *A. diantaeus* *A. pullatus* *A. nearcticus* *Culiseta spp.* *Culex territans* *Mansonia perturbans* *Anopheles earlei*

1.2 AIMS AND OBJECTIVES OF THE STUDY

The study had four specific objectives:

1) To describe the distribution of mosquitoes in Saskatchewan and the adjacent N.W.T., particularly as it relates to such population parameters as species composition, relative abundance and diversity. The study represented a continuation of Rempel's analysis of the geographic distribution of mosquitoes in Saskatchewan, but was updated and enlarged to include the rest of northern Saskatchewan and the adjacent areas of Keewatin District, N.W.T..

2) To investigate the seasonal distribution of mosquitoes in the study area.

3) To describe the distribution and variation in species habitat throughout the study area.

4) To ascertain those environmental factors which play a prominent role in determining mosquito distribution patterns.

Upon determining those factors that were limiting in the mosquito habitat, an attempt was made to predict the potential spread of a species into uninfested areas and to predict the time and extent of mosquito occurrence in a given area.

Chapter 2

LITERATURE REVIEW

2.1 SPECIES DISTRIBUTION AND ABUNDANCE

For purposes of zoogeographic analysis, the distributional records of a species and the limits of its current distribution require critical evaluation. Rempel (1953) specifies the limits of mosquito distribution on the basis of the ecological zone in which the particular species is found. Outside this zone, Rempel assumes, the species may be present in low numbers and in sporadic habitats, but not influenced by the general climate or vegetation so much as by local variations in the micro-habitat caused by differences in physiographic and edaphic factors.

Records indicating that a species exists in certain localities, especially along the periphery of the range of the species, also require critical evaluation in order to determine if the species is endemic (see for example, Freeman, 1952; and Brust, 1968). In some cases a species may be carried outside of its climatically limited range, either because of significant departures from the climatic normal, or because of man's activities. For example, a predominately southern grassland mosquito, A. *campestris*, has long been recorded from the vicinity of Churchill, Manitoba (Hocking et. al., 1950). In fact some of the limiting climatic conditions for this species, used in a bioclimatic analysis by Haufe and Burgess (1956), were taken from the climate of Churchill. But whether it is endemic there or whether its presence

there merely results from importation from more southerly areas is
not clear. Recent studies in Manitoba by Brust (1968) indicate that
perhaps the latter is the more probable answer.

Proper taxonomic identification is also important. Confusion of
the distributional records of the mosquito A. *cataphylla* with the
closely related, abundant species A. *communis* temporarily rendered
inexplicable the expanded distribution of the former species in the
southern regions of the boreal forest (Iversen, et. al., 1973). Modern
synonomy, taxonomic revisions and the splitting of a given species
into two or more species while retaining the name of the original can
confuse the record for zoogeographic analysis.

For zoogeographic purposes the nature of mosquito distribution
may have a different meaning as well. In the strict sense the nature
of current distribution usually means the actual geographic or seasonal
distribution (distribution in space and time). However, it may also
mean the pattern and organization of species populations and may be
discerned in terms of the actual species comprising the total mosquito
population of an area. A more specific aspect of population patterns
or distribution lies in the relative abundance of the various mosquito
species.

Two broad approaches are used to analyze species population
patterns in different situations, namely, (1) comparisons based on
the shapes, patterns, or equations of species abundance curves and
(2) comparisons based on diversity indices, which are ratios or

other mathematical expressions, of species - importance relationships (Odum, 1971). It is important to recognize that species diversity, as measured by diversity indices, has a number of components which may respond differently to geographical, developmental, or physical factors. One major component is the species 'richness' or 'variety' component expressed by simple ratios between total species, S, and total numbers (or importance values), N. A second major component of diversity is the 'evenness' or 'equitability' component, which deals with the apportionment of individuals among the species. Both of these diversity components are dealt with in greater detail in section 3.4.1.

The widely used Shannon function or $\bar{H}$ index combines the richness and evenness components as one overall index of diversity. This index which uses "information content" as a measure of diversity is being increasingly adopted by researchers (see for example, MacArthur and MacArthur, 1961; Lloyd and Ghelardi, 1964; and McNaughton, 1978). Diversity in this connection means the degree of uncertainty attached to the specific identity of any randomly selected individual. The greater the number of species and the more equal their proportions, the greater the uncertainty and hence the diversity. The Shannon index is one of the best for making comparisons where one is not interested in separating out diversity components because it is reasonably independent of sample size. It is also normally distributed, so that routine statistical methods can be used to test

for significance between means (Odum, 1971).

2.2 FACTORS LIMITING THE DISTRIBUTION AND ABUNDANCE OF MOSQUITOES

2.2.1 Winter cold as a limiting factor

Mosquito distribution in temperate regions is greatly affected by winter cold. The life cycle of species endemic to such regions usually includes some physiological mechanism (such as diapause, hibernation, seasonal variations in cold-hardiness) that permits survival in what would otherwise be a lethally cold winter period. Species of tropical or subtropical origin, which breed continuously throughout the year and which are unequipped with such mechanisms, have their population fluctuate markedly if they are subjected to cold winter conditions.

Conversely, an outstanding feature of northern mosquitoes is their tolerance of very low temperatures in winter. Winter hardiness seems to involve the slowing down of essential functions in a conformable way and ultimately to a very low level and in avoiding intracellular ice formation (Salt, 1961). Freezing tolerance may be obtained in two ways, either by having a high glycerol content or through desiccation of the tissues; but, safely frozen by whichever method, the species is virtually unaffected by further cooling within the natural range.

In the temperate zone the distribution of many mosquitoes is related to winter temperature, but this phenomenon is not likely to find a counterpart in the arctic zone (Downes, 1964).

Ross (1964) relates that considerable differences in cold

hardiness and acclimatization ability exist among different mosquitoes species, and even in races and strains of the same species. The ability of different species to overwinter in a given climate appears, to a great extent, related to the original habitat; those species from hot climates are susceptible to winter cold, whereas the hardy groups which originated in temperate regions or which have been long established there, are not. Different aspects of winter severity must be considered, such as the lowest temperature reached, number of days below certain temperature levels, and the suddenness of the onset of the cold period. The choice of a suitable criterion for evaluating winter severity must depend on the biology of the species concerned (Downes, 1964).

2.2.2 Summer temperatures as limiting factors

Temperature conditions of the summer season may limit mosquito distribution by not providing sufficient warmth for normal reproduction and development and also by interfering with normal activities or by causing high mortality as a result of excessively hot temperatures (McLintock, 1964). Further, species with obligatory diapause or hibernation phases in their life cycle may be prevented from developing normally when exposed to continuously warm, though not lethal, temperature conditions (Brust, 1968).

In response to the stimulus of Merriam's (1898) Life-Zone System, many attempts were made to correlate the distribution of individual insect species with the amount of heat available at different climatic localities during the developmental or summer growing period of the

life cycle (Bodenheimer, 1938). The basis for this type of analysis
is the thermal constant theory of Sanderson and Peairs (1913), which
relates the threshold and duration of development to temperature.
The thermal constant and the threshold of development are physiological
characteristics of a species easily determined in the laboratory. The
major premise in using the thermal constant as a climatic indicator of
distribution is that a species will find a satisfactory climatic
environment in any locality warm enough to allow the accumulation of a
sum of daily temperatures above the developmental threshold and equal
to the thermal constant (see Fig. 2.2).

From the current knowledge of the thermal constant as a measure
of the heat required for satisfactory development, its use as a
limiting factor in mosquito distribution may be challenged on several
points (see also criticisms of the Life-Zone concept, Daubenmire, 1938;
Kendeigh, 1954). In many cases there may be shown localities north of
the existing range of a mosquito species where the climate is warm
enough to permit the complete development of a generation (Downes,
1964), and consequently the limiting factor for poleward distribution
must be some other aspect of temperature, or some other factor of the
physical environment. The constancy of the thermal constant has also
been questioned, especially in connection with naturally fluctuating
temperatures or other factors of the environment (Haufe and Burgess,
1956). Further, the use of only the developmental phases of a
mosquitoe's life cycle for determining climatic limits is open to
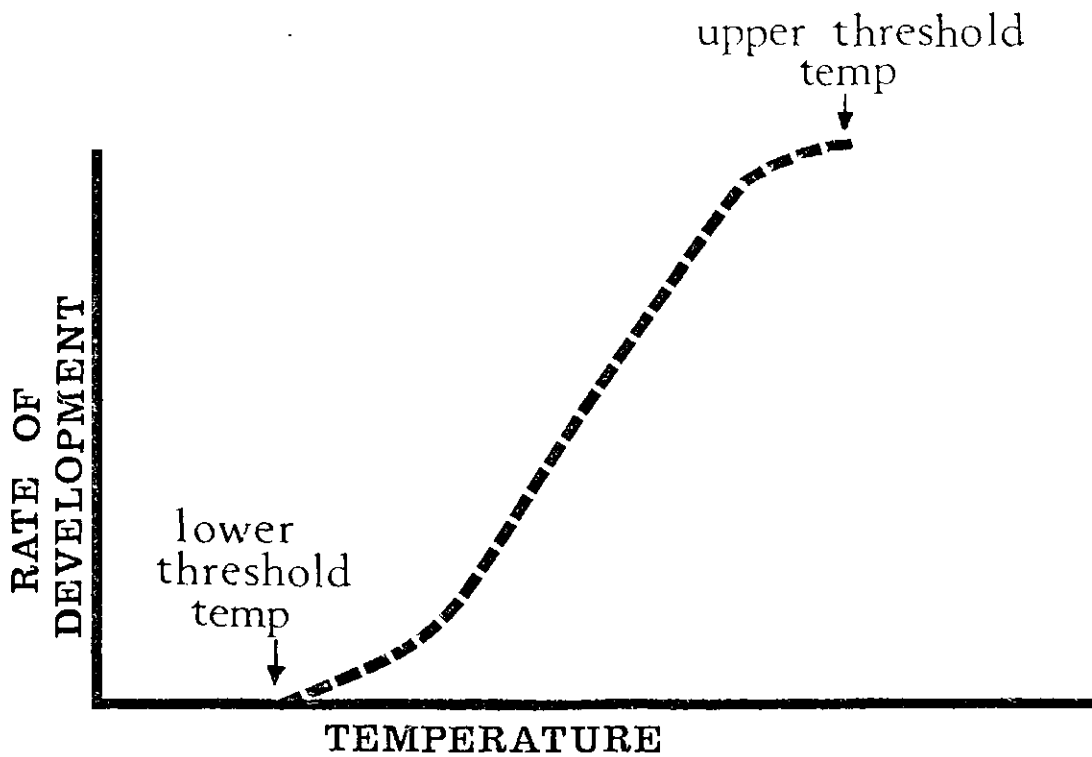
Figure 2.2   Temperature as it affects rate of insect development. The
              thermal constant is the product of time x temperature above
              the lower threshold and below the upper threshold of
              development (after, Gilbert et. al., 1977).

criticism (Horsfall, 1974; Tauber and Tauber, 1976). Temperature effects on adult maturation, longevity, reproduction, and habitat selection must also be considered. Only when all such factors are considered and proper allowances and correlations are applied to the thermal constant may an estimate of the geographical distribution and abundance of a mosquito species be determined on the basis of heat availability.

2.2.3 Moisture as a limiting factor

Moisture conditions of the environment, either in the form of water vapor in the air or as absorbed or free water in the soil, ground litter, or plant tissue, act on mosquitoes in different ways; by influencing evaporation rates which in turn modify body water content and body temperature, by affecting behaviour and reproduction, or by facilitating pathogenic and parasitic attack (Happold, 1965; Brust, 1968; Shemanchuk, 1978). Environmental humidity usually becomes a dominant factor affecting mosquitoes when temperature conditions are favorable (Haufe, 1952), especially when such humidities are extremely high or low. In many cases, however, the importance of extremes in humidity (dry or wet) is difficult to evaluate, for such conditions are closely correlated with corresponding extremes of temperature.

Nevertheless, in many instances the distributional patterns of mosquitoes may be closely correlated with conditions of moisture or humidity, regardless of the exact mechanism by which climate exerts its effect. One such mechanism is mean annual or seasonal precipitation

although the exact effect of either type of precipitation on mosquito distribution is difficult to assess. For example, many *Aedes* mosquito species in northern boreal forest areas must have adequate precipitation during the spring and summer to provide a satisfactory water content in the soil, and their spread into the arid and semi-arid tundra regions of the country can be expected to be limited by lack of precipitation (Freeman, 1952; Hocking et. al., 1950). However, the current northern limits of some species do not conform to either the mean annual precipitation patterns in this region nor to similar relative humidity patterns. Hence, on a broad regional basis, soil-moisture conditions suitable for mosquito development cannot always be correlated with the usual meteorological data, and correlations between climate and species distribution cannot be established. In tundra areas, for example, other factors such as permafrost effects on soil moisture become increasingly dominant. Similarly, the abundance and distribution of the sleeping-sickness mosquito, C. *tarsalis*, cannot be explained on the basis of climatic data alone, since irrigation practices in many local areas of southern Saskatchewan provide the required moisture conditions for its increased abundance there (McLintock and Iversen, 1975).

2.2.4 Dispersal

The absence of a mosquito may be due to the species having failed to reach the area being studied. On a local scale few mosquito species seem to be restricted in distribution by poor powers of dispersal, but

more experimental work is needed to test this general conclusion.
Mosquitoes have many special adaptations for dispersal and this
results in rapid colonization of new areas. On a global scale
dispersal is a critical factor and barriers to dispersal help to
determine distribution patterns among continents, islands or otherwise
restricted areas.

An example of this is given by Downes (1964) who hypothesized
that the arctic mosquitoes have dispersed in the recent geological
past, following the retreat of the Pleistocene ice sheets and that
this glacial epoch, no doubt, considerably affected mosquito
distribution and speciation. The mosquitoes living at present in the
arctic are the progeny of those populations that lived in the refugia,
which are known to have existed (see Porsild, 1955). Huge tongues of
ice must have separated the existing species into isolated populations
and because of this isolation and environmental pressure and selection,
these eventually evolved into distinct species or subspecies. Downes
also feels that those species in the boreal forest zone evolved along
the southern periphery of the ice sheet, well isolated from those
living in the refugia. Present distributional patterns indicate that
the major refugia were situated in the Yukon, in Alaska and possibly
in Siberia (Freeman, 1952).

2.2.5 Behaviour

The distribution of a mosquito species may be limited by the

behaviour of individuals in selecting their habitat. Habitat selection by ovipositing mosquitoes provides some good examples in which a species can survive in a wider range of habitats than it usually occupies.

In Manitoba, for example, Brust (1973) found that the production of mosquitoes occurred in only a small portion of the total area; in 1968, the total area of producing pools amounted to 5 acres out of the 5120 acres surveyed. The reasons for this are not clear. Early workers assumed that something in the water prevented the larvae from surviving, and they neglected to study the behaviour of females in selecting sites in which to lay eggs. More recent work has emphasized the role of habitat selection in female mosquitoes and has shown that larvae can develop over a much wider range of conditions than those in which eggs are laid (Corbet and Danks, 1975). Thus, although we presume that the female selects a type of habitat more suitable for the larvae, many of the places she avoids are suitable for growth and development.

The reasons why some pools are selected, and others are not include the following: (1) some are more chemically attractive to ovipositing females (Hudson and McLintock, 1967; Osgood, 1971); (2) some are close to plant cover which provides suitable resting sites for gravid females (Bodman and Gannon, 1950); and (3) some are close to blood source for female mosquitoes (Horsfall, 1942; Dixon and Brust, 1972).

2.2.6 Interrelations with other organisms

Mosquitoes may be limited in their local distribution by the presence of other organisms - their food plants, hosts, predators, diseases and competitors.

Many authors have said that predation on mosquito larvae is an important factor limiting their numbers and distribution. The work of Baldwin et. al. (1955), James (1961) and Happold (1965) has shown that many organisms do prey on mosquito larvae, although the extent of this is unknown. Furthermore, some authors have discovered parastic fungi that are host-specific to certain species of mosquitoes. Shemanchuk (1978) reports, for example, that the fungus *Coelomomyces psorophorae*, parastic on mosquito larvae of *Culiseta inornata*, has persisted in irrigated areas of southern Alberta and larval mortalities up to 80% have occurred in some breeding pools.

Intraspecific competition, if severe enough, can result in a smaller adult population. Surtees (1959) has shown experimentally that mortality in *Aedes aegypti* larvae is highest when there is a high population density. Competition for space is severe in a dry year; where a moss mat is present, larvae may be isolated in patches of water as the water level subsides (Happold, 1965).

2.2.7 Other factors

Many other physical and chemical factors in addition to the above can limit the distribution of mosquitoes. Most of these factors involve local distributions rather than distribution over a larger

geographic area. Often these factors are involved in habitat selection.

Some observations indicate that snow usually provides a protection against lethal air temperatures in the case of subterranean stages of mosquitoes (Mail, 1934; Shemanchuk, 1965). This factor is a major limitation on the survival of those species that overwinter as adults which, in turn, regulates the rate of buildup of the mosquito population the following summer.

Many studies show that mosquito behaviour can be regulated by light intensity (Eldrige et. al., 1976; Maloney and Wallis, 1976; Barnard and Mulla, 1977). Such diurnal responses to light may have definite adaptive advantages for many species, especially northern ones (Downes, 1964). Most important for zoogeographic analysis is the possibility that different measures of a climatic factor limiting some particular activity will be brought into play, depending upon diurnal light rhythms. For example, mosquitoes that oviposit only at night are restricted in this activity by nocturnal temperatures, the best statistical measure of which would be the mean minimum daily temperatures encountered in a locality or in a season. Dusk or evening activity would be under the control of late afternoon temperatures, the best measure of which is the mean daily temperature (Maloney and Wallis, 1976).

Soil or substrate structure can be important for the amount of vegetative cover surrounding the larval pool and the nutrient content

of the soil may also affect local breeding pools (Haufe and Burgess, 1956). Substrate structure can be important for larvae that attach to solid substances or burrow into soft sand or mud for protection (Haufe, 1952). In addition to modifying the effect of temperature, wind affects the efficiency of mosquitoes in flight; winds at velocities of about 15 kmph or greater completely prevent most flight activity (Hocking et. al., 1950).

2.3 FORECASTING DISTRIBUTION AND ABUNDANCE

Prediction of mosquito abundance and distribution depends largely on the accuracy of meteorological forecasting. Long-range forecasts are not possible until appropriate methods and models have been perfected. However, short-range prediction of specific mosquito emergence and survival parameters is feasible where daily meteorological records representative of the immediate area are available. For example, Haufe and Burgess (1956) demonstrate that the thermal effect of meteorological conditions can be additively compiled from day to day to indicate from established developmental regimes the expected time of appearance of a given species. The accuracy of this type of prediction increased progressively day by day from the time of general appearance of open water at the edges of mosquito pools to the date of general emergence of the adult mosquitoes. It was then possible to predict future outbreaks, both in time and space, by watching the weather in that particular year.

CHAPTER 3

MATERIALS AND METHODS

3.1 STUDY AREA

The area encompassed by this study represents a cross-section of
the grassland, boreal forest and tundra regions of the western interior
and adjacent arctic areas of Canada. The study area includes the
province of Saskatchewan and the adjacent southern and central portions
of Keewatin District, N.W.T. (Fig. 3.1). Within this area of over
one-third million square miles are represented two of the major
physiographic regions of North America, the Canadian Shield and the
Interior Plains or Borderlands region (Bostock, 1974). Both of these
are characterized by a variety of terrain features but only the Alberta
Plateau portion of the Interior Plains exhibits considerable relief.

3.2 SAMPLING LOCATIONS

During the spring and summer months of 1974 and 1975, samples of
living mosquitoes were collected from sites considered representative
of the distinct ecological zones found in the study area. Between the
months of May and September, sampling sites were established in
Saskatchewan at Weyburn, Saskatoon, MacDowall, Prince Albert National
Park, and Wollaston Lake Post and in the N.W.T. at Ennadai Lake, Rankin
Inlet, and Baker Lake (Fig. 3.1). Descriptions of the locations and
the sample sites are given in Table 3.1.

An effort was made in each locality to select sample sites that
would give a representative sample of all mosquito species in the
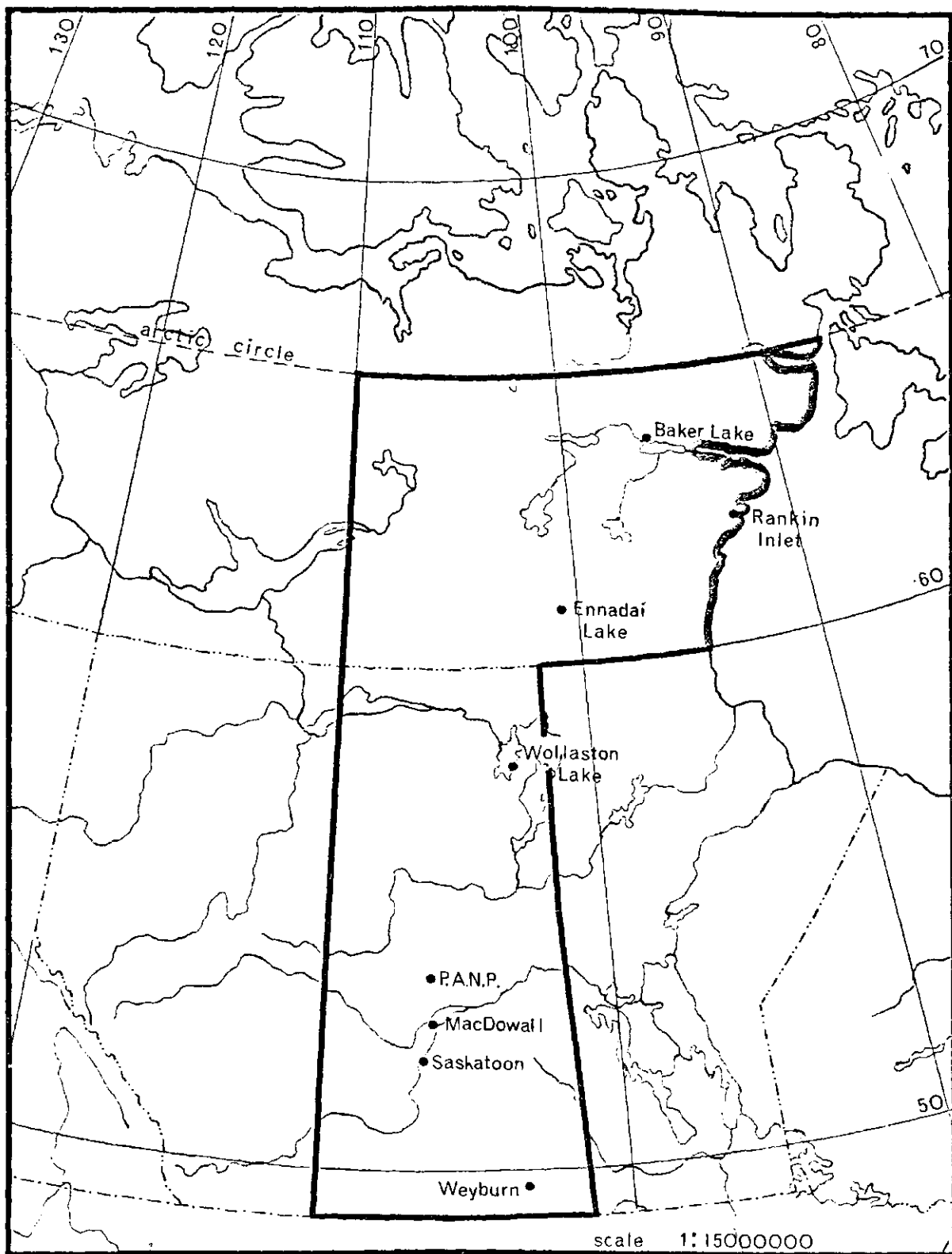
Figure 3.1
Study area showing sampling locations.

Table 3.1 Sampling locations and sample sites within the study area, 1974-75

Location	Coordinate location	Light trap	Number of adult collection sites	Number of larval collection sites	Radius of collection sites	Comments
Weyburn, Saskatchewan	49°41'N 103°52'W	Yes	12	10	40 km	Light trap located 10 km SE of Weyburn near the municipal golf course
Saskatoon, Saskatchewan	52°07'N 106°33'W	Yes	9	4	4 km	Light trap located at Saskatoon Forestry Farm
MacDowall, Saskatchewan	53°01'N 106°07'W	No	4	7	5 km	Near McFarlane Creek, 3 km south of MacDowall
Prince Albert National Park, Saskatchewan	53°40'N 106°06'W	No	5	5	10 km	Near the junction of McKenzie Creek and the Spruce River at the extreme southeast corner of the park
Wollaston Lake Post, Saskatchewan	58°03'N 103°33'W	No	10	5	10 km	On the east shore of Wollaston Lake
Ennadai Lake, N.W.T.	61°08'N 100°33'W	No	13	13	30 km	On the northeast arm of Ennadai Lake near the mouth of the Kazan River
Rankin Inlet, N.W.T.	62°45'N 92°10'W	No	5	4	20 km	On the west coast of Hudson Bay
Baker Lake, N.W.T.	68°18'N	No	4	1	10 km	At the northwest end of Baker Lake, near the mouth of the Thelon River

area. The selection of these sites is dealt with in greater detail
in section 3.3, but generally they reflect the widest range of
habitat types within the particular area. Wherever possible,
replicate samples were made in 1974 and 1975.

3.3 SAMPLING TECHNIQUES

3.3.1 Larvae and pupae

Mosquito larvae and pupae were collected throughout the spring
and summer season from their breeding sites in each sampling location.
The types and locations of these breeding pools will be discussed in
section 3.3.3.

Larvae and pupae samples were collected by dipping with a 500 cc
water dipper and concentrated in a 20-mesh screen filter funnel.
Contents of the funnel were then rinsed on to cotton terry towelling
that lined the bottom of 41 cm x 23 cm x 5 cm enamel trays (Fig. 3.2a,
3.2b). After the excess water was drained off, the trays containing
the larvae and pupae were transported to the laboratory where the
larvae and pupae were washed off the towelling back into the trays,
with Bates' (1941) "Medium S". Dry sterilized powdered "Tetra Min"
fish food (Hayes et. al., 1974) was added to each tray. The trays
were held at room temperature and covered with glass plates to
retard evaporation.

Collections were made at approximately weekly intervals from a
variety of different sites. The total length of the sampling period
varied with different locations, generally reflecting the shorter
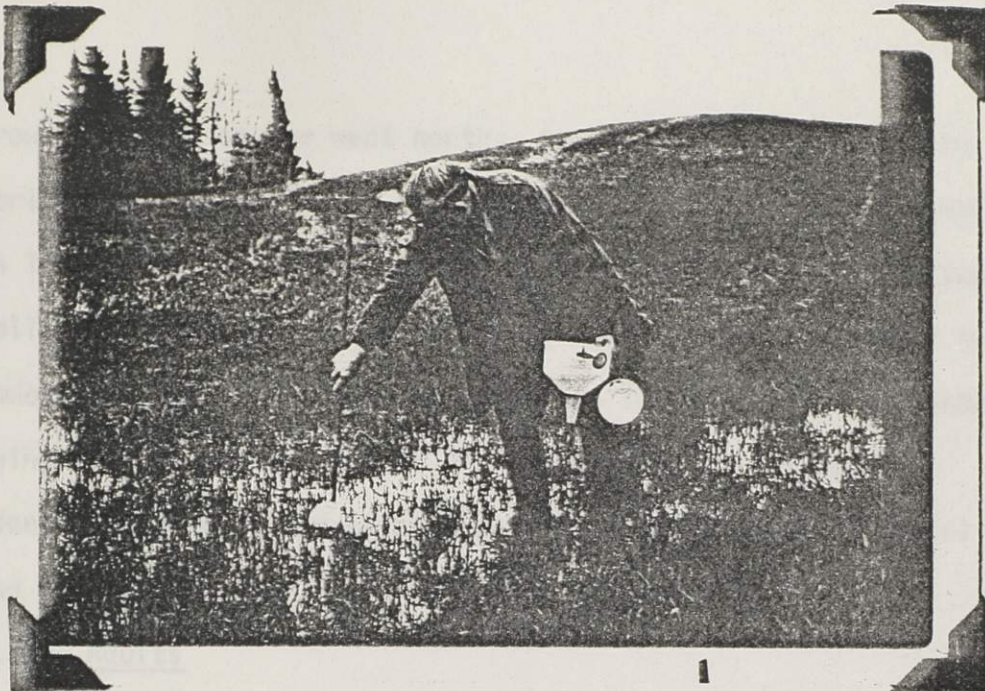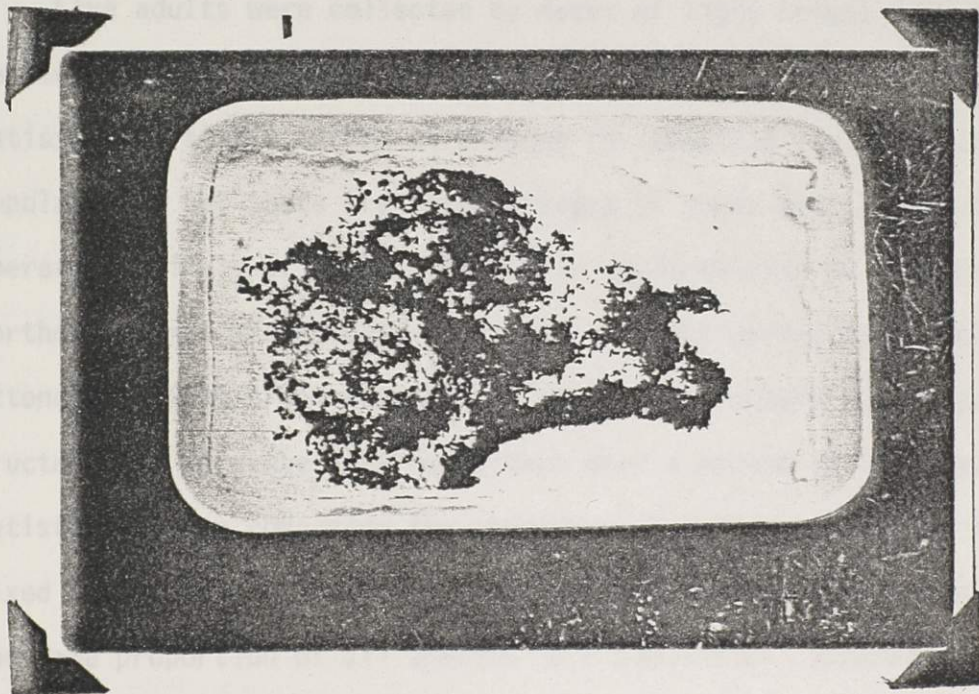
Figures 3.2a, 3.2b

Demonstration of larval sampling technique at MacDowall,
Saskatchewan (a) and enamel trays used to transport larval sample
to the laboratory (b).

growing season as one went north. A complete list of sampling periods for larvae, pupae, and adults for each locality is shown in Table 3.2. In some instances, the numbers of larvae and pupae collected, particularly at the beginning of the season, were too numerous to be identified individually, identification in these cases being made on random samples of larvae from each collection. Identifications of larvae were based largely on keys by Rempel (1950) and Barr (1958).

3.3.2 Adults

Live adults were collected by means of light traps, aspirators, and sweep nets. Light traps are generally considered to be the most satisfactory single method at present for sampling adult mosquito populations, but there are disadvantages in their use. Light traps, operated entirely at night, lose their applicability in extreme northern summer situations, where the daylight period is greatly extended. Light traps have proven to be satisfactory for measuring fluctuations in numbers of mosquitoes over a period of time but less satisfactory for comparing the abundance of different species in a mixed population. There is evidence that a light trap does not take the same proportion of all species in a population, apparently because some species are attracted more than others by light (Reed, 1959; Barr et. al., 1960; Downey, 1962). For this reason light trap catches are sometimes supplemented by collections made by other methods and some investigators have derived numerical factors to

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Table 3.2. List of sampling periods, both for mosquito larvae and adults,
for each locality in the study area

	LARVAE	ADULTS
Saskatchewan		
Weyburn	May - Sept. 16, 1975	June 4 - Sept. 30, 1974
Saskatoon	June 6, 1974	May 17 - Sept. 30, 1974
MacDowall	May 27 - June 6, 1974 May 23 - July 11, 1975	May 27 - Sept. 4, 1974
Prince Albert National Park	May 27 - June 6, 1974 June 7, 1975	May 27 - Sept. 4, 1974
Wollaston Lake	June 11-13, 1974	June 11 - August 14, 1974
Northwest Territories		
Ennadai Lake	June 21-29, 1975	June 20 - July 22, 1975
Rankin Inlet	June 21-28, 1974	June 25 - July 31, 1974
Baker Lake	July 15, 1974	July 15-16, 1974

compensate for differences in the attraction to light, (Love and Smith, 1957). Subsequent analyses by McLintock et. al. (1966) reveal that the following inferences may be made concerning light trap catches in Western Canada. (1) Light traps do not indicate whether there are more mosquitoes in one area than in another, in any one period of time (size of catch is influenced by the specific trap location). (2) They do indicate, however, the magnitude of mosquito fluctuations from year to year, differences in species composition from one area to another, and differences in relative abundance of various species from locality to locality. Through comparisons of light trap catches with catches using different methods (labelled "Miscellaneous Catches"), the researchers also indicated that the light trap catches probably only overestimated the relative abundance of A. *campestris*. Over a period of years then, and backed up with data from other trapping methods, light traps appear to be a reliable method for sampling the overall mosquito population of a given area.

The light traps used in this study were of the New Jersey type modified for taking the mosquitoes alive (McLintock, 1946), the light source being a 100-watt incandescent bulb (Fig. 3.3). The traps were operated each night from 6:30 p.m. until 7:00 or 8:00 a.m. in both the Weyburn and Saskatoon sites.

Sampling methods other than light traps were employed in the remaining localities. In each of these localities the use of light

Figure 3.3

A New Jersey type light trap modified for taking mosquitoes alive.

traps was not appropriate for several reasons. These included such factors as extremely long daylight periods in many of the northern sites, remoteness of these sites and the general lack of power sources for the light. In these localities mosquitoes were collected during the daylight period, through the use of aspirators and sweep nets. Mosquitoes were collected in their resting places or from domestic animals or from ourselves. The usual resting places were barns, chicken coops, culverts, or in the grass, shrubbery or other natural vegetation. Collections made other than by light trap alone were labelled "Miscellaneous". To ensure that the widest possible species range was sampled, miscellaneous collections were conducted in a wide variety of habitats, for various time periods and at different times of the day.

In addition, previously published records of mosquito species and distribution supplemented the data obtained in the field. Most of this information was obtained from the species-distribution records of Dr. J. McLintock of the Agriculture Canada Research Station, Saskatoon.

Adults collected by these various sampling methods were then placed in wire screen cases (cylindrical in shape) of the same type used in the light traps. In the case of the light traps, the cage containing the mosquitoes was simply removed from the trap in the morning. The cages were then placed in humidified cardboard cartons and sent directly to the laboratory to be identified. In the laboratory the mosquitoes were removed from the cages by means of an

aspirator and identified, as far as possible, to species. Badly
rubbed specimens that could not be distinquished with certainty were
labelled "indeterminate". Two northern species, A. *punctor* and
A. *hexodontus*, could not be separated morphologically as adult
females and when encountered, were labelled A. *punctor-hexodontus*.
Identification of adults were based on keys by Carpenter and La Casse
(1955), Vockeroth (1950, 1954a, 1954b), Rempel (1953) and Barr
(1958).

3.3.3 Environmental factors

The methods used for sampling these factors have been grouped as
follows:

Climatic factors - Temperature, precipitation, relative humidity
(RH), hours of bright sunshine, and wind velocity values were collected.
Reliable, long term records (Ministry of Transport, Meteorological
Branch) were available for all of the localities sampled in the study
area. Daily, weekly and monthly data values were obtained from the
Monthly Record (Ministry of Transport); hourly values were available
from the hourly log sheet of local weather stations. Temperature,
relative humidity and the presence or absence of precipitation and
wind were recorded at the time of each collection. Temperature and
relative humidity were recorded by means of a hand-held, sling
psychrometer.

Edaphic factors - A wide variety of potential larval sites,
reflecting differences in relief, soils, vegetation as well as

micro-climate were sampled. The sampled pools varied in size, shape, depth and location since it was important to measure the maximum variation in mosquito development that might be attributed to physical characteristics of the pool and to edaphic factors of the surrounding terrain. The pools formed a series ranging from the completely exposed type that is common on the tundra or on the prairies, to those partially sheltered by vegetation that is characteristic of the boreal forest. Actual larval pools were described and classified as to type and location. Water levels were recorded along with specific measurements of pool size, amount of shade, temperature, and pH of the water (sampled by battery operated, portable pH meters - Sargent Welch model RB and Corning model 5).

Biotic factors - The vegetation immediately surrounding larval pools (within .5 m) was identified to species. Since many of the pools were relatively small, all plant species surrounding each site could be sampled. The vegetation in the vicinity of the pools (within 100 m) was sampled through the use of a line transect technique (Wilde, 1954). A minimum of four transects were chosen at random; plant coverage was described by species along each transect at each sampling location. Observations on the vegetation type and density were also recorded at each adult collection site. These were visual observations only, describing the gross vegetation features of the area (tree species, ground cover species, etc.). Identifications of plant species were based on keys and descriptions by Carmichael

(1976a, 1976b); Budd and Best (1969); Teed and Rowe (1973); Cunningham (1975); Porsild (1955, 1957); and Campbell et. al. (1973), (see Appendix B).

Another biotic factor that can be extremely important in influencing mosquito abundance and distribution is the presence or absence of mosquito predators. For example, Hocking et. al. (1950) have noted the importance of Chaoborinae species and other insects in limiting the numbers of mosquito larvae as far north as Churchill. To ascertain the presence or absence of these predator species in this study, any predators that were included in the larval collections were recorded and identified as far as possible to genera or species. Genus and species identifications were based on keys by Johannsen (1933, 1935, 1937) and Lehmkuhl (1975).

3.4 DATA ANALYSIS

3.4.1 Analysis of species distribution and abundance records

Unlike the population of a single species, a mosquito community has a series of attributes that do not occur in its individual species components and have meaning only with reference to the community level of integration. Three characteristics of a mosquito community were measured: (1) Relative abundance, (2) Dominance, and (3) Species diversity.

Species lists were compiled for each sampling location. The lists were broken down into the three component parts:

(1) Each population was measured throughout the entire

developmental period on a weekly basis. This is necessary when examining mosquito populations because the size and variety of each population is undergoing continual change over relatively short periods of time.

(2) A population index was employed for individual species and populations on a weekly basis. The population index equals the average daily (or weekly) log $(n + 1)$ catch for the period, where n equals the number of individuals. This index is used because it is generally characteristic of large insect collections from a single, temperate locality or region that a few species are predominant and a relatively large number of species are represented only by a few specimens. This was the case with the mosquito catches in the study area.

(3) The species within each population were classified as to their dominance. Dominance is related to the concept of species diversity, and some of the measures of diversity discussed in Chapter 2 (such as Shannon's index) could also be considered as measures of dominance. A simple community dominance index has been defined as follows, (McNaughton, 1968):

Community dominance index = percentage of abundance
contributed by the two
most abundant species

$$= 100 \times \frac{y_1 + y_2}{y} \qquad (3:1)$$

where y_1 = abundance of most abundant species

y_2 = abundance of second most abundant species

y = total abundances for all species

The differences in mosquito dominance and variety from one ecological region to another were then examined and compared.

(4) To determine species diversity, and hence overall stability of a population, the Shannon index of general diversity has been used (Shannon and Weaver, 1963). This expression is

$$\bar{H} = -\Sigma \frac{n_i}{N} \log_2 \frac{n_i}{N} \qquad (3:2)$$

where n_i is the importance value for each species and N is the total of all importance values. Lloyd and Ghelardi (1964) have pointed out that this measure has two separate components, species richness and the "equitability" or "evenness" of species abundances. Species richness is simply S, the number of species in the sample. Several expressions have been employed to measure the relative abundance or evenness component: here the following index has been used,

$$e = \frac{\bar{H}'}{\bar{H}' \, max.} \qquad (3:3)$$

where $\bar{H}'$ is the Shannon index and $\bar{H}'$ *max.* is $\log_2 S$ (see Odum, 1971). This index represents the ratio of the observed diversity to the maximum diversity possible for the same number of species. It has a maximum value of unity when all species are equally abundant, while the minimum value is defined by the situation in which all species except the most abundant are represented by only one individual; the more individuals in the sample, the closer e approaches zero.

Since the components of the Shannon formula can vary

independently of one another, it is obvious that two samples having
identical $\bar{H}$ values may in fact be very different. Therefore, the formula
has been broken down into the two components of species richness (S)
and relative abundance (e) in order to analyze diversity patterns.
It was also possible to correlate changes in diversity patterns from
one area to another with changes in either species richness or
relative abundance through the use of a standard regression technique.

3.4.2 Climatic analysis and correlation with distribution and abundance

Any useful method for analyzing the distribution, abundance and
developmental periods of mosquitoes on the basis of meteorological
conditions is practical only if it depends on weather factors that are
normally recorded at weather stations. The temperature condition of
a breeding pool or adult resting site is dependent largely on
meteorological phenomena, but it may be influenced considerably by
edaphic or biotic factors as well. The probability of estimating the
period of mosquito development (and hence their abundance and
distribution) so far as it is related to the temperature regime of the
environment depends theoretically on the degree to which the
environment is affected by meteorological conditions which can be
predicted or recorded.

At least four meteorological factors were considered to have
measurable effects on the environment of immature and adult mosquitoes:
air temperature, wind, hours of bright sunshine, and precipitation.

Rainfall has been described as a limiting factor for mosquito prevalence in temperate areas by McLintock et. al. (1966). Mosquito development in subarctic or arctic muskeg with underlying permafrost is rarely restricted by insufficient water in breeding pools. The correlations in the subarctic and arctic areas were confined therefore to three factors: air temperature, wind and daily sunshine.

The analysis proceeded as follows:

(1) Developmental periods and seasonal fluctuations in abundance for the species found in a particular location were calculated according to the procedures in section 3.4.1. Where possible, an assessment was also made of the thermal constant, threshold and optimum temperature ranges required to complete development for a species.

(2) The meteorological conditions prevailing in each locality were measured, including temperature and humidity values at each collection site. The latter procedure is important because some mosquito species might choose a site that is suitable for development on a micro-environmental level, even though this site is located within a developmentally unsuited macro-environment.

(3) Patterns in mosquito abundance and distribution were then explained in terms of various environmental factors that could be responsible for these patterns. For example, weekly abundance and occurrence of mosquito species was compared with weekly mean temperatures, precipitation, wind and other meteorological data. The interdependence of meteorological factors that contribute to the

environment of mosquitoes was recognized in all comparisons. The modifying roles that edaphic or biotic factors play in determining mosquito patterns were also assessed.

CHAPTER 4

RESULTS

4.1 GEOGRAPHIC DISTRIBUTION AND ABUNDANCE OF MOSQUITOES

From June 4 to September 30, 1974 and from June 20 to July 22,
1975, 40,604 female mosquitoes were collected representing 33 species
(Table 4.1). It is characteristic of large insect catches from a
single locality or region that a few species are predominant and a
relatively large number of species are represented by only a few
specimens. This was the case with the mosquito catches in the study
area. Although no species were common to all locations, eight species
(A. *punctor*, A. *hexodontus*, A. *nigripes*, C. *inornata*, A. *communis*,
A. *fitchii*, A. *impiger* and A. *campestris*) together made up from 70-80%
of the total catches from the individual locations. The figures did
not indicate whether there were more mosquitoes in one district than
in another in any one period of time (size of catch is influenced by
the specific trap locations), but they did show that the species
composition of the different districts varied and that the relative
abundance of the different species varied from locality to locality.
In the case of the light traps at Saskatoon and Weyburn, some species
were attracted by light more than others, but in Table 4.1 a
comparison of the percentages under "Light" with those under "Misc."
indicates that the light trap catches probably only overestimated the
relative abundance of A. *campestris*. Light trap catches at Weyburn
showed 16.6% of the total number caught were of this species, compared

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Table 4.1   Relative Abundance of Female Mosquitoes in the Study Area, 1974-75

	Weyburn Light (June 4–Sept. 30 1974)		Weyburn Misc.* (Aug. 26–Sept. 6 1974)		Saskatoon Light (June 4–Sept. 30 1974)		Saskatoon Misc. (May 17–Sept. 30 1974)		MacDowall Misc. (May 27–Sept. 4 1974)		Prince Albert National Park Misc. (May 27–Sept. 4 1974)		Wollaston Lake Misc. (June 11–Aug. 14 1974)		Ennadai Lake Misc. (June 20–July 22 1975)		Rankin Inlet Misc. (June 25–July 31 1974)		Baker Lake Misc. (July 15–July 16 1974)		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
A. punctor-hex.	0	-	0	-	0	-	0	-	0	-	0	-	0	-	3209	60.2	3316	43.4	1328	35.7	7853	19.3
A. nigripes	0	-	0	-	0	-	0	-	0	-	0	-	0	-	413	7.7	2713	35.5	2311	62.1	5437	13.4
C. inornata	2600	46.4	128	15.1	593	20.1	1221	55.4	8	<1	7	<1	2	<1	0	-	0	-	0	-	4557	11.2
A. communis	0	-	0	-	0	<1	0	-	581	19.8	2583	32.6	186	12.9	312	5.8	0	-	0	-	3479	8.6
A. fitchii	164	2.9	0	-	112	3.8	190	8.6	786	26.8	1795	22.6	0	-	0	-	0	-	0	-	3233	8.0
A. impiger	0	-	0	-	0	-	1	<1	0	-	2	<1	0	-	1057	19.8	1613	21.1	80	2.6	2751	6.8
A. campestris	927	16.6	18	2.1	1446	48.9	183	8.3	278	9.5	1376	17.4	52	3.6	0	-	0	-	0	-	2576	6.3
A. excrucians	0	-	0	-	0	-	0	<1	97	3.3	729	9.2	999	69.5	284	5.3	0	-	0	-	1990	4.9
A. punctor	0	-	0	-	110	3.7	1	<1	9	<1	5	<1	17	1.2	0	-	0	-	0	-	1936	4.8
A. flavescens	1132	20.2	2	<1	95	3.2	120	5.4	195	6.6	632	8.0	0	-	0	-	0	-	0	-	1380	3.4
A. eudes	0	-	0	-	0	-	0	<1	29	<1	303	3.8	0	-	0	-	0	-	0	-	833	2.1
A. vexans	147	2.6	13	1.5	327	11.1	13	<1	44	1.5	10	<1	0	-	0	-	0	-	0	-	832	2.0
A. spencerii	33	<1	461	54.2	23	<1	239	10.8	314	10.7	212	2.7	1	<1	1	√	0	-	0	-	810	2.0
A. cataphylla	2	<1	2	-	22	<1	18	<1	434	14.8	61	<1	9	<1	0	-	0	-	0	-	578	1.4
A. canadensis	0	-	0	-	1	<1	1	<1	0	-	0	-	21	1.5	0	-	0	-	0	-	519	1.3
C. tarsalis	356	6.4	12	1.4	62	2.1	33	1.5	4	<1	0	-	0	-	0	-	0	-	0	-	463	1.1
A. dorsalis	219	3.9	1	<1	137	4.6	94	4.3	96	3.3	0	-	0	-	0	-	0	-	0	-	455	1.1
A. cincreus	0	-	0	-	0	-	0	-	4	<1	170	2.1	2	√	58	1.1	0	-	0	-	326	<1
A. earlei	9	<1	97	11.4	24	<1	77	3.5	0	-	1	<1	0	-	0	-	0	-	0	-	212	<1
A. nigromaculis	4	<1	118	13.9	0	-	0	-	49	1.7	9	<1	0	-	0	-	0	-	0	-	122	<1
A. pionips	0	-	0	-	0	-	0	-	0	-	16	<1	35	2.4	0	-	0	-	0	-	93	<1
C. impatiens	0	-	0	-	0	-	0	-	8	<1	16	<1	88	6.1	0	-	0	-	0	-	88	<1
N. perturbans	1	√	0	-	0	-	0	-	0	-	0	-	4	√	0	-	0	-	0	-	25	<1
A. stricticus	0	-	0	-	0	-	0	-	0	-	3	<1	14	√√	0	-	0	-	0	-	20	<1
C. incidens	0	-	0	-	0	-	0	-	0	-	0	-	6	√	0	-	0	-	0	-	14	<1
C. alaskaensis	0	-	0	-	2	<1	0	-	1	<1	3	<1	0	-	0	-	0	-	0	-	9	<1
A. stimulans	1	√	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	4	<1
C. morsitans	0	-	0	-	0	-	4	<1	0	-	0	-	2	√	0	-	0	-	0	-	4	<1
A. triseriatus	0	-	0	-	0	-	0	-	1	<1	0	-	0	-	0	-	0	-	0	-	2	<1
A. riparius	0	-	0	-	0	-	0	-	0	-	0	-	2	√	0	-	0	-	0	-	1	<1
C. restuans	1	√	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	1	<1
C. minnesotae	0	-	0	-	1	<1	1	<1	0	-	0	-	0	-	0	-	0	-	0	-	1	<1
TOTAL	5596		850		2955		2203		2938		7930		1437		5334		7642		3719		40604	

*Miscellaneous catches = Catches by aspirator, Malaise trap, Double Ramp trap.

to only 2.1% of the Weyburn miscellaneous catches. For Saskatoon, the percentage of this species in relation to the total number was 48.9% for the light trap catches and only 8.3% for the miscellaneous catches. The relatively high numbers of C. *inornata* listed in the Saskatoon miscellaneous column represent a sampling bias for roadside culverts, the preferred resting place for large numbers of this species.

Table 4.2 indicates that most of the dominant mosquito species in the study area belong to the genus *Aedes*[1]. With the exception of *Culex tarsalis* and *Culiseta inornata* in the grasslands, representatives of other genera were quite rare. In each region several species were predominant. Thus in the grassland region they were A. *flavescens*, A. *campestris* and C. *inornata*, closely followed by A. *dorsalis* A. *vexans*, A. *spencerii* and C. *tarsalis*. In this region the *dorsalis* group of *Aedes* was strongly represented (Table 4.4). In the aspen grove section the place of A. *flavescens* was taken by A. *fitchii*. In the mixed-wood forest section, A. *fitchii* again predominated along with other members of the *stimulans* group of *Aedes* (such as A. *excrucians* and A. *eudes*) (Table 4.4). In addition, species of the *communis* group of *Aedes* (A. *communis*, A. *cataphylla*, A. *punctor*, A. *pionips*) (Table 4.4) became increasingly common in the mixed-wood areas; A. *cinereus* and A. *canadensis* were common as well. In northern wooded areas and in tundra areas the so-called "black-legged"

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[1]This large genus has been further subdivided into groups as shown in Table 4.3.

Table 4.2   Mosquito species found in the study area[1]

AEDES

  Sub genus *Ochlerotatus*
    Aedes campestris Dyar & Knab
    Aedes canadensis (Theobald)
    Aedes cataphylla Dyar
    Aedes communis (De Geer)
    Aedes diantaeus Howard, Dyar & Knab
    Aedes dorsalis (Meigen)
    Aedes eudes Howard, Dyar & Knab
    Aedes excrucians (Walker)
    Aedes fitchii (Felt & Young)
    Aedes flavescens (Muller)
    Aedes hexodontus Dyar
    Aedes impiger (Walker)
    Aedes implicatus Vockeroth
    Aedes increpitus Dyar
    Aedes intrudens Dyar
    Aedes melanimon Dyar
    Aedes nigripes (Zetterstedt)
    Aedes nigromaculis (Ludlow)
    Aedes pionips Dyar
    Aedes pullatus (Coquillett)
    Aedes punctor (Kirby)
    Aedes rempeli Vockeroth
    Aedes riparius Dyar & Knab
    Aedes spencerii (Theobald)
    Aedes sticticus (Meigen)
    Aedes stimulans (Walker)
    Aedes trichurus (Dyar)

  Sub genus *Finlaya*
    Aedes triseriatus (Say)

  Sub genus Aedimorphus
    Aedes vexans (Meigen)

  Sub genus Aedes
    Aedes cinereus Meigen

ANOPHELES

  Sub genus Anopheles
    Anopheles earlei Vargas
    Anopheles walkeri Theobald

MANSONIA

  Sub genus *Coquillettida*
    Mansonia perturbans (Walker)

CULEX

  Sub genus Culex
    Culex restuans Theobald
    Culex tarsalis Coquillett

  Sub genus Neoculex
    Culex territans Walker

CULISETA

  Sub genus Culiseta
    Culiseta alaskaensis (Ludlow)
    Culiseta impatiens (Walker)
    Culiseta incidens (Thomson)
    Culiseta inornata (Williston)

  Sub genus Culicella
    Culiseta minnesotae Barr
    Culiseta morsitans (Theobald)

PSOROPHORA

  Sub genus *Grabhamia*
    Psorphora signipennis (Coquillett)

WYEOMYIA

  Sub genus Wyeomyia
    Wyeomyia smithii (Coquillett)

*-Denotes species that have been previously recorded from the study area
  but were not encountered in 1974-75.

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[1]
  See Appendix A

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Table 4.3.   *AEDES* GENUS – Subgenera
              and Groups

(Barr, 1958)

I.   Sub genus (*Ochlerotatus*)

- Group *taeniorhynchus*
  (1) *nigromaculis*

- Group Annulipes or *stimulans*
  (1) *excrucians*
  (2) *fitchii*
  (3) *flavescens*
  (4) *increpitus*
  (5) *riparius*
  (6) *stimulans*
  (7) *eudes*

- Group *dorsalis*
  (1) *campestris*
  (2) *canadensis*
  (3) *dorsalis*
  (4) *melanimon*

- Group *communis*
   (1) *cataphylla*
   (2) *communis*
   (3) *diantaeus*
   (4) *hexadontus*
   (5) *intrudens*
   (6) *impiger*
   (7) *nigripes*
   (8) *pionips*
   (9) *pullatus*
  (10) *punctor*
  (11) *rempeli*
  (12) *spencerii*
  (13) *sticticus*
  (14) *implicatus*
  (15) *trichurus* (Barr, p. 110)

II. Sub genus (*Finlaya*)

- Group (H)
  (1) *triseriatus*

III. Sub genus (*Aedimorphus*)

- Group *vexans*
  (1) *vexans*

IV. Sub genus (*Aedes*)
  (1) *cinereus*

Table 4.4   Geographic distribution of mosquitoes in the study area

Ecological zone	Species		
	Abundant	Common	Rare
Grassland region - Weyburn	Aedes flavescens Aedes campestris Culiseta inornata	Aedes dorsalis Aedes fitchii Aedes vexans Aedes spencerii Aedes nigromaculis Culex tarsalis Anopheles earlei	Aedes cataphylla *Aedes excrucians Aedes stimulans *Aedes melanimon Aedes cinereus *Aedes riparius *Aedes canadensis *Aedes increpitus *Aedes punctor *Aedes sticticus *Aedes implicatus *Aedes triseriatus *Aedes eudes Culex restuans *Culex territans Culiseta morsitans *Culiseta minnesotae Mansonia perturbans *Psorophora signipennis
Boreal forest region Aspen grove section - Saskatoon	Aedes campestris Culiseta inornata	Aedes fitchii Aedes punctor Aedes flavescens Aedes dorsalis Aedes vexans Aedes spencerii Anopheles earlei Culex tarsalis	Aedes communis Aedes canadensis Aedes cataphylla *Aedes sticticus *Aedes implicatus Aedes stimulans Aedes impiger Aedes eudes *Aedes cinereus *Aedes trichurus *Aedes pionips *Aedes riparius *Aedes increpitus *Aedes nigromaculis *Aedes excrucians *Culex restuans *Culex territans *Culiseta alaskaensis Culiseta morsitans *Culiseta impatiens Culiseta minnesotae *Mansonia perturbans

*Denotes species that have been previously recorded from the study area but were not encountered in 1974-75.

Table 4.4 (continued)

Ecological zone	Species		
	Abundant	Common	Rare
Boreal forest region Mixed-wood forest section (agricultural) - MacDowall	Aedes fitchii Aedes communis Aedes canadensis Aedes cataphylla	Aedes excrucians Aedes punctor Aedes eudes Aedes cinereus Aedes spencerii Aedes pionips	Aedes flavescens Aedes vexans Aedes dorsalis Aedes stimulans Aedes absenratus Aedes riparius Aedes increpitus Aedes implicatus *Aedes trichurus *Aedes sticticus *Aedes campestris Mansonia perturbans Anopheles earlei Culiseta inornata Culiseta alaskaensis
Boreal forest region Mixed-wood forest section (non-agricultural) - Prince Albert National Park	Aedes communis Aedes fitchii Aedes excrucians	Aedes punctor Aedes eudes Aedes vexans Aedes cataphylla Aedes cinereus	*Aedes stimulans Aedes campestris *Aedes increpitus Aedes flavescens Aedes implicatus Aedes canadensis *Aedes impiger Aedes spencerii *Aedes dorsalis Aedes pionips *Aedes riparius Aedes sticticus *Aedes intrudens *Aedes diantaeus *Aedes pullatus *Aedes trichurus *Culiseta incidens Culiseta inornata Culiseta alaskaensis *Culex tarsalis Mansonia perturbans *Anopheles walkeri Anopheles earlei *Wyeomyia smithii

Table 4.4 (continued)

Ecological zone	Species		
	Abundant	Common	Rare
Boreal forest region Northern coniferous- northwestern transition forest section - Wollaston Lake	Aedes punctor Aedes fitchii	Aedes excrucians Aedes flavescens Aedes canadensis Aedes pionips Culiseta impatiens	Aedes communis Aedes cataphylla Aedes cinereus Aedes sticticus Aedes triseratus *Aedes diantaeus *Aedes pullatus *Aedes spencerii Culiseta alaskaensis Culiseta incidens
Boreal forest tundra region Northwestern transition forest section tundra region - Ennadai Lake	Aedes hexodontus Aedes punctor Aedes impiger	Aedes nigripes Aedes communis Aedes excrucians Aedes cinereus Aedes rempeli	Aedes cataphylla *Aedes spencerii *Aedes flavescens *Aedes riparius *Aedes campestris *Aedes pionips *Culiseta impatiens *Culiseta alaskaensis
Tundra region (coastal) - Rankin Inlet	Aedes nigripes Aedes punctor Aedes hexodontus Aedes impiger		Aedes rempeli
Tundra region (interior) - Baker Lake	Aedes nigripes Aedes punctor Aedes hexodontus	Aedes impiger	*Aedes rempeli

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Aedes species were predominant. A. *punctor* was by far the most wide-spread species, being found throughout the northern wooded and tundra areas. In the northwestern transition section and on the tundra, however, the species A. *hexodontus*, A. *impiger*, A. *communis* and A. *nigripes* were found in great abundance. Of particular interest, A. *excrucians*, a common woodland species in the southern boreal forest, extended its range well into the tundra areas, breeding in exposed tundra pools underlain with permafrost (see following section on habitat distribution).

4.2 SEASONAL DISTRIBUTION AND ABUNDANCE OF MOSQUITOES

The sequence of appearance of adult mosquitoes varied in the seven study locations (Fig. 4.1-4.7).

In the grassland region (Fig. 4.1) there was a marked succession of species, and a number of generations of individual species, with the first species appearing in May and the last emerging in early September. The sequence fluctuated markedly from year to year being greatly influenced by the temperature and by the amount and distribution of rainfall. The sequence outlined here for 1974-1975 is typical of years with normal or above-normal rainfall and below-normal temperatures.

The first species to appear was A. *spencerii* with adults generally emerging by the end of May. It is possible for this species to have a second generation in mid-July and a third in late August or early September. The second and third peaks of abundance did occur at Weyburn in 1974. These were due to heavy rains in July
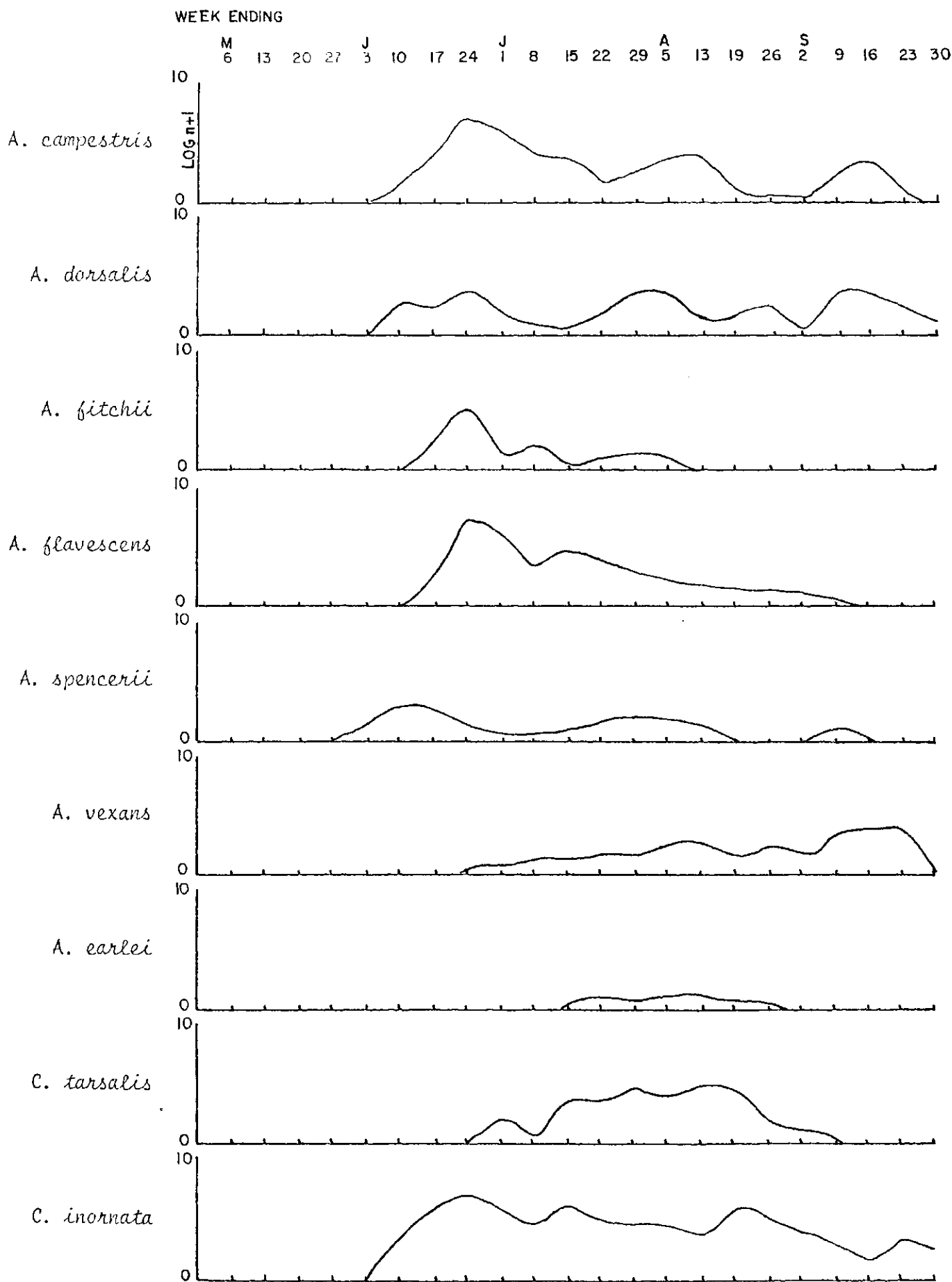
Figure 4.1 Life histories of some species of mosquitoes at Weyburn, Sask. A. *cataphylla*, A. *nigromaculis*, A. *stimulans*, C. *restuans* and M. *perturbans* were too rare to analyze their life histories.

WEEK ENDING

	M				J				J				A				S			
	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12	19	26	2	9	16	23	30

A. campestris
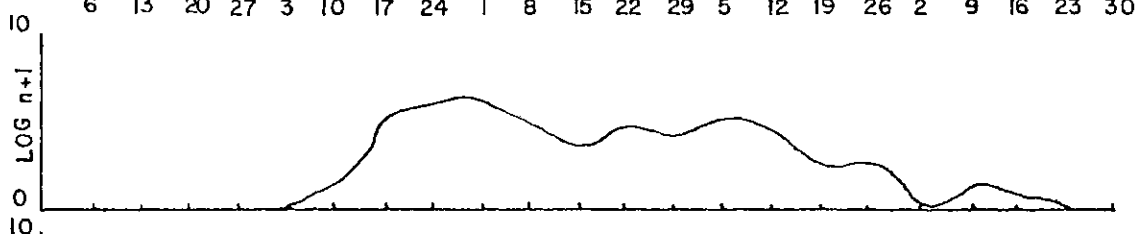
A. cataphylla
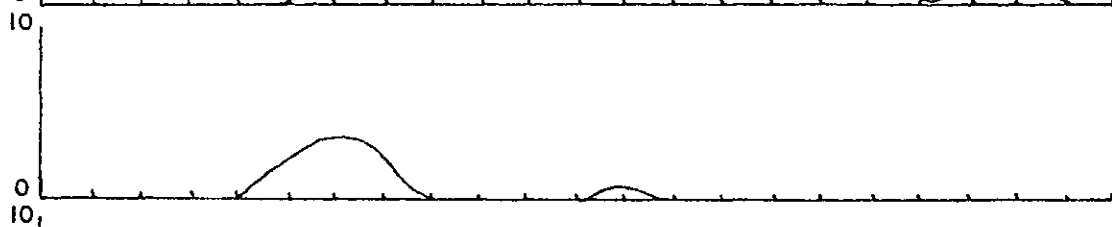
A. dorsalis
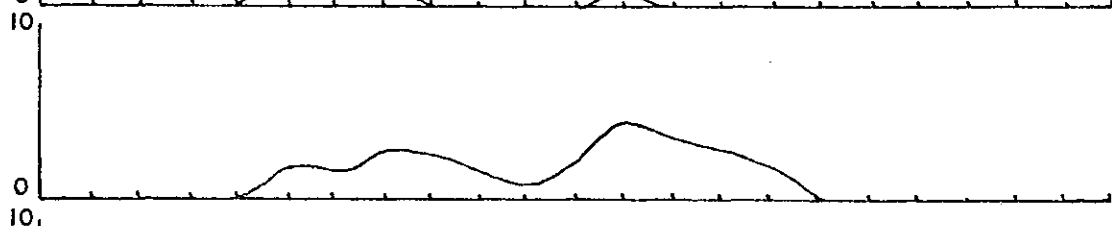
A. fitchii
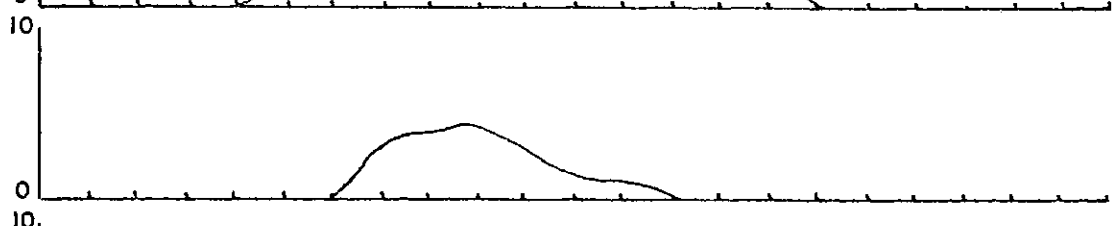
A. flavescens
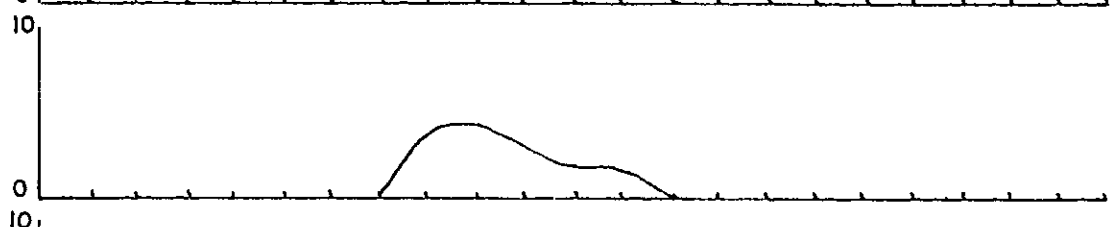
A. punctor
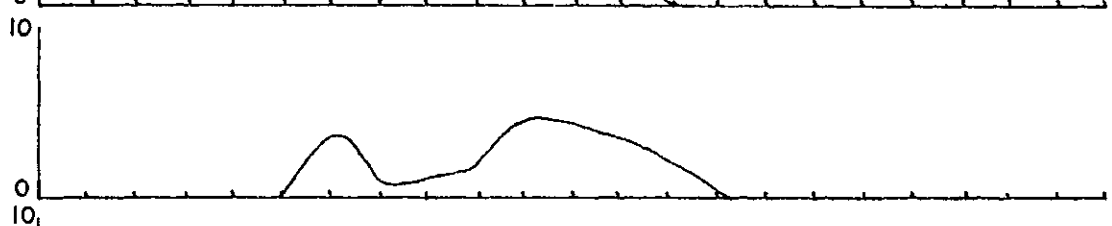
A. spencerii
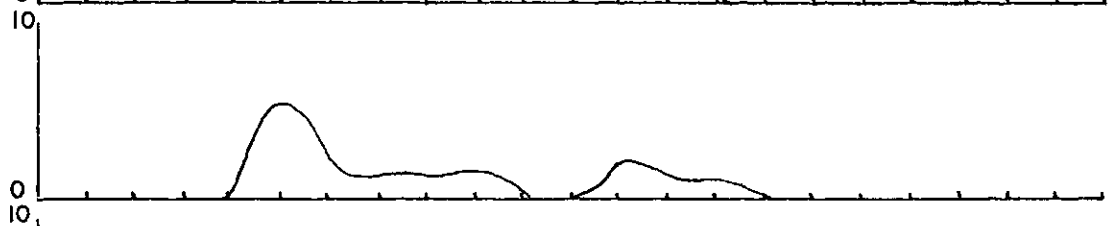
A. vexans
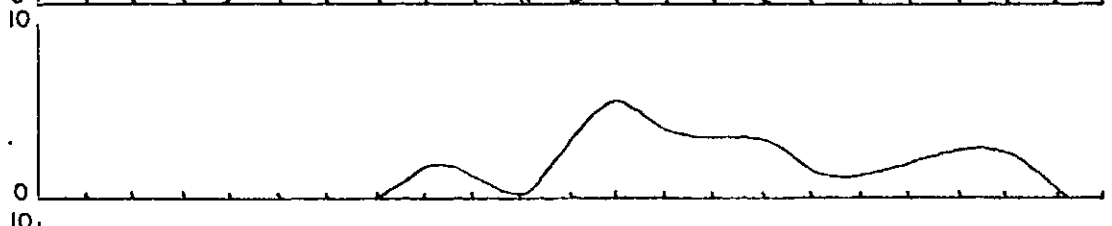
A. earlei
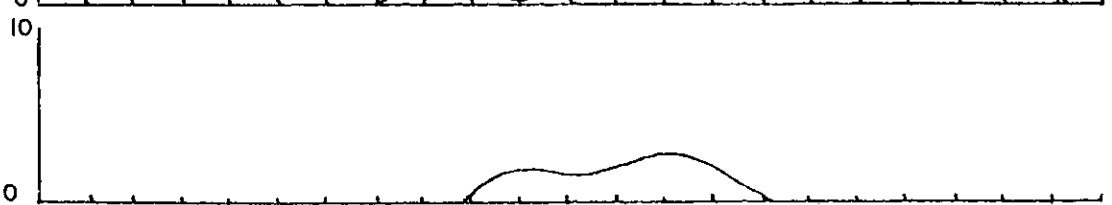
SASKATOON
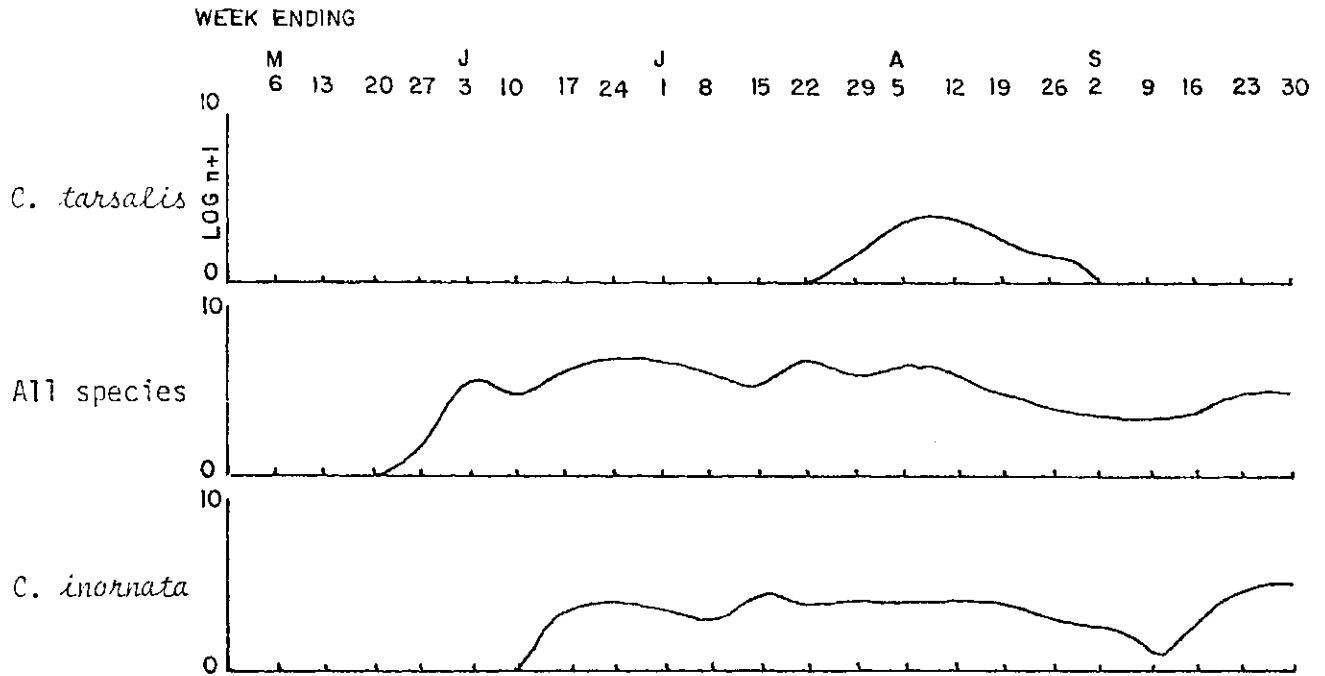
Figure 4.2.   Life histories of some species of mosquitoes at Saskatoon, Sask.
A. *stimulans*, A. *canadensis* and A. *communis* were too rare to
analyze their life histories.
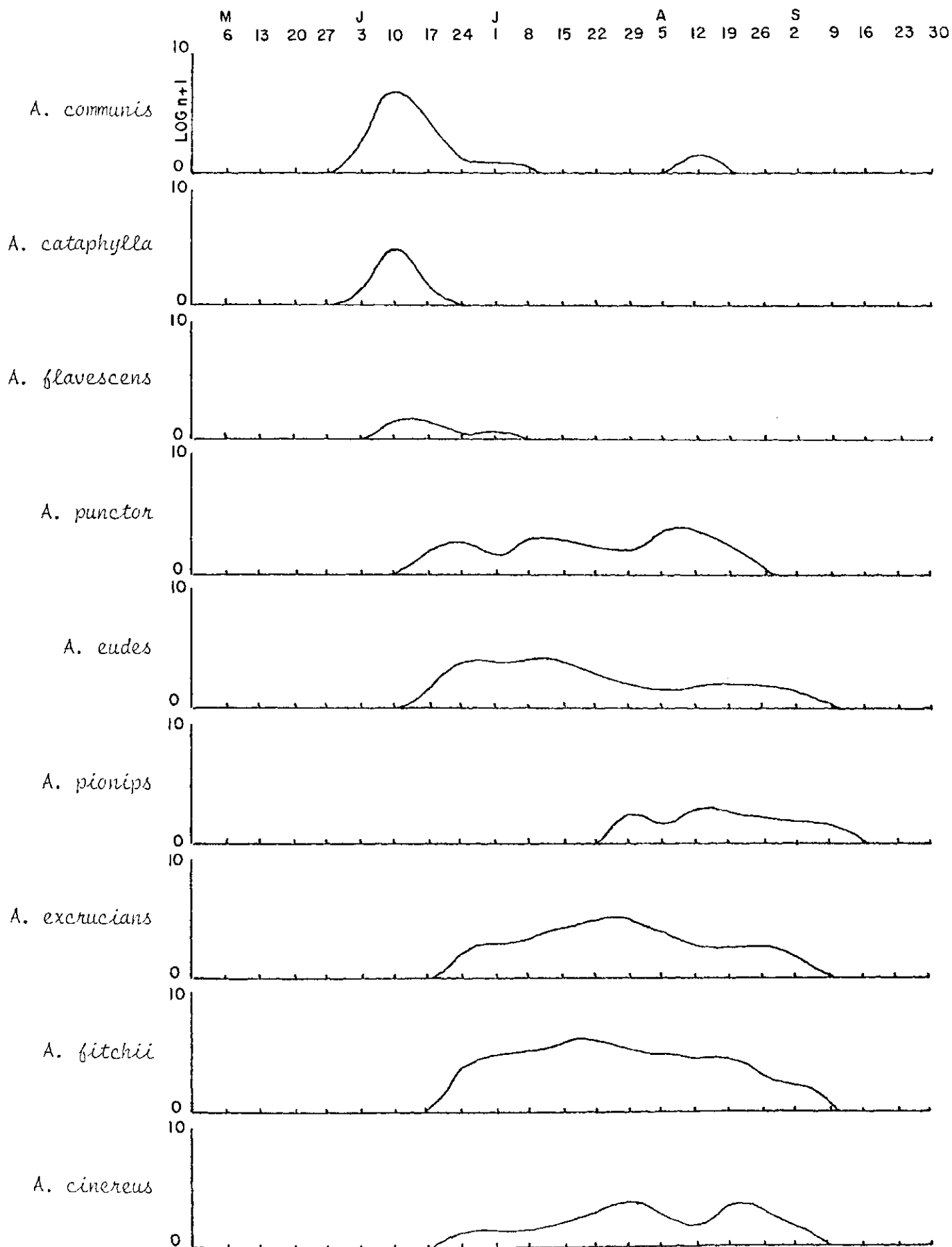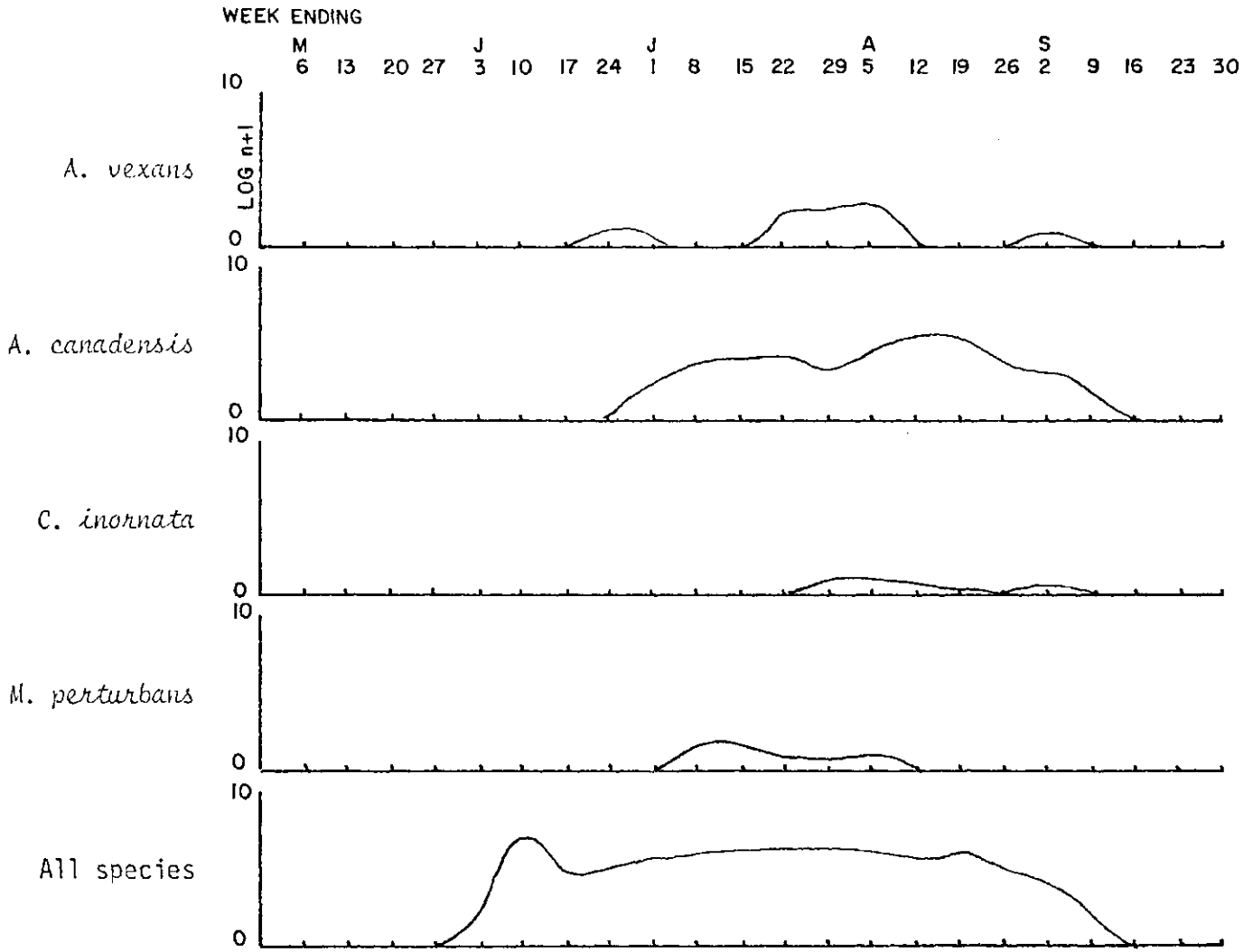
Figure 4.3. Life histories of some species of mosquitoes at MacDowall, Sask. A. *dorsalis*, A. *spencerii*, A. *riparius*, A. *stimulans* and A. *earlei* were too rare to analyze their life histories.

PRINCE ALBERT NATIONAL PARK
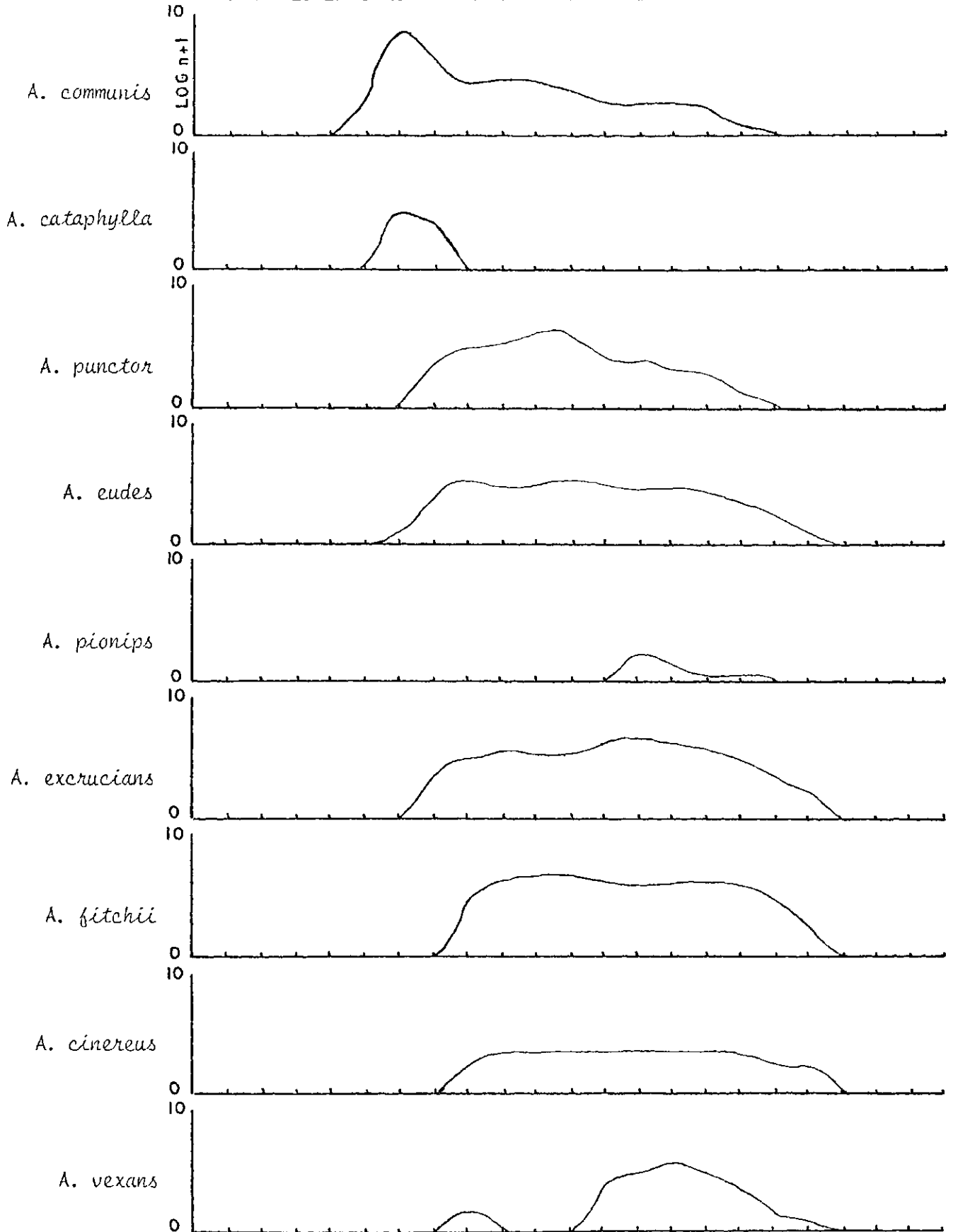
PRINCE ALBERT NATIONAL PARK
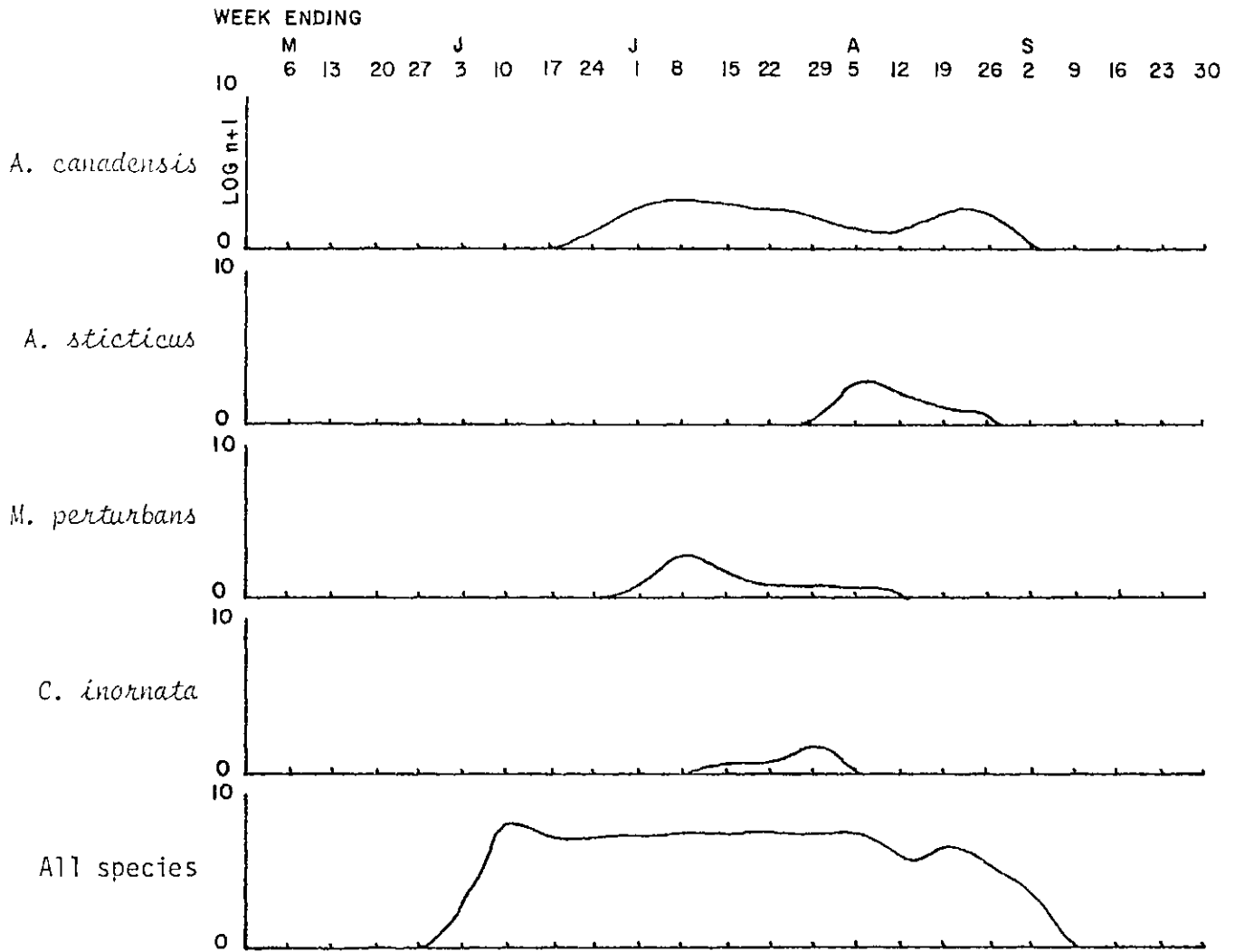
Figure 4.4   Life histories of some species of mosquitoes at Prince Albert
National Park, Sask.   A. *spencerii*, A. *campestris*, A. *flavescens*,
A. *riparius*, A. *earlei* and C. *alaskaensis* were too rare to analyze
their life histories.

WEEK ENDING
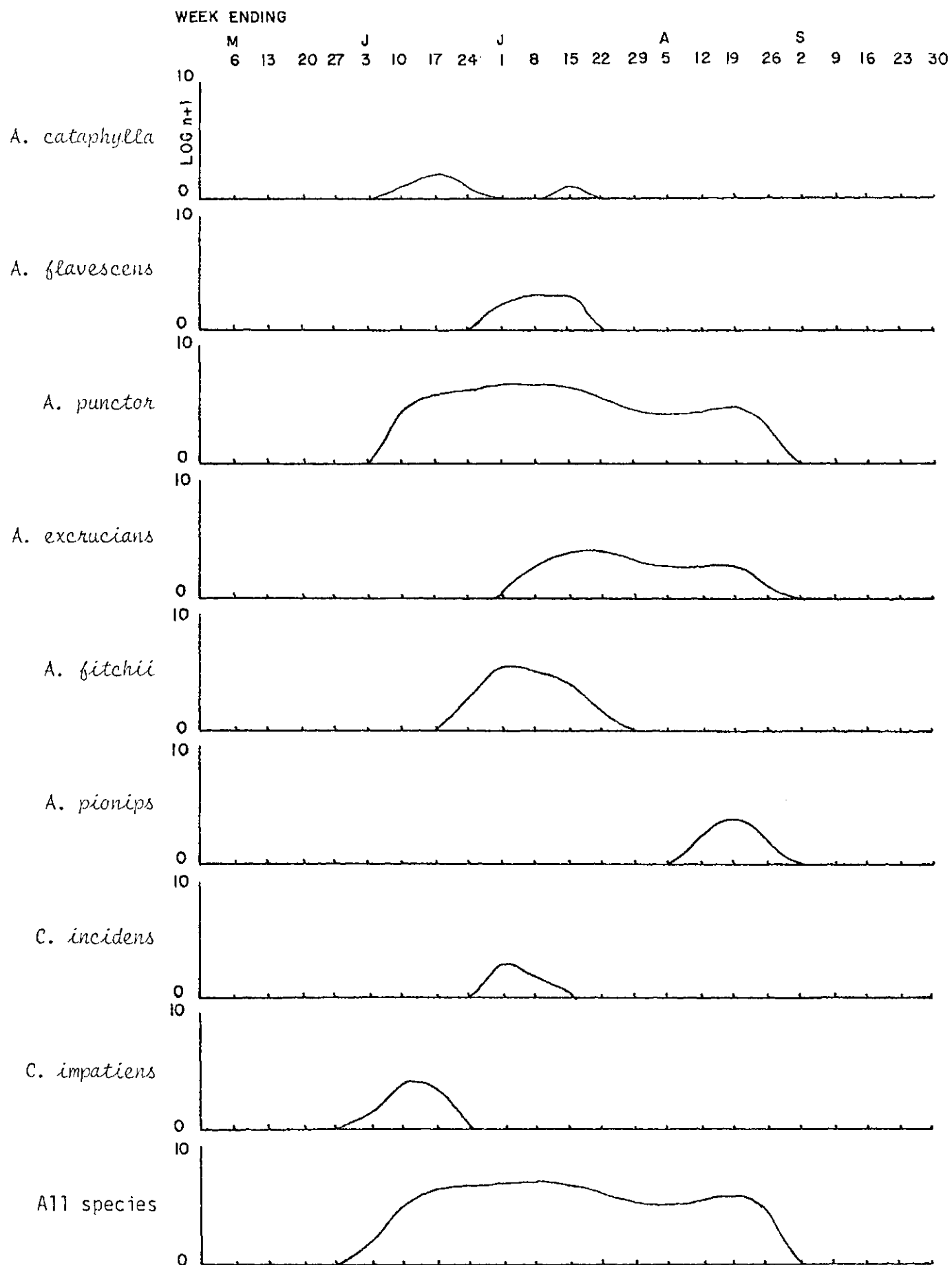
Figure 4.5   Life histories of some species of mosquitoes at Wollaston Lake, Sask.
A. *communis*, A. *triseriatus*, A. *sticticus* and C. *alaskaensis* were too

ENNADAI
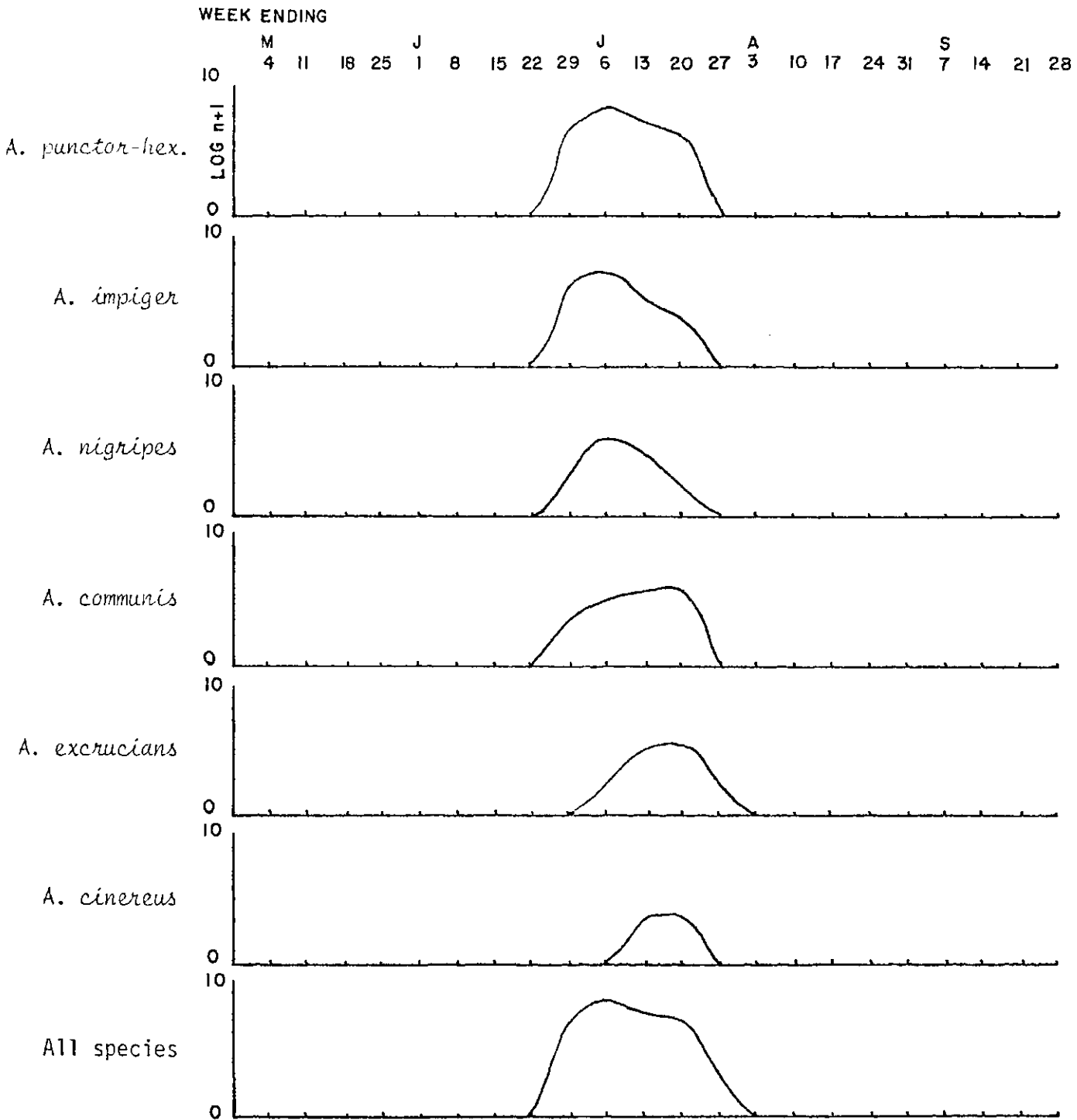
Figure 4.6   Life histories of some species of mosquitoes at Ennadai Lake, N.W.T.
              A. *cataphylla* and A. *rempeli* were too rare to analyze their life
              histories.
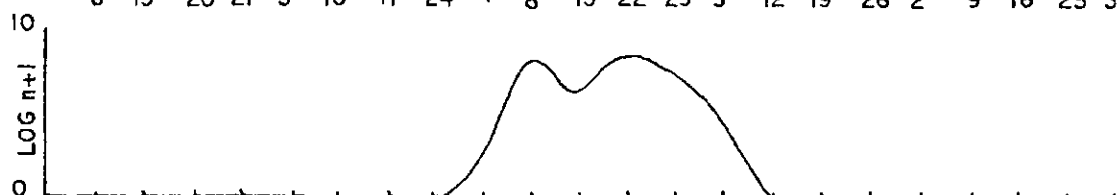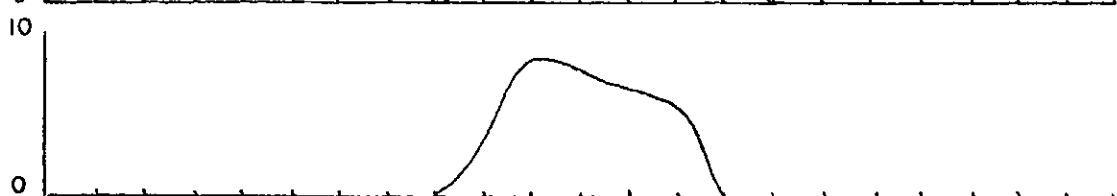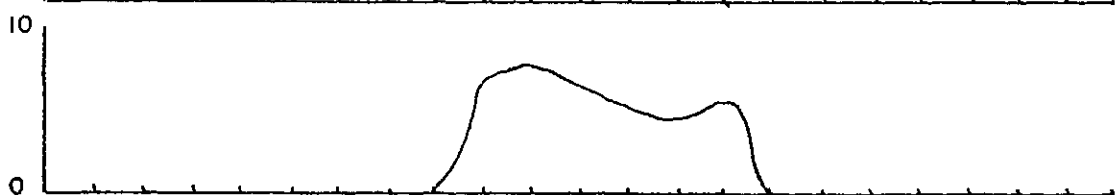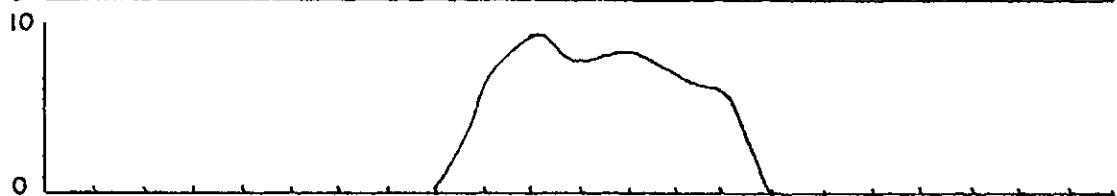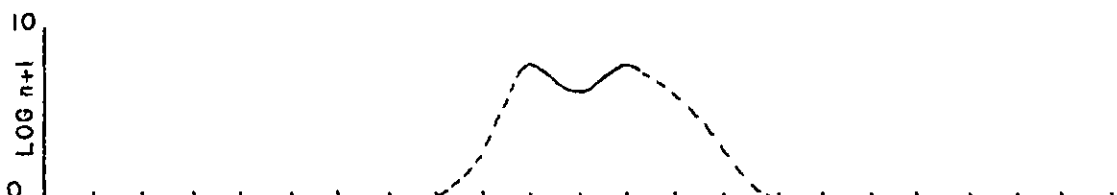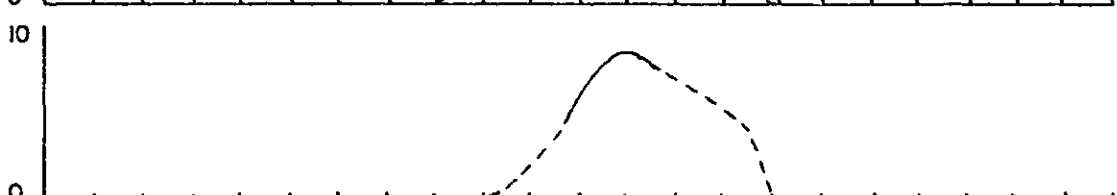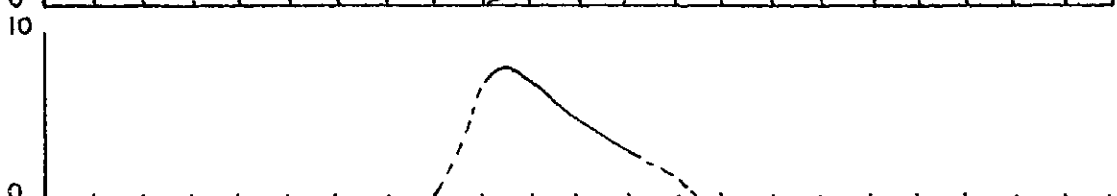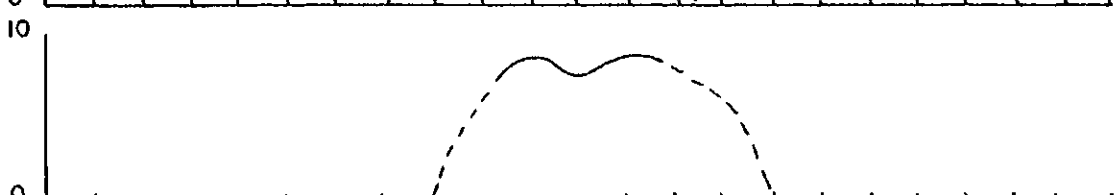
Figure 4.7   Life histories of some species of mosquitoes at Rankin Inlet and Baker Lake, N.W.T. A. *rempeli* was too rare to analyze its life history. Broken lines represent unknown seasonal pattern of development.

and August, which submerged eggs laid in previous years. On all three occasions, the peaks were therefore first generation mosquitoes being hatched at different times. A. *campestris* emerged in early June. A. *flavescens* and A. *fitchii* appeared in the middle of June and C. *inornata* was first collected in mid-June; several generations followed in quick succession and resulted in a large population by fall. Although C. *tarsalis* appeared a little later, it was generally concurrent with C. *inornata*, since their breeding habits were similar. In 1974, the cool weather seriously limited the abundance of this species. A. *dorsalis* and A. *vexans* appeared in late June and early July, respectively. Although second generations are possible in August or early September, cool weather in 1974-75 seriously limited the abundance of these two species. Thus, in the grassland area the numbers of mosquitoes were subject to extensive and irregular fluctuations.

At the southern edge of the aspen grove section (Fig. 4.2) the first major emergence of mosquitoes took place toward the end of May. This population was made up largely of the following species: A. *spencerii*, A. *campestris*, A. *dorsalis*, A. *fitchii*, C. *inornata* and A. *punctor*. A. *cataphylla*, A. *flavescens* and C. *tarsalis*, although present, were never found in large numbers. With the exception of A. *cataphylla*, the above species persisted for the remainder of June and July. A. *vexans* became common in July. When heavy rains occurred in August 1974, a second brood of A. *vexans* emerged in early September.

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At the northern edge of the aspen grove section and in the mixed-wood forest section (Fig. 4.3, 4.4) the first emergence, in early June, consisted of A. *communis* and A. *cataphylla*. This was quickly followed by huge numbers of A. *punctor*, A. *eudes*, A. *fitchii* and, a few weeks later, by A. *candensis*, A. *cinereus* and A. *pionips*. A. *vexans* was again one of the last to appear.

In the extreme northern wooded areas (Fig. 4.5) most species emerged by mid-June and persisted till the end of July or early August. Each species had only one generation. The first half of the summer, June and July, was therefore noted for its great mosquito abundance, while the second half, August and September, was more or less mosquito free. In the tundra area, this seasonality of abundance was even more extreme, with only the latter portion of June and the month of July having great numbers of mosquitoes (Fig. 4.6, 4.7). While actual numbers of mosquitoes were probably higher than in more southern locations, the number of dominant species in tundra areas dropped to only four, A. *punctor*, A. *hexodontus*, A. *nigripes* and A. *impiger*.

4.2.1 Daily fluctuations in abundance

Two surveys in 1975, one at Ennadai Lake and one at Weyburn, each lasting 24 hours, were performed to investigate the daily pattern of activity. Sweep net samples were taken every three hours starting at 0900 hours C.S.T. one day, and ending at 0600 hours the following day. Mosquito activity, temperature, wind, cloud cover, relative humidity

and the time of sunrise and sunset were also recorded.

The detailed results of the surveys, July 13-14, 1975 (Ennadai Lake) and August 10-11, 1975 (Weyburn), are presented in Fig. 4.8. The weather was hot with only a few clouds during the daylight hours in both locations. Both histograms show a rapid rise in activity to a maximum in the evening, followed by a drop to almost zero after dark. At sunrise and during the early hours of the morning there was a rise in activity to a second maximum. During the main daylight hours, 1000 to 1800 hours at Weyburn, 0800 to 2000 hours at Ennadai Lake, activity dropped to a minimum.

4.3 SPECIES DIVERSITY, DOMINANCE AND RELATIVE ABUNDANCE

Table 4.5 shows the values of $\bar{H}$, S and e for the eight ecological zones. Trends in $\bar{H}$ and S from one zone to the next are identical, with high values occurring in the south and low values in the extreme north.

The highest values of $\bar{H}$ and S occurred in the aspen-grove/mixed wood forest interface, where a variety of boreal forest and grassland mosquitoes were found.

The regression of $\bar{H}$ against $\log_2 S$ (Fig. 4.9) shows that changes in mosquito diversity were closely related to variations in species richness. The relationship is expressed by the equation

$$\bar{H} = .78 + 4.51 \ (\log_2 S) \qquad (4:1)$$

The data shows a close fit to the linear form. Since the slope of the regression is $\bar{H}/\log_2 S = \bar{H}/\bar{H}_{max} = e$ [formula (3:3)] the figure

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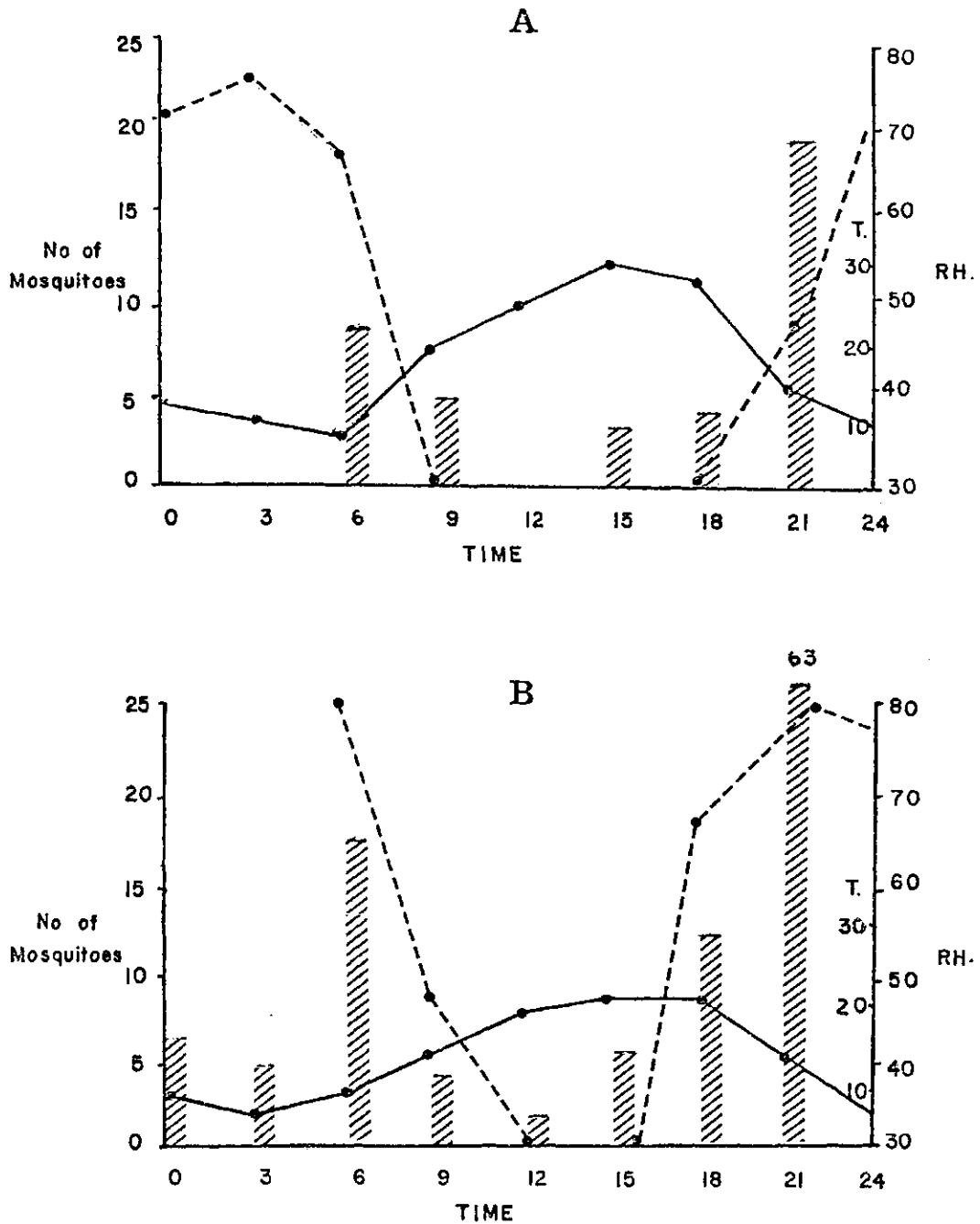
Figure 4.8

The results of eight, three-hour counts on August 10-11, 1975 at Weyburn (A) and July 13-14, 1975 at Ennadai Lake (B). Solid line, temperature; dotted line, relative humidity; and vertical bars, number of mosquitoes per sample.

Table 4.5   Values of $\bar{H}$, S and e for mosquito populations in eight
            ecological zones. $\bar{H} = -\Sigma (n_i/N) \log_2 (n_i/N)$; S = number of
            species; $E = \bar{H}/\log_2 S$.

Ecological zone	$\bar{H}$	S	e
Prairie grassland	.665	14	.175
Aspen grove	.703	14	.185
Aspen grove - mixed wood forest	.718	18	.172
Mixed wood forest	.792	18	.190
Northern coniferous - northwestern transition forest	.439	14	.115
Northwestern transition forest - tundra	.520	8	.173
Tundra (coastal)	.460	4	.230
Tundra (interior)	.324	4	.162
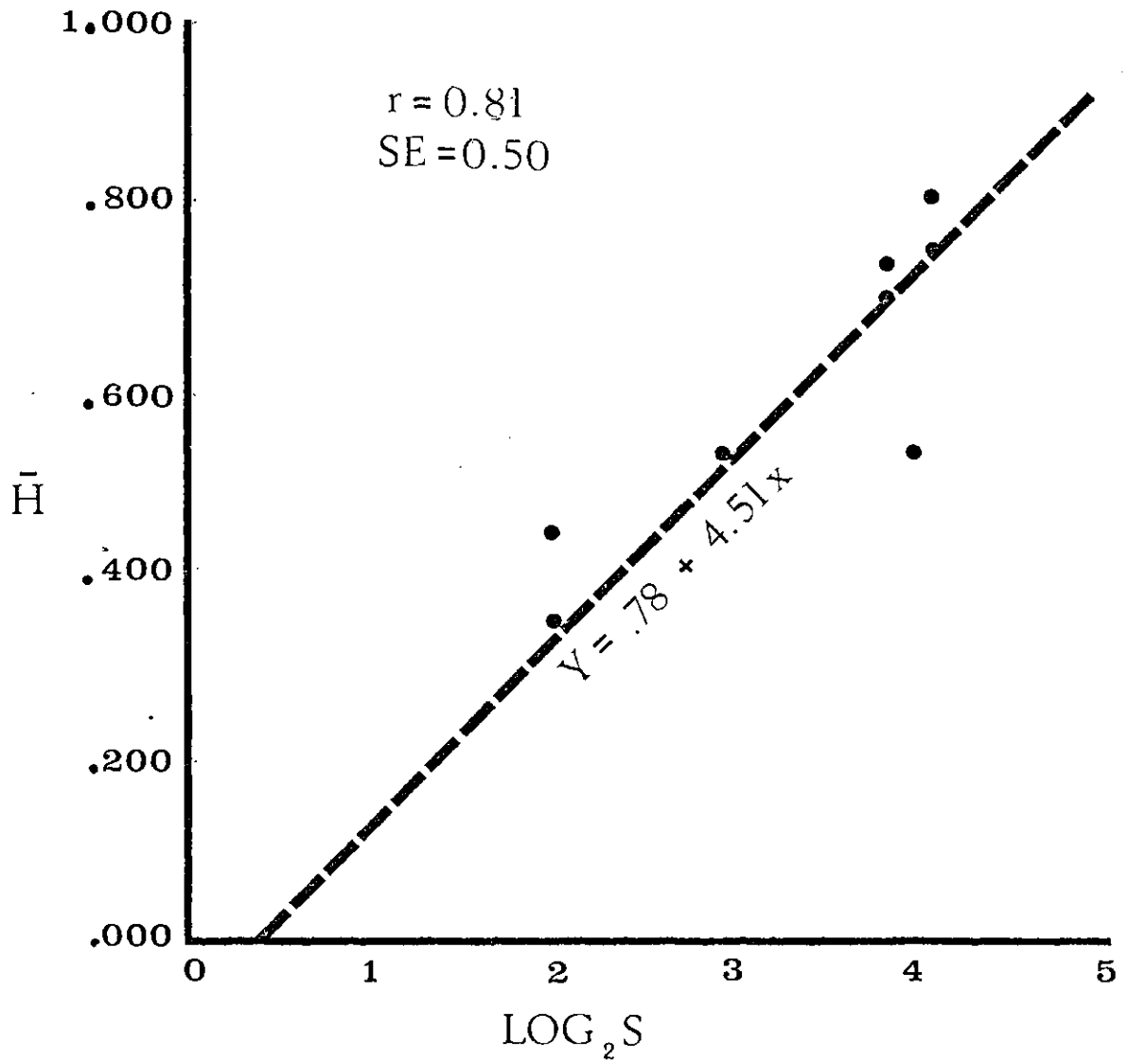
Figure 4.9

Regression of diversity ($\bar{H}$) against the logarithm of the number of species ($log_2 S$) for eight locations.

demonstrates the stability of the relative abundance component as well as the correlation between $\bar{H}$ and species richness.

Dominance, defined by the community dominance index, is inversely related to diversity. Fig. 4.10 illustrates this relationship for mosquitoes in the study area with fewer species predominant in the grassland or tundra areas in comparison to the forested region.

4.4 ENVIRONMENTAL FACTORS INFLUENCING DISTRIBUTION AND ABUNDANCE OF MOSQUITOES

4.4.1 Weather and climate

The influence of weather on mosquitoes can be discerned in terms of a winter phase which controls the initial water regime at the start of the summer season, and a summer phase.

Winter and spring 1974 - The early part of the winter was mild and relatively·dry throughout the study area. Snow totals, up to the middle of March, were 5-10 percent below the long term average. In late March and April, a striking difference developed between the central and the northern and southern extremities of the area. In the extreme north and south near-average precipitation occurred and the snow cover was gone by late April. In central regions precipitation was above average for March and April. With the exception of the Northwest Territories, temperatures throughout the study area were cooler than normal.

At the beginning of May, the southern part of Saskatchewan was dry and cool, although spring pools persisted in many areas. In

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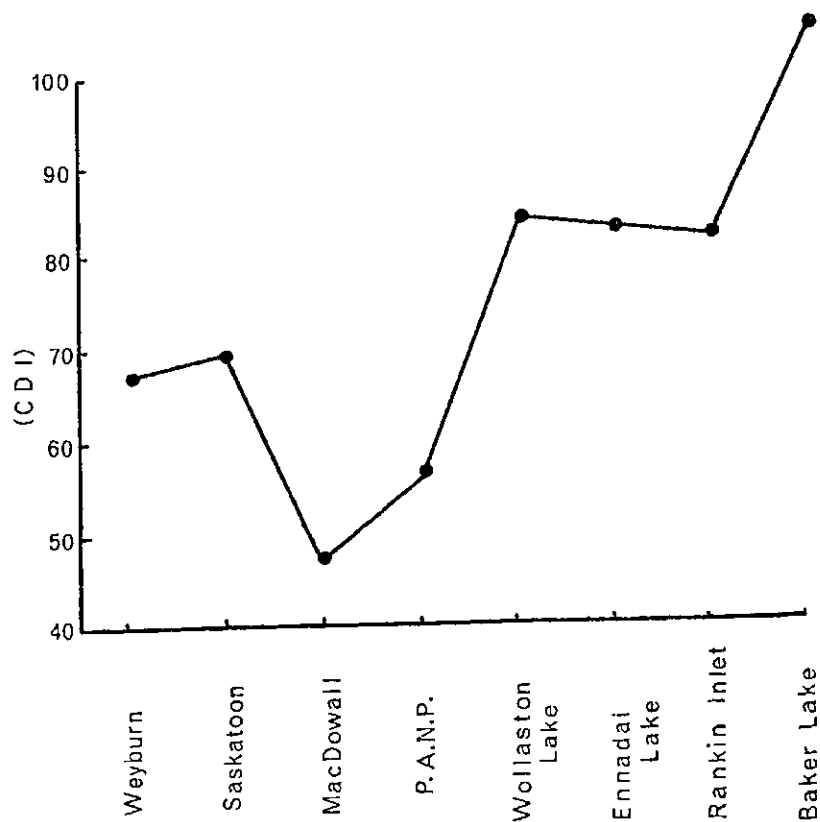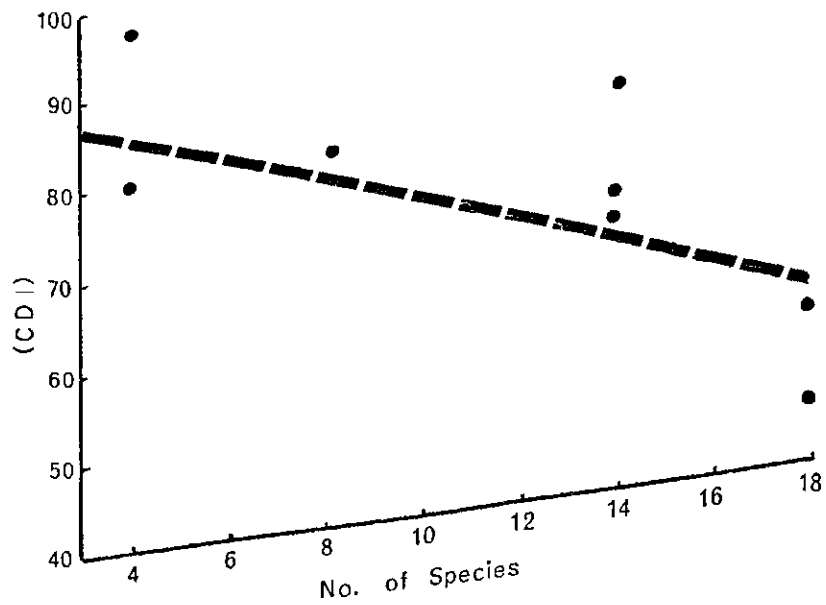
Figure 4.10   Relationship of dominance and species diversity in mosquito populations in the study area.   Dominance is defined as the percentage of the population contributed by the two most abundant species (after McNaughton, 1978).

central Saskatchewan the ground was wet, with much standing water. The adjacent Northwest Territories had temperatures above normal; precipitation and the amount of water standing were normal for the time of year.

Summer 1974 - The general summer temperature and precipitation regime is given in Table 4.6. Most of southern and central Saskatchewan had above average precipitation with the greatest excess in the central, mixed wood forest region; rainfall was below normal in the extreme northeastern parts of Saskatchewan and the N.W.T.. Temperatures were a little more variable than usual but seasonal means for the first three months did not differ much from climatic normals. In August and September, temperatures were well below normal throughout the entire region. Because monthly means tend to obscure weather variations weekly averages of temperature, precipitation and hours of bright sunshine are given in Table 4.7. Variations of -4 to +5 ℃ from the mean occurred during the summer.

May 1974 - The warm spell in the N.W.T. which lasted with few breaks from May 12 to 31 was the most significant feature. Daytime temperatures occasionally reached 12°C, about 4°C above seasonal normals. Further south, cooler weather prevailed: mean daily temperatures were 5°C below normal in the Saskatoon-Prince Albert region; there were rain showers throughout most of the month. Rainfall was above average in the southern part of the study area while sunshine was high and winds were moderately strong.

Table 4.6   Monthly mean temperature, precipitation and normals at locations in the study area
(Temperature - degrees celsius; Precipitation - millimeters of water)

	May		June		July		August		September	
	Mean temp.	ppt.	Mean temp.	ppt.	Mean temp.	ppt.	Mean temp.	ppt.	Mean temp.	ppt.
Weyburn										
1974	7.9	36.4	16.8	22.6	20.2	25.7	15.2	102.1	9.4	18.8
Norm.	11.0	49.8	16.1	78.5	20.9	53.1	18.6	44.2	12.3	35.8
Saskatoon										
1974	7.8	88.9	15.7	67.3	18.0	82.0	14.3	56.4	9.1	28.5
Norm.	--	--	--	--	--	--	--	--	--	--
Prince Albert (MacDowall)										
1974	6.2	98.0	14.9	76.0	17.8	79.5	13.6	164.4	7.6	60.7
Norm.	9.5	35.8	14.3	57.2	17.7	64.3	16.2	53.1	10.2	34.8
Waskesiu (P.A.N.P.)										
1974	4.2	150.4	14.1	97.5	15.7	144.3	11.8	81.3	4.8	53.9
Norm.	8.8	32.3	--	--	16.9	70.9	15.2	57.7	9.5	48.0
Collins Bay (Wollaston Lake)										
1974	3.9	22.4	11.8	72.4	15.6	95.8	12.6	63.0	4.8	38.1
Norm.	--	--	--	--	--	--	--	--	--	--
Ennadai Lake										
1974	0.0	1.5	10.1	10.4	14.7	114.8	10.5	59.9	0.5	22.9
Norm.	-3.8	17.5	6.6	30.2	12.8	52.1	11.6	38.6	4.0	38.6
Chesterfield (Rankin Inlet)										
1974	-4.6	0.5	4.8	20.6	9.7	23.6	7.9	37.1	-0.5	31.5
Norm.	-6.8	15.8	2.4	25.9	8.7	41.4	8.3	37.3	2.6	40.4
Baker Lake										
1974	-4.4	3.6	8.0	23.4	13.2	49.8	8.9	17.5	-1.3	27.2
Norm.	-7.2	9.4	3.2	16.0	10.7	35.6	9.8	34.5	2.4	33.8

Table 4.7 Weekly mean temperature (x̄), precipitation (ppt.) and hours of daily bright sunshine (D.B.S.) values at locations in the study area

Week ending	Weyburn			Saskatoon			Prince Albert (MacDowall)			Waskesiu (P.A.N.P.)		
	x̄ (°C)	ppt. (mm)	D.B.S. (hr)	x̄ (°C)	ppt. (mm)	D.B.S. (hr)	x̄ (°C)	ppt. (mm)	D.B.S. (hr)	x̄ (°C)	ppt. (mm)	D.B.S. (hr)
May 6	8.3	0.3	49.1	6.7	4.8	30.7	1.7	24.4	23.7	1.1	14.0	Not available
May 13	7.2	23.6	30.3	7.2	21.1	24.1	6.7	22.9	22.3	4.4	29.2	
May 20	6.1	47.0	30.7	6.7	8.6	46.3	5.6	9.9	27.1	2.2	85.3	
May 27	8.9	12.2	43.8	9.4	54.4	60.7	7.8	39.1	48.2	6.7	19.6	
June 3	12.2	3.3	77.8	11.1	--	78.1	10.0	2.0	60.3	6.1	4.1	
June 10	13.3	22.6	55.5	12.2	24.4	45.0	11.7	16.5	36.8	10.6	19.1	
June 17	15.0	T	96.8	15.0	0.5	95.8	15.0	2.5	90.5	13.3	4.3	
June 24	20.6	0	86.2	20.6	4.3	101.4	18.9	0.3	94.4	18.3	0.3	
July 1	20.6	0	96.6	16.1	35.3	83.1	15.6	55.9	67.2	15.0	42.4	
July 8	18.9	16.0	66.3	16.1	5.8	65.6	16.7	4.1	73.7	15.0	10.9	
July 15	20.6	4.3	82.9	19.4	60.7	89.9	19.4	57.2	69.5	16.1	99.3	
July 22	23.3	5.3	92.1	20.6	14.2	95.4	20.0	9.9	78.3	16.7	8.6	
July 29	18.3	0	99.9	16.1	0.8	95.1	16.1	5.3	90.7	15.0	10.9	
August 5	17.2	7.6	76.1	18.9	0.8	91.0	18.3	27.2	82.9	17.2	12.2	
August 12	18.3	24.9	57.0	15.6	26.7	41.8	15.0	81.5	36.3	13.9	32.8	
August 19	15.6	50.0	42.4	13.9	20.6	43.7	13.3	41.9	35.5	11.1	11.4	
August 26	14.4	11.7	50.6	13.3	0.5	77.7	12.2	4.3	76.8	10.0	30.0	
Sept. 2	10.0	7.9	54.5	10.0	8.4	57.4	8.3	12.5	53.4	6.7	7.1	
Sept. 9	11.1	14.7	30.3	10.6	6.4	28.2	7.8	29.5	27.6	5.0	31.0	
Sept. 16	10.6	3.8	38.3	11.1	11.7	39.9	9.4	8.6	45.0	6.1	8.4	
Sept. 23	10.6	T	48.6	10.6	0.5	42.4	9.4	1.8	47.3	8.3	2.3	
Sept. 30	6.7	0.3	40.7	5.6	9.9	32.0	3.9	20.8	22.7	0.6	12.2	
Mean weekly temp. TOTAL	14.0	255.5	1347.0	13.0	320.4	1365.3	11.9	473.1	1210.2	10.0	495.4	

Table 4.7 (continued)

Week ending	Collins Bay (Wollaston Lake)			Ennadai Lake			Chesterfield (Rankin Inlet)			Baker Lake		
	x̄ (°C)	ppt. (mm)	D.B.S. (hr)	x̄ (°C)	ppt. (mm)	D.B.S. (hr)	x̄ (°C)	ppt. (mm)	D.B.S. (hr)	x̄ (°C)	ppt. (mm)	D.B.S. (hr)
May 6	-3.9	10.4	51.4	-13.3	1.5		-18.3	0.5		-18.9	2.3	62.9
May 13	3.9	T	48.6	-1.1	--		-3.9	--		-5.0	.8	48.1
May 20	2.8	2.5	70.6	1.1	T		-1.7	T		-2.2	T	70.2
May 27	8.9	--	67.2	8.9	--		0.6	--		2.2	T	63.7
June 3	7.8	20.8	37.7	1.7	T		-0.6	T		1.1	1.3	78.1
June 10	7.2	14.7	68.3	5.6	7.1		2.2	3.3		4.4	T	75.1
June 17	12.8	10.2	58.5	12.8	--		5.6	--		10.0	--	117.7
June 24	15.6	23.6	82.5	13.9	T		5.6	17.3		11.7	7.6	79.4
July 1	15.0	19.1	57.8	11.7	3.3		8.3	T		10.0	15.0	90.5
July 8	14.4	10.2	58.5	12.2	22.4		5.6	2.8		10.6	22.4	40.3
July 15	16.7	48.0	33.8	15.6	31.5		11.1	13.5		12.8	12.5	82.1
July 22	16.7	10.7	78.8	16.1	9.1		13.9	6.6		13.3	6.1	75.8
July 29	15.0	20.3	55.3	15.0	46.0		8.3	.8		15.0	8.9	61.1
August 5	17.8	--	84.5	17.8	7.4		11.1	T		16.7	1.8	71.7
August 12	15.0	8.6	47.6	12.2	21.8		8.9	26.4		11.7	5.8	44.5
August 19	10.6	11.7	53.7	7.2	10.2		6.7	3.1		5.6	4.8	50.3
August 26	12.2	28.7	39.5	9.4	26.4		7.2	7.1		7.8	3.8	48.5
Sept. 2	8.9	13.7	52.3	6.7	0.3		5.6	0.5		4.4	1.5	39.9
Sept. 9	5.6	8.4	34.5	3.3	2.3		3.3	20.1		2.8	9.1	30.4
Sept. 16	7.2	5.8	19.7	1.7	T		0.0	3.1		-0.6	5.1	16.4
Sept. 23	6.1	9.9	31.4	0.0	13.0		-1.1	5.3		-1.1	9.7	16.4
Sept. 30	-1.1	14.0	11.0	-5.0	7.4		-6.1	13.0		-6.7	3.1	18.2
Mean weekly temp.	9.8			7.0		Not available	3.3		Not available	4.8		
TOTAL		291.3	1143.2		198.0			111.7			121.6	1281.3

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June 1974 - June is normally a wet month and June 1974 was no exception: near normal rainfall occurred throughout the entire study area. The last week in June was particularly wet in the southern boreal forest region. Temperatures were near average except for the N.W.T. where they were again 4-5°C above the long-term average. They were initially low but there was a marked trend upward towards the end of the month, a warming trend which coincided with wet weather in most areas. Sunshine was also near average although the mean wind-speed was lower than usual.

Wet and consistently warm weather from June 19 to July 5 was significant in speeding up both larval development and reproductive phases of most mosquito species. The influence of this type of weather was particularly noticeable at Weyburn, Saskatoon, MacDowall and Prince Albert National Park. At MacDowall and Prince Albert National Park, about 50 mm of rain fell in the last week of June, maintaining larval pools established from the heavy rains in May.

July 1974 - The weather was notably warm and moist until about the twenty-second, providing extremely favourable conditions for mosquito production and survival. Most areas then changed toward showers and cooler weather, though rain was very meagre at Weyburn. The cool weather was associated with light winds although sunshine levels remained remarkably high.

August 1974 - Temperatures remained cool throughout the entire

region in August. The period from August 19 to 31 was particularly
cool, especially in southern and central portions of Saskatchewan.
Total rainfall at Baker Lake and Chesterfield Inlet was below normal.
However, south of Wollaston Lake it was cloudy and wet. Rain, often
associated with thunderstorms, fell on 17 days at Prince Albert and
Saskatoon and was 100-200% above average. Over 70 mm of rain fell on
August 9. In most areas of central and southern Saskatchewan
abnormally high rainfall maintained larval pools or produced new ones.
Mosquito abundance remained at fairly high levels in these areas.

September 1974 - From September 1-6 and during the last week in
September, rainstorms continued to move through the central portions
of the province. Over 30 mm fell at Prince Albert; the national park
received 37 mm but other areas received only light rainfall.
Temperatures throughout the entire study area remained cool ranging
from 3° below normal in the south to 4° below normal in the north. The
continued cool weather seriously curtailed mosquito activity throughout
the study area.

Ennadai Lake 1975 - Cool, dry conditions prevailed at this
station in 1975, the only locality where 1975 mosquito distribution
and abundance records were collected. Snow accumulation during the
preceding winter approached normal levels, producing numerous larval
pools in the spring. May and June mean weekly temperatures were
several degrees lower than in 1974, although they paralleled the
long-term averages more closely than those in 1974. The last week in

June and the first week in July were decidedly warmer (+6°C) than 1974 but subsequently cooler conditions again prevailed, well below normal levels. With the exception of the first two weeks in June, precipitation was also lower than in 1974 and, again, below the long term average. Wind speeds were above average and above those levels recorded in 1974. Winds over 15 kph were recorded for 60% of the time.

4.4.2 Habitat preference

The mosquito fauna of a particular region depends upon a complex of factors including rainfall, wind, soil type, acidity (pH) of water, organic content of water, and the presence or absence of vegetation near the breeding site. Vegetation appeared to be especially important in the present study.

A wide variety of larval habitats[1] were investigated through the study area and were classified as follows:

(1) Semi-permanent snowmelt pools

   (a) Open grass or sedge pools
   (b) Wooded pools

(2) Temporary floodwater pools

(3) Permanent marshy pools

(4) Artificial pools

(5) Rock pools

[1]For a more detailed description see Appendix B.

Most pool types were found throughout the study area. The latter
habitat type, the rock pool, was confined to more northerly subarctic
and arctic areas.

Larvae of 24 species were found in the various habitat types,
(Table 4.8). Generally speaking, *Aedes* larvae and pupae developed
before the main growth of aquatic plants or in flood water pools
caused by rainfall during the summer. *Culex*, *Culiseta* and *Anopheles*
larvae were mainly found in July and August in those habitats which
contained water throughout the year. Although large in size, the
variation in vegetation comprising the latter habitat type was limited.

A comparison of the differences in species distribution among the
various habitats revealed that the most productive environment - the
semi-permanent, open grass pool - was dominated by A. *spencerii*,
A. *flavescens*, A. *campestris* in the grassland area, A. *fitchii*,
A. *excrucians* and A. *punctor* in the boreal forest and A. *nigripes*,
A. *punctor* and A. *impiger* on the tundra. With the exception of
A. *hexodontus*, many of the species found in this habitat were also
found in smaller numbers in open sedge habitats. The principal species
found in open grass or sedge pools were those frequently encountered
in the open as adults (see also Happold, 1965a).

A. *communis* was often the most numerous species in forest pools.
A. *pionips*, A. *punctor* and smaller numbers of other species
were often encountered in forest pools as well. A. *earlei*,

Table 4.8   Mosquito species breeding in the study area, showing habitat distribution

	Semi-permanent snowmelt pools			Temporary floodwater pools	Permanent marshy pools		Artificial pools	Bare rock pools	
	Open-grass	Open-sedge	Wooded		Grass	Sedge		With vegetation	Without vegetation
A. *spencerii*	A			A					
A. *flavescens*	A	C							
A. *dorsalis*	C	C		C					
A. *eudes*	C		C						
A. *campestris*	A	C		C					
A. *fitchii*	A								
A. *communis*			A						
A. *cataphylla*			C						
A. *pionips*			C						
A. *diantaeus*			R						
A. *implicatus*	R		R						
A. *punctor*	A	C	A		C	C		R	
A. *hexodontus*	C	A			C	C		R	
A. *vexans*	C			A	R				
A. *cinereus*	C		C						
A. *canadensis*			C						
A. *excrucians*	A	C	C						
A. *riparius*	R								
A. *nigripes*	A	C			C	C		R	
A. *impiger*	A		C					R	
A. *rempeli*								C	C
A. *earlei*					C				
C. *inornata*				C	A	C	A		
C. *tarsalis*				C	C	C			
TOTAL	15	7	11	6	7	5	1	5	1

A = abundant;   C = common;   R = rare

C. *inornata* and C. *tarsalis* were found in more permanent water such
as along the margins of lakes. C. *inornata*, however, bred abundantly
in artificial pools formed when stagnant water collected at the bottom
of roadside culverts. These culverts served as excellent breeding and
resting sites for this species, often supporting a huge population.

The most abundant species of mosquitoes in a given area were
often found in many breeding locations, (Tables 4.4, 4.8). The
remaining species were more restricted in their habitats; this may
be one of the reasons why they were less common.

4.4.3 Predators

More than eight species of aquatic animals associated with
mosquito larvae were collected during this study (Table 4.9). Most
of the species had a wide distribution throughout the study area
and some were effective predators of mosquito larvae, notably
Dytiscidae, Hydrophilidae, Limnephilidae and Odonata species. In the
spring, however, when *Aedes* larvae were abundant these animals rarely
attained the numbers of the mosquito larvae.

During the course of the work at Rankin Inlet, N.W.T. in 1974,
mermithid worms (Class: Nematoda) were found to infect some species
of *Aedes* larvae. Of the 319 A. *nigripes* larvae, 22% were infected
with the worms, and of the 25 A. *impiger* larvae 8% were infected. The
mermithid attacks were fatal to the mosquito larvae, so the percentages
represent the minimal estimates of infection in the larval populations.

Table 4.9   List of predators found in mosquito larvae collections in
the study area

SCIENTIFIC NAME   COMMON NAME

INSECTS

Odonata   (Dragonflies and Damselflies)
    Aeshnidae   Darners
    Agrionidae   Broadwinged damselflies

Hemiptera   (True Bugs)
    Corixidae   Water boatmen
    Notonectidae   Back swimmers
    Hydrometridae   Water measurers

Trichoptera   (Caddisflies)
    Limnephilidae   Northern caddisflies

Coleoptera   (Beetles)
    Dytiscidae   Predaceous diving beetles
    Hydrophilidae   Water scavenger beetles

Diptera   (Flies)
    Culicidae   Mosquitoes (*Mochlonyx* spp.)
    Dixidae   Dixid midges

NEMATODES

Nemathelminthes   (Nematode worms)
    Mermithoidae   Mermithid worms

4.5 FORECASTING DISTRIBUTION AND ABUNDANCE

Accurate prediction of adult insect emergence depends on the variation that may be expected, (1) in assessment of effects of environmental factors on rate of development, and (2) in measurement of meteorological and edaphic factors that are known to influence rate of development. In the case of mosquitoes, the effect of atmospheric temperature conditions on breeding pools can be additively compiled from day to day to indicate from established thermometabolic cycles the expected time of appearance for a given species (see for example, Haufe and Burgess, 1956).

Applying the above method to this study, maximum and minimum air temperatures were used in correlations between pool temperature and meteorological conditions. The daily averages of the maximum and minimum air temperatures were correlated with the daily average temperatures of the water in an exposed mosquito pool at Ennadai Lake, N.W.T. for 19 consecutive days during a normal period of mosquito development (June 21 - July 9, 1975). Air temperatures were recorded as Stevenson screen values, 1.2 m from the ground; the temperatures of the pool were recorded as the daily average temperature taken at a depth of 2 cm below the surface of the water in the deepest part of the pool. The pool, an open-grassy type, was situated on the south side of an esker and had a coarse, gravelly substrate. Mosquito species present included A. *excrucians* and A. *hexodontus*. The above procedure provided 19 pool temperatures for correlation with air temperature over the study period. The

regression for this correlation is shown in combination with the dot chart in Fig. 4.11. The coefficient of correlation between temperatures of the pool and air temperatures was 0.84, with a standard error of regression of ±2.46.

From the known thermal constants and lower thresholds of development of the two mosquito species (Table 4.10) the total number of "degree-days" above the threshold for each species were compiled. The results are shown in Table 4.11. Assuming that embryonic development began for both species on June 2, 1975 (this represents the date when the ice had completely left the surface of the pool), and that the sum of the total number of "degree-days" must be equal to or greater than the thermal constant for each species before adult emergence occurs, then the date of the first emergence of A. *excrucians* would be expected on June 30, 1975 and that of A. *hexodontus* on June 23, 1975 (Table 4.11). These are the dates when the total number of degree-days achieved in the pool, surpassed the thermal constants of the two species (228.5 for A. *excrucians* and 105.3 for A. *hexodontus*). Collections of larvae, pupae and emerging adults from the pool revealed that the actual date of the first emergence of A. *excrucians* was July 2, 1975 (a difference of two days from the predicted date) and that of A. *hexodontus* was June 25, 1975 (a difference of two days from the predicted date).
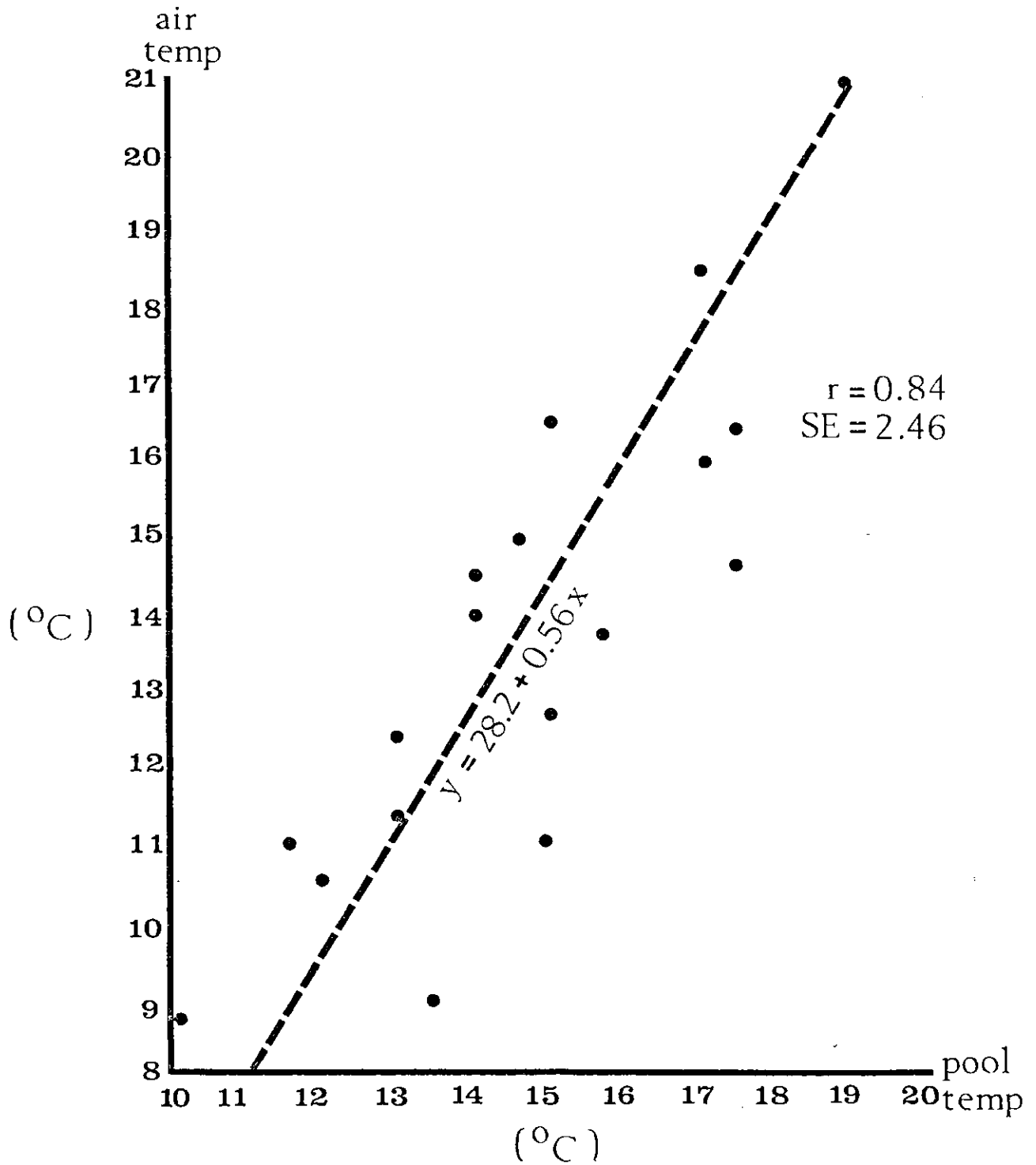
Figure 4.11

Regression of air temperature against water temperature for 19 days at a breeding pool, Ennadai Lake.

Table 4.10 Thermal constants and lower thresholds of
development of *Aedes* mosquitoes at Churchill,
Manitoba (Haufe and Burgess, 1956)

Species	Thermal constant (°C x days)	Lower threshold of development °C
A. *impiger*	150.1	1.1
A. *nigripes*	150.1	1.1
A. *punctor*	127.7	3.4
A. *communis*	161.3	3.4
A. *hexodontus*	105.3	7.3
A. *pionips*	217.3	3.9
A. *excrucians*	228.5	4.5
A. *flavescens*	228.5	4.5
A. *campestris*	161.3	3.4
A. *cinereus*	127.7	3.4

[Note that the tundra species of mosquito (A. *impiger* and
A. *nigripes*) have lower thresholds of development
approximately 1.1°C; the forest species (A. *communis*, A.
punctor, A. *excrucians*) have a range of 3.4-4.5°C]

Table 4.11   Calculation of "degree-days" above developmental threshold
for A. *excrucians* and A. *hexedontus*, from breeding pool temperatures
at Ennadai Lake, N.W.T.

Date	Mean daily air temp. (x)	Mean daily pool temp. (y)	Degrees above threshold (4.5° A. *excrucians*)	Degrees above threshold (7.3° A. *hexodontus*)
June				
3	3.9	*10.0**	5.5 ⎫	2.8 ⎫
4	6.1	*11.1*	6.6 ⎬	3.9 ⎬
5	3.9	*10.0*	5.5	2.8
6	4.4	*10.6*	6.1	3.4
7	6.1	*11.1*	6.6	3.9
8	10.6	*13.9*	9.4	6.7
9	10.6	*13.9*	9.4	6.7
10	9.4	*13.3*	8.8	6.1
11	10.0	*13.3*	8.8	6.1
12	7.2	*11.7*	7.2	4.5
13	6.1	*11.1*	6.6	3.9 ⎬ 105.4
14	2.8	9.4	4.9	2.2
15	3.9	*10.0*	5.5 ⎬ 237.4	2.8
16	5.0	*10.6*	6.1	3.4
17	7.8	*12.2*	7.7	5.0
18	10.0	*13.3*	8.8	6.1
19	12.2	*14.4*	9.9	7.2
20	13.3	*15.6*	11.1	8.4
21	14.4	18.3	13.8	11.1
22	10.0	15.6	11.1	8.4 predicted firs emergence
23	9.4	12.8	8.3	5.6 ←
24	16.1	18.3	13.8	11.1
25	18.3	17.8	13.3	10.6 actual first emergence
26	13.3	16.7	12.2	9.5
27	11.7	15.6	11.1	8.4
28	10.6	13.3	8.8	6.1
29	14.4	15.0	10.5 predicted first emergence	7.8
30	11.7	13.3	8.8 ←	6.1
July				
1	13.3	14.4	9.9 actual first emergence	7.2
2	18.9	17.8	13.3 ←	10.6
3	21.1	20.0	15.5	12.8
4	16.1	16.1	11.6	8.9
5	13.3	14.4	9.9	7.2
6	13.9	14.4	9.9	7.2
7	7.8	14.4	9.9	7.2
8	7.2	10.0	5.5	2.8
9	10.0	11.7	7.2	4.5

*Numbers in italics are estimates based on the regression equation
$y = 28.2 + 0.56x$.

CHAPTER 5

DISCUSSION

5.1 GEOGRAPHIC DISTRIBUTION AND ABUNDANCE OF MOSQUITOES

The distribution records of mosquito species obtained in this study indicate that they may be divided into groups each associated with a particular type of ecological region (Fig. 5.1).

By far the largest group in the study area consisted of Boreal forest species. The group included: *A. canadensis*, *A. cataphylla*, *A. cinereus*, *A. communis*, *A. diantaeus*, *A. eudes*, *A. excrucians*, *A. fitchii*, *A. implicatus*, *A. pionips*, *A. punctor*, *A. riparius*, *A. sticticus*, *A. stimulans*, *C. alaskaensis* and *C. impatiens*.

This is consistent with Vockeroth (1954a), who states that his group extends across northern Canada in the forested areas, and reaches down into the United States in both the east and the west. The exact distribution and relative abundance of these species varied greatly.

A. diantaeus, *A. implicatus*, *A. riparius* and *A. stimulans* were rare of comparatively rare everywhere; *A. cataphylla* was abundant along the southern edge of the forests; *A. eudes*, *A. excrucians* and *A. fitchii* were widespread and abundant in the south and central portions of the Boreal area, with only *A. excrucians* occurring as far north as the treeline. *A. communis* and *A. punctor* were common throughout the entire region.

TUNDRA

A. *hexodontus*
A. *impiger*
A. *nigripes*
A. *punctor*
A. *rempeli*

BOREAL

A. *canadensis*
A. *cataphylla*
A. *cinereus*
A. *communis*
A. *diantaeus*
A. *eudes*
A. *excrucians*
A. *fitchii*
A. *implicatus*
A. *pionips*
A. *punctor*
A. *riparius*
A. *sticticus*
A. *stimulans*
C. *alaskaensis*
C. *impatiens*

GRASSLAND

A. *campestris*   A. *spencerii*
A. *dorsalis*   A. *vexans*
A. *flavescens*   C. *inornata*
A. *nigromaculis*   C. *tarsalis*
                         A. *earlei*

FIG 5.1

REGIONAL DISTRIBUTION
OF MOSQUITOES
IN THE STUDY AREA

SCALE 1:2000000

Four species (A. *flavescens*, A. *campestris*, A. *dorsalis* and
A. *vexans*) were found in great numbers in the grassland area and
occurred in small numbers and at varying distances into the forested
regions. The remaining grassland species, of which C. *inornata*,
C. *tarsalis*, A. *earlei*, A. *nigromaculis* and A. *spencerii* were the
most common, were largely confined to the grassland area.

Four species may be considered Arctic, and were the most abundant
mosquitoes of most of the northern tundra. A. *nigripes* was truly
Arctic and did not appear to breed south of the treeline. The
exceptions are certain coastal localities and in the Rocky Mountains
of Alberta, British Columbia and the United States (Freeman, 1952a;
Vockeroth, 1954a). *Aedes hexodontus, punctor* and *impiger* ranged
throughout the Arctic, but were most abundant just north of the treeline.
With the exception of A. *punctor* which ranged quite far south, they
also occurred a short distance south of the treeline.

Two species did not fall into any of these groups. A. *triseriatus*
had a peculiar discontinuous distribution in the study area, being
reported from two localities, Regina and Wollaston Lake. Its
distribution in eastern North America is likewise as discontinuous
(Carpenter and LaCasse, 1955). A. *rempeli* is known from only five
localities, two north and the other three south of the treeline.

5.2 SEASONAL DISTRIBUTION AND ABUNDANCE OF MOSQUITOES

Some species have only one generation in a season, while others
have two or more. The eggs of certain species require stimuli such as

freezing or high temperatures before they will hatch; in the case of others, some of the eggs will not hatch at the first submergence in water (McLintock, 1944; Rempel, 1953). As a result it was found that in many habitats, particularly those of a permanent or semipermanent nature, there was a succession of species in the course of a season. The first species to appear in a pool was not always the first to disappear; there was an overlap of generations, and this was reflected in an adult population of an area.

The studies on seasonal distribution and abundance revealed several interesting features throughout the entire study area. First, the total population fluctuated during the summer months, and these fluctuations were not constant in time, number, and amplitude from one location to the next. Second, some of the peaks of abundance of individual or groups of species coincided with the peaks of the total population (Fig. 5.2). For example, in all locations the first population peak represented mainly the black-legged univoltine (only one generation a year) species. *Communis* group species - A. *impiger*, A. *nigripes*, A. *punctor*, A. *communis* and A. *spencerii* - were typical examples. The second peak represented the residue of this population plus the peak populations of the *Stimulans* or *Dorsalis* group of *Aedes* and dominant species of the other genera, (mainly C. *inornata*, C. *tarsalis* and A. *earlei*). Finally, a third peak arose when second generations of the multivoltine (one to several generations a year) species began to appear, and were added to the now dwindling

Grassland - 1st. peak (*A. spencerii*), 2nd peak (*A. dorsalis*, *A. campestris*, *A. flavescens*, *C. inornata*), 3rd peak (*C. inornata*, *C. tarsalis*, *A. vexans*)

Boreal Forest - 1st peak (*A. communis*, *A. cataphylla*), 2nd peak (*A. fitchii*, *A. eudes*, *A. excrucians*, *A. punctor*, *A. pionips*, *A. canadensis*, *A. cinereus*), 3rd peak (largely nonexistent)

Tundra - 1st peak (*A. nigripes*, *A. impiger*, *A. punctor*, *A. hexodontus*), 2nd and 3rd peaks (nonexistent)

Figure 5.2   Composition of peak levels of mosquito abundance for the three main ecological regions in the study area.

populations. A major component of the third peak was those univoltine species whose eggs did not hatch in the spring but did so when sufficient flooding took place later in the summer. In 1974-75, the third peak was small or nonexistent in most localities, probably due to below-normal summer temperatures throughout the study area.

The reason for this seasonal occurrence of different species or groups of species is not clear. Seasonal distribution and abundance may be influenced by the degree of cold resistance of the various species. While pronounced cold resistance characterizes all northern mosquito species, specific differences in the degree of cold tolerance significantly distinguish the less adapted stages in both the univoltine and multivoltine life cycles. For example, the *Aedes* found in the study area can be arranged naturally in serial order based on water temperatures typical for a critical advance in stage: (1) temperatures at which the eggs hatch; (2) temperatures characteristic of optimum development; (3) the seasonal order of appearance of the species as adults (Table 5.1). Whether the criteria used be (1), (2) or (3), the resulting arrangement is practically the same. Larvae of the earliest species precede the latest in the study area by two months. Larvae of all forms manifesting the multivoltine cycle presumably never tolerate cold as well as any of the univoltine *Aedes*, and larval cold tolerance and seasonal emergence are thus closely bound up with the life cycle type.

Table 5.1 Seasonal occurrence of adult *Aedes* species in the study
area. Dates are based on first appearance of adults.

Grassland and Boreal Forest Regions

Late May - Early June	Mid June - Late June	Early July - Mid July
cataphylla	*flavescens*	*vexans*
spencerii	*euedes*	*sticticus*
implicatus	*fitchii*	*pionips*
dorsalis	*excrucians*	*triseriatus*
campestris	*punctor*	*nigromaculis*
communis	*stimulans*	*diantaeus*
	riparius	
	canadensis	
	cinereus	

Tundra Region

Late May - Early June	Mid June - Late June	Early July - Mid July
	nigripes	*rempeli*
	impiger	*excrucians**
	punctor	*cataphylla**
	hexodontus	*cinereus**

*Ennadai Lake, N.W.T. only.

5.2.1 Daily fluctuations in abundance

Temperature has been found to affect mosquito distribution and abundance on a daily basis. The histograms of mosquito activity illustrated in Fig. 4.8, generally follow the changes in relative humidity during the daylight hours and there was an inverse correlation with temperature. In a similar experiment in north-eastern Alberta, Happold (1965b) has shown that when the weather is cloudy and humid during the daylight hours mosquito activity remains at almost the same level throughout the daylight hours. A cloudy, humid day produces relatively constant relative humidities and temperatures, and only a small variation in mosquito activity. The same phenomenon was observed in densely wooded habitat, where relatively constant humidity and temperature levels combined to stimulate activity during the daylight hours.

5.3 SPECIES DIVERSITY, DOMINANCE AND RELATIVE ABUNDANCE

The results indicate that in a given ecological community, mosquito species diversity could be adequately described by merely counting the number of species present; i.e., their relative abundances as measured by the evenness index (ε) could be disregarded. Therefore, we can conclude that the factors which regulate mosquito species diversity do so by determining the number of species which can co-exist in a given habitat. Hypotheses as to the causes of diversity have been reviewed by Pielou (1966) and only one will be considered here.

MacArthur and MacArthur (1961) showed that in temperate regions the diversity of many organisms can be correlated to foliage

diversity. That is, diversity increases with the number of layers in the vegetation and with the evenness of foliage apportionment among the layers. Applying this relationship to the data in Table 4.5, we find that tundra and grasslands (one-layered) are less diverse than shrublands or aspen groves (essentially two-layered); coniferous forests (up to three-layered) often have somewhat sparse shrub and herbaceous layers and therefore have diversities in between those of two-layered and other forested (three-layered) communities. Therefore, it is possible that foliage diversity determines the number of available niches (at least in the physical sense) and thus the number of mosquito species which can co-exist within a given ecological community.

While foliage diversity may explain the correlation of species richness to diversity in temperate communities, it is still not clear why the species relative abundance component as measured by the evenness index (Table 4.5), remained so stable from community to community.

Most insects (including mosquitoes) are generally considered to be "opportunistic" (MacArthur, 1964); i.e. a given species can reproduce quickly and become extremely abundant when conditions are favourable. Since their environment is characterized by relatively high climate variability, a species can only achieve high numbers temporarily, and equilibrium numbers only exist as long-term averages taken over several generations or throughout the entire season. Therefore, a

number of mosquito samples taken either at different times or in different communities is likely to have highly variable species abundance distributions. The fact that this was not the case in the present study indicates two possible explanations. (1) The samples taken in each ecological zone were large enough and taken over an adequate time frame, to represent long-term "average" or equilibrium populations. (2) Individual mosquito species may not be as "opportunistic" as was previously assumed. They may represent "equilibrium" species whose physical environment and resources are relatively stable from one generation to the next, and whose densities are partly determined by territoriality and behaviour (see MacArthur, 1964). The more northerly univoltine aedines, for example, appeared to lay the same number of eggs for both 1974 and 1975 and their numbers were at equilibrium from one generation to the next. The result is that in most mosquito communities the available species partition the habitat in a characteristic way, and a series of samples from the same or from different localities will yield similar distributions of species abundance.

5.4 ENVIRONMENTAL FACTORS LIMITING THE DISTRIBUTION AND ABUNDANCE OF MOSQUITOES

5.4.1 Weather and climate in relation to distribution and abundance

Although many factors may contribute toward the distribution and abundance of the mosquito population in a region, none are more

important than the limitations imposed by certain climatic variables -
namely, temperature and moisture. Since the larvae are aquatic it
follows that precipitation will be an important factor. However, a
correlation between total rainfall and mosquito abundance does not
necessarily follow. Water availability is the critical key to
moisture effects on mosquitoes. The amount of available or standing
water is the difference between the amount of precipitation and
evaporation. In the grassland area, if the land is dry, the water
from melting snow or rain will be soaked up so quickly that little
will be left in depressions. Again, if the precipitation falls in
the form of a slow prolonged drizzle, little water will accumulate.
If a rain is followed by strong warm winds, evaporation will quickly
dispose of the water in shallow places bringing all breeding to an
end. Moreover, it has been found repeatedly that maximum mosquito
development takes place when the habitat has been subjected to
alternate drying and flooding (Rempel, 1953; Brust and Costello,
1969). It is well established that not all eggs hatch at the first
flooding; only alternate drying and flooding assures the hatching of
the remainder.

Water availability as a factor in mosquito development is more
stable in extreme northern areas. The effect of evaporation is not
as great as in southern areas. Furthermore, many larval pools are
underlain with permafrost, making water drainage difficult. As a
result, many pools are maintained at relatively constant levels

throughout the summer season.

The life-histories of the species have a bearing on the effectiveness of such meteorological controls as well. The mosquitoes of the study area belong to seven different genera but only four of these can be considered as common or abundant. Among the four genera there are three different types of life cycle each affected in different ways by temperature and precipitation. These life cycles have been described in detail by McLintock et. al. (1966) and will only be briefly mentioned here. All species of *Anopheles*, *Culex*, and *Culiseta* have a life cycle in which generation follows generation all summer (obligatorily multivoltine). These mosquitoes all lay floating eggs on water and their embryonic development is continuous from the moment the eggs are laid. Members of these three genera overwinter as adult females. They lay their eggs on the more permanent or semi-permanent types of surface water such as sloughs, ponds, seepage from irrigation canals, flooded hoof prints of livestock, flooded roadside ditches, and a variety of artificial containers (see Table 4.8). The abundance of these species in a season depends mainly on temperature which governs the rate of ovarian, embryonic, larval, and pupal development and consequently the number of generations; but the favourable range of temperatures is different for different species. Rainfall has only an indirect effect on these multivoltine species in maintaining water levels and prolonging the persistence of semi-permanent pools; it is possible for these species to be abundant during

a comparatively dry summer (McLintock and Rempel, 1963).

The species of *Aedes*, the most numerous throughout the entire study area, have a radically different life cycle which in turn depends on a completely different set of climatic variables. These species all overwinter in the egg stage but differ in the response of eggs to flooding and temperature. Most of these species lay their eggs on the wet mud at the edges of pools formed by rain and melting snow. In one group of species the eggs go into diapause soon after being laid and will not hatch, when flooded, until they have been subjected to a period of conditioning at low tempertures. These species have only one generation per year (obligatorily univoltine), their eggs do not hatch until the following or some subsequent year to that in which they were laid. The abundance of these species depends directly on precipitation, and temperature serves only to retard or hasten their development. These species occur as explosive but short-lived outbreaks in the spring or following heavy rains during the summer.

Aedes of the second group are more adaptable in their life cycle. They are basically multivoltine but if weather conditions are unfavourable they can become univoltine (facultatively univoltine). Like the first group of *Aedes*, they lay their eggs on the mud at the edges of pools and the egg deposits parallel the edges of the water bodies. Immediately after egg-laying, the embryonic development of an egg proceeds to completion. If at the time embryonic development is complete, the eggs are submerged in water by heavy or persistent rains, they will hatch but if the pool has been drying and the location of the

eggs has dried by the time embryonic development is complete, then the embryos go into diapause and will not hatch until after a period of conditioning at low temperatures. This, of course, will be in the following or some subsequent year. In a dry summer these species will be scarce. In a summer with sufficient rain to increase water levels these species will be abundant but will reach their greatest abundance in a hot, wet summer (McLintock et. al., 1966).

When the collecting started in late May - early June 1974, mosquitoes were not sufficiently abundant to be annoying. Univoltine *Aedes* species were the most abundant mosquitoes and the multivoltine A. *dorsalis* and overwintered females of *Culiseta* species were also present.

The cool May weather in the southern part of the study area moderated by June 19, and showery and consistently warm weather was probably significant in speeding up mosquito development throughout the entire area. The influence was particularly noticeable at Prince Albert National Park and MacDowall. In all areas, however, conditions appeared optimal for the production and survival of mosquitoes.

In July, the weather was notably warm until July 22. This was again favourable for mosquito production and survival; the numbers of mosquitoes trapped gradually increased with the univoltine *Aedes* still predominating in most areas. Between July 1 and 8 a more rapid increase

in the multivoltine species in the grassland and for the remainder of the season they dominated all the catches in this area. *C. inornata* was the predominant multivoltine species. Increasing numbers of *C. tarsalis* began to have a noticeable effect on the size of the catches during the latter half of July. The univoltine *Aedes* also continued to increase in numbers but at a much slower rate and both groups reached their summer peaks between June 24 and August 5 depending on location. In the N.W.T. maximum mosquito abundance was reached on July 8; all species were univoltine in habit.

In August, decline in mosquito numbers followed the decrease in mean weekly temperatures. In the southern boreal forest, however, abnormally high rainfall maintained larval pools or created new ones. Although temperatures were low, there were still two periods in the second half of the month when temperature means were occasionally above normal. In this area, between Prince Albert National Park and Saskatoon, mosquito abundance remained at a relatively high level compared to other locations in the study area. Continued cool weather in September seriously curtailed all mosquito activity throughout the study area.

Weather factors considered favourable for promoting mosquito development during May, June, July and August, 1974, are summarized in Fig. 5.3. With the below-normal temperatures and above-normal rains, we could have expected the univoltine *Aedes* to be more abundant than the multivoltine species in the total catches of such a season.
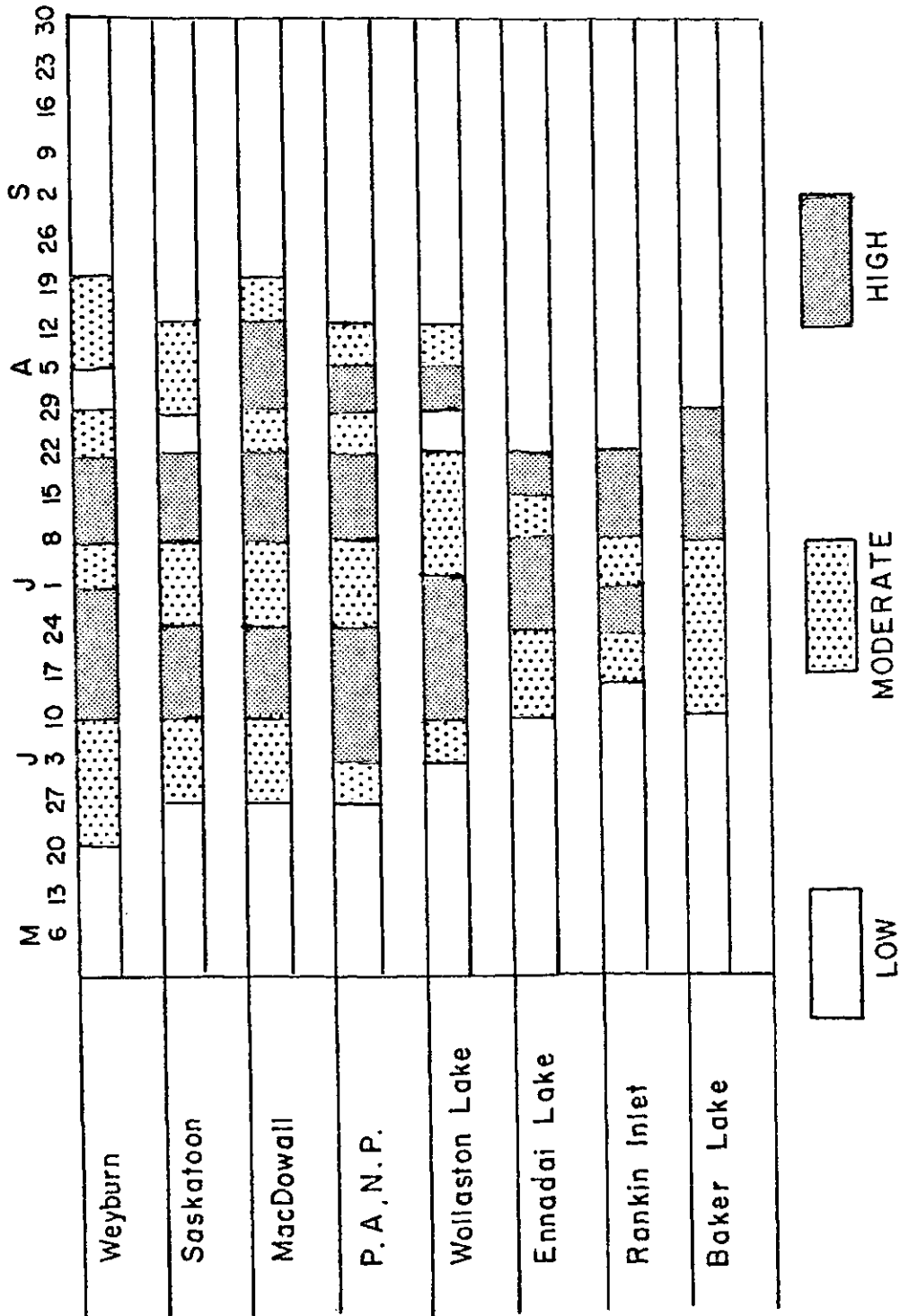
Figure 5.3   Estimated influence of temperature and rainfall on breeding of mosquitoes in the study area 1975 (after Fraser and Brust, 1976).

Undoubtedly this was the case in northern areas but Table 4.1 indicates
that was not the case in southern Saskatchewan in the summer of 1974.
This suggests that in southern Saskatchewan, temperatures below the
meteorological normals for the summer were adequate for rapid
development of some multivoltine species. This had particular
application to C. *inornata*, a species known to be tolerant of low
temperatures in the laboratory and in the field (McLintock, 1952;
McLintock and Rempel, 1963) and belonging to a genus in which tolerance
to low temperatures appears to be characteristic.

It is also likely that the relative numbers of mosquitoes each
year are determined by the number of eggs available for hatching and
the amount of snowfall during the previous winter. The number of eggs
that hatch in the spring is partly dependent on the extent and
distribution of breeding pools. If pools are widespread, numerous
eggs will be wetted and immersed, and a larger adult population will
follow. After several years of small snowfall (and small pools,
poorly distributed), there may be an accumulation of eggs in regions
which were not flooded in these years; a heavy snowfall will then
result in a large population the following summer. A similar
suggestion was made by Rempel (1953) to explain the very large numbers
of prairie mosquitoes which occur in some years. The large snowfall
in parts of the study area in 1973-1974, combined with large amounts
of summer rainfall, was followed by a large mosquito population in 1974,
about twice that found in 1975. The snowfall in the preceding winter

may be the most important single factor regulating the initial size of the mosquito population.

5.4.2 Habitat preference

The studies on the larvae showed that each species had a preference for particular habitats, but since the distinction between these habitats was often not great (temporary floodwater pools in grassy ditches or open-grass sloughs, for example), most species were found in more than one habitat type. None of the species encountered in 1974-75 showed a preference as distinct as that of A. rempeli, which only developed in stenothermal rock-crevice pools in the arctic. The study showed that larvae of certain mosquito species could, in fact, develop in a wide range of water conditions. This suggests that the preferences as found in nature are due to the selection of the habitat by the adult female mosquito. This is in accordance with the findings of other researchers, most notably Happold (1965a), Osgood (1971) and Dixon and Brust (1972). Happold (1965a) hypothesized that since the larvae of several species are found together in pools of water, the females of certain species must react in a similar manner to the same environmental variables. Similarly, in those species whose larvae occur in a wide variety of habitats, females must be stimulated to lay by a wide variety of environmental variables. If the species in the study area all required specialized habitats, the environment would probably not be able to support so many species. It was apparent also that the commonest species had a wider range of

habitats than the less common species.

5.4.3 Predators

Predation and parasitism are said to be important factors in limiting the numbers of mosquito larvae, but with regard to the mosquitoes in the study area at least, there was little evidence to support this. Aedes larvae were generally the only aquatic animals present in pools between egg hatching and the emergence of adults, so predators could not be considered a limiting factor. The works of Baldwin et. al. (1955), James (1961) and Happold (1965a), have shown that many insect predators do prey on mosquito larvae. However, the predators studied are often dependent upon more permanent water for development, where relatively few Aedes larvae occur.

Parasites may be more effective than predators in controlling mosquito larvae, especially those that have an egg stage or a spore stage that can survive the drying of temporary pools and whose life cycle can be synchronized with that of the mosquito. Mermithid nematodes were the most effective parasites of mosquito larvae in the study area. Fairly high levels of natural parasitism were recorded from about 50% of the pools studied at Rankin Inlet, N.W.T. in 1974. The life cycle of the nematode appeared to be well synchronized with that of the two affected species, A. nigripes and A. impiger.

The study by Shemanchuk (1978), of the fungus Coelomomyces psorophorae found in Culiseta inornata at Lethbridge, Alberta is also encouraging. He found fairly high levels of infection, and larval

mortalities of up to 80% in some breeding pools. On a wider geographic scale, however, this cannot be considered a limiting factor by itself.

5.5 FORECASTING DISTRIBUTION AND ABUNDANCE

Any useful method for predicting the period of mosquito development on the basis of weather conditions is practical only if it depends on weather factors that are normally recorded at weather stations. This study demonstrates the necessity of continuous records as opposed to spot readings of meteorological variables for any mathematical models which attempt to predict mosquito occurrence. It also indicates that the temperature conditions of a breeding pool are dependent largely on weather factors, but they are influenced also by edaphic or topographic factors.

Edaphic factors cannot be neglected in the study of mosquito development, especially when rates of development are compared for different geographical areas. The effects of weather and climate are modified continually by subsoil temperatures to a degree that varies with site, elevation and geographic location. The site and substrate structure of the study pool at Ennadai Lake, for example, was that of a pool underlain with coarse gravel on the south facing slope of an esker. Temperatures in this pool often exceeded 25°C in the daytime, a situation radically different from more sheltered, wooded pools where daytime temperatures would only reach 18-20°C. The differences between the two pool types had important consequences for the different types

of mosquitoes developing in them. A. *excrucians*, for example, had relatively large temperature requirements for development (see Table 4.10), and was a dominant woodland species with the larvae being frequently collected from open woodland pools of the sedge or grass type. However, it was able to extend its range into the tundra areas by breeding in open pools, exposed to the warming rays of the sun. It is apparent, therefore, that any attempt to forecast distribution and abundance of mosquitoes must take into account the variability of micro-environmental factors in relation to mosquito habitat. This is important because some species might choose a site that is suitable for development on a micro-environmental level, even though this site is located within a developmentally unsuited macro-environment.

Chapter 6

CONCLUSION

During the spring and summer months of 1974 and 1975, mosquitoes were collected from eight locations considered representative of three distinct ecological zones in Saskatchewan and Keewatin District, N.W.T. - the grasslands, the boreal forest, and the tundra. Thirty-five species of mosquitoes were collected comprising 25 species of *Aedes*, six of *Culiseta*, two of *Culex*, one of *Anopheles* and one of *Mansonia*.

Each ecological zone had a characteristic group of mosquito species within it, with several species predominating. There was a general decrease in the number of species as one went north. The area found to have the highest diversity of mosquito species was the aspen grove-mixed wood area where a wide variety of grassland and boreal forest species were found. In a given ecological zone, the diversity of the mosquito population could be adequately described by merely counting the number of species present.

The sequence of appearance of larvae and adult mosquitoes varied throughout the three ecological zones. In southern areas there was a marked succession of species with several generations of individual species. In northern wooded areas and on the tundra there was usually one great emergence of species with only one generation per year.

Correlations of life cycle type (univoltine-multivoltine) with seasonal occurrence and geographic distribution were also noted. There was a decrease in the number of multivoltine species as one went

northward in the study area. Only cold-tolerant species possessing the univoltine life cycle were able to succeed in extreme northern areas. Similarly, there was correlation of habitats with type of life cycle. The species belonging to the univoltine cycle bred in temporary waters or the drying margins of semi-permanent waters. The earlier species developed in snow melt-water or similar flood-water pools. The later species required water which persisted longer. Species with a multivoltine cycle occurred only in permanent waters or the most persistent residual pools of the semi-permanent type. The most abundant multivoltine or univoltine species were found in those habitats having the widest geographic distribution and possessing a range of environmental conditions.

The environmental conditions of the mosquito habitat affected species distribution and abundance in the following ways: (1) the rate of snow melt in the spring and the amount of snow or rain determined the date and the extent of egg-hatching. The nature and the extent of the moisture in the breeding pools was of particular importance to the univoltine species; (2) the temperature of the water and air determined the rate of development of the eggs, larvae and pupae, the rate of ovarian development in the adult females and the general level of acitivity in adults. In a cold year, such as 1974 or 1975, the period between the first and last emergence of adults was prolonged. This had a particular effect on the multivoltine species, where the number of generations per season and the level of activity in the adults were

reduced; (3) the fact that the larvae of many mosquito species could develop in a wide range of water conditions and habitat types suggests that much of the pattern of larvae distribution was due to the selection of the habitat by the adult female mosquito. This suggestion is further reinforced by the fact that the production of mosquitoes occurred in only a small number of available pools. Many pools, essentially the same with respect to physical parameters such as temperature, moisture, nutrient status, pH, etc., were left unoccupied by mosquitoes; (4) predation was not as effective as parasitism in limiting mosquito distribution or abundance. On a local scale, parasites like the mermithid nematodes were very effective in limiting mosquito numbers. On a wider geographic scale, however, predation or parasitism could not be considered limiting factors by themselves.

It was possible to use much of the foregoing information to forecast mosquito abundance and distribution, especially on a local scale. From known developmental periods, it was possible to predict the expected time of occurrence of two species by adding up the number of heat units or "degree-days" available to these species in a given year. Furthermore, a species such as A. *excrucians* was able to extend its geographical range into an area with an unfavourable macro-climate provided that a habitat existed where the minimum thermal requirements were available for completion of development of that species.

REFERENCES

Andrewartha, H.G. and L.C. Birch. 1954. The distribution and abundance of animals. Univ. of Chicago Press, Chicago.

Baldwin, W.F., H.G. James and H.E. Welch. 1955. A study of predators of mosquito larvae and pupae with a radioactive tracer. Can. Ent. 87: 350-356.

Barnard, D. and M. Mulla. 1977. Temporal patterns of pupation and emergence in the mosquito *Culiseta inornata* (Diptera:Culicidae). Can. Ent. 109: 1387-1392.

Barr, A.R. 1958. The mosquitoes of Minnesota (Diptera:Culicidae:Culicinae). Univ. of Minnesota Agr. Expt. Sta.. Tech. Bull. 228: 1-154.

Barr, A.R., T.A. Smith and M.M. Boreham. 1960. Light intensity and attraction of mosquitoes to light traps. Jour. Econ. Entomol. 53: 876-880.

Bates, M. 1941. Studies in the technique of raising anopheline larvae. Amer. J. Trop. Med. 21: 103-122.

Bodenheimer, F.S. 1938. Problems of Animal Ecology. Oxford Univ. Press, Oxford, England.

Bodman, M.T. and N. Gannon. 1950. Some habitats of eggs of *Aedes vexans*. J. Econ. Ent. 43: 547-548.

Bostock, H.S. 1974. Physiographic regions in National Atlas of Canada, Ottawa : 6.

Brust, R.A. 1968. Temperature-induced intersexes in *Aedes* mosquitoes: Comparative study of species from Manitoba. Can. Ent. 100(8): 879-891.

Brust, R.A. 1973. Distribution of *Aedes* mosquito larvae and their control. Can. Dept. Nat. Def., Def. Res. Bd. Rept DR217: 133-137.

Brust, R.A. and R.A. Costello. 1969. Mosquitoes of Manitoba. II. The effect of storage temperature and relative humidity on hatching of eggs of *Aedes vexans* and *Aedes absurratus* (Diptera:Culicidae). Can. Ent. 101: 1281-1291.

Budd, A.C. and K.F. Best. 1969. Wild plants of the Canadian Prairies. Can. Dept. of Agric. Publ. 983, Ottawa.

Burgess, L. 1974. The Canadian Agricultural Insect Pest Review. 52: 21-23.

Campbell, J.B., K.F. Best and A.C. Budd. 1966. Ninety-nine range
    forage plants of the Canadian Prairies. Can. Dept. Agric. Publ.
    964, Ottawa.

Carmichael, L.T. 1976a. Common marsh plants of Saskatchewan. Sask.
    Mus. Nat. Hist. Publ., Regina.

Carmichael, L.T. 1976b. Woodland wildflowers of Eastern Saskatchewan.
    Sask. Mus. Nat. Hist. Publ., Regina.

Carpenter, S.J. and W.J. LaCasse. 1955. The mosquitoes of North
    America (north of Mexico). Univ. of California Press, Berkely.

Corbet, P.S. and H.V. Danks. 1975. Egg-laying habits of mosquitoes in
    the high arctic. Mos. News. 35(1): 8-14.

Cunningham, G.C. 1975. Forest flora of Canada. Dept. of Northern Aff.
    and Nat. Res. Forestry Br. Bull. 121, Ottawa.

Daubenmire, R.F. 1938. Merriams life zones of North America. Q. Rev.
    Biol. 13: 327-332.

Dixon, R.D. and R.A. Brust. 1972. Mosquitoes of Manitoba. III.
    Ecology of larvae in the Winnipeg area. Can. Ent. 104: 961-968.

Downes, J.A. 1964. Adaptations of insects in the arctic. Paper
    No. 15 in the program "Studies on Arctic Insects", Entomology
    Research Institute, Can. Dept. of Agriculture.

Downey, J.E. 1962. Mosquito catches in New Jersey mosquito traps and
    ultra-violet light traps. Bull. Brooklyn Entomol. Soc. 57: 61-63.

Edwards, F.W. 1932. Diptera, Family Culicidae. Fasc. 194, 258 pp.
    in Wytsman, T. ed., Genera Insectorum, Brussels.

Eldrige, B., M. Johnson and C. Bailey. 1976. Comparative studies of
    two North American mosquito species, *Culex restuans* and *Culex
    salinarius*: Response of temperature and photoperiod in the
    laboratory. Mos. News. 36(4): 506-513.

Fraser, H.M. and R.A. Brust. 1976. VII. Weather conditions affecting
    mosquito populations in southern Manitoba during 1975. Can. J.
    Pub. Health. 67: 40-46.

Fredeen, H. 1975. The Canadian Agricultural Insect Pest Review.
    53: 28.

Freeman, T.N. 1952a. Interim report of the distribution of the mosquitoes obtained in the Northern Insect Survey. Can. Dept. Nat. Def., Def. Res. Bd., Envir. Prot. Tech. Rept. 4, Ottawa.

Freeman, T.N. 1952b. Some problems of insect biology in the Canadian Arctic. Arctic 5: 175-177.

Frohne, W.C. 1954. Mosquito distribution in Alaska with special reference to a new type of life cycle. Mos. News. 14: 10-13.

Gilbert, N., A.P. Gutierrez, B.D. Frazer and R.E. Jones. 1977. Ecological Relationships. W.H. Freeman and Company, San Francisco.

Gillies, M.T. 1969. The ramp-trap, an unbaited device for flight studies of mosquitoes. Mos. News. 29: 189-193.

Gillett, J.D. 1972. The mosquito: its life, activities and impact on human affairs. Doubleday & Company, Inc., New York.

Gressitt, J.L. 1958. Zoogeography of Insects. Ann. Rev. Ent. 3: 207-230.

Happold, D.C.D. 1965a. Mosquito ecology in central Alberta. I. The environment, the species and studies of the larvae. Can. J. Zool. 43: 795-819.

Happold, D.C.D. 1965b. Mosquito ecology in central Alberta. II. Adult populations and activities. Can. J. Zool. 43: 821-846.

Haufe, W.O. 1952. Observations on the biology of mosquitoes (Diptera: Culicidae) at Goose Bay, Labrador. Can. Ent. 84: 254-263.

Haufe, W.O. and L. Burgess, 1956. Development of *Aedes* (Diptera: Culicidae) at Fort Churchill, Manitoba, and prediction of dates of emergence. Ecology 37: 500-519.

Hayes, R.O., M. Montoya, G.C. Smith, D.B. Francy and W.L. Jakob. 1974. An analysis of *Culex tarsalis* Coquillett laboratory rearing productivity. Mos. News. 34: 462-466.

Hocking, B., W.R. Richards and C.R. Twinn. 1950. Observations on the bionomics of some northern mosquito species. Can. J. Res. (D)28: 58-80.

Hocking, B., and L.R. Pickering. 1954. Observations on the bionomics of some northern species of *Simuliidae* (Diptera). Can. J. Zool. 32: 99-119.

Horsfall, W.R. 1942. Biology and control of mosquitoes in the rice area. Univ. Arkansas, Agric. Exp. Sta. Bull. 427: 1-46.

Horsfall, W.R. 1974. Effect of simulated seasonal conditions on hatching of eggs of a univoltine mosquito. Ent. Soc. Amer. Ann. 67(6): 991-992.

Hudson, A. and J. McLintock. 1967. A chemical factor that stimulates oviposition by *Culex tarsalis* Coquillet (Diptera:Culicidae). Animal Behaviour. 15(2-3): 336-341.

Iversen, J.O., R.J. Wagner, C. DeJong and J. McLintock. 1973. California encephalitis virus in Saskatchewan: isolation from boreal *Aedes* mosquitoes. Can. J. Pub. Health. 64: 590-593.

James, H.G. 1961. Some predators of *Aedes stimulans* (Walker) and *Aedes trichurus* (Dyar) in woodland pools. Can. J. Zool. 39: 533-540.

Jenkins, D.W. 1958. Ecology of arctic and subarctic mosquitoes. Proc. Tenth Int. Congress of Entomology. 1: 627-634.

Johannsen, O.A. 1933. Aquatic Diptera, Part I. Nemocera, exclusive of Chironomidae and Ceratopogonidae. Cornell Univ. Ag. Exp. Sta. Memoir 164. Ithaca, N.Y.

Johannsen, O.A. 1935. Aquatic Diptera, Part II. Orthorrhapha-Brachycera and Cyclorrhapha. Cornell Univ. Ag. Exp. Sta. Memoir 177. Ithaca, N.Y.

Johannsen, O.A. 1937. Aquatic Diptera, Part III. Chironomidae: Subfamilies Tanypodinae, Diamesinae and Orthocladinae. Cornell Univ. Ag. Exp. Sta. Memoir 205. Ithaca, N.Y.

Kendeigh, S.C. 1954. History and evaluation of various concepts of plant and animal communities in North America. Ecology. 35: 152-171.

Krebs, C.J. 1972. Ecology: The experimental analysis of distribution and abundance. Harper and Row, New York.

Lehmkuhl, D.M. 1975. Field guide to Aquatic Insect families. Blue Jay 33(4): 199-219.

Lloyd, M. and R.J. Ghelardi. 1964. A table for calculating the equitability component of species diversity. Jour. Anim. Ecol. 33: 217-225.

Love, G.J. and W.W. Smith, 1957. Preliminary observations on the relation of light trap collections to mechanical sweep net collections in sampling mosquito populations. Mos. News. 17: 9-14.

MacArthur, R.H. 1964. Environmental factors affecting bird species diversity. Amer. Nat. 98: 387-397.

MacArthur, R.H. and J. MacArthur. 1961. On bird species diversity. Ecology. 42: 594-598.

Mail, G.A. 1934. The mosquitoes of Montana. Bull. Montana State Coll. Agr. Expt. Sta. No. 288.

Maloney, J. and R. Wallis. 1976. Response of colonized *Culiseta melanura* to photoperiod and temperature. Mos. News. 36(2): 190-196.

Margalef, D.B. 1958. Information theory in ecology. Gen. Syst. 3: 36-71.

McLintock, J. 1944. The mosquitoes of the greater Winnipeg area. Can. Ent. 76(5): 89-104.

McLintock, J. 1946. Collecting and handling mosquitoes on western equine encephalitis investigations in Manitoba. Can. Jour. Res. (E) 24: 55-62.

McLintock, J. 1964. The laboratory cultivation of *Culiseta*. Bull. Wld. Hlth. Org. 31: 459-460.

McLintock, J. 1976. *Anopheles walkeri* Theobald in Saskatchewan and notes on *Culiseta silvestris minnesotae* Barr. Mos. News. 36: 308-310.

McLintock, J. and J.G. Rempel. 1963. Midsummer mosquito abundance in southern Saskatchewan, 1962. Mos. News. 23: 242-249.

McLintock, J., A.N. Burton, H. Dillenberg and J.G. Rempel. 1966. Ecological factors in the 1963 outbreaks of western encephalitis in Saskatchewan. Can. J. Pub. Health. 12: 561-576.

McLintock, J. and J. Iversen. 1975. Mosquitoes and human disease in Canada. Can. Ent. 107: 695-704.

McNaughton, S.J. 1978. Stability and diversity of ecological communities. Nature. 274: 251-253.

Merriam, C.H. 1898. Life zones and crop zones of the United States. Bull. Div. Biol. Survey, U.S.D.A.. 10: 1-79.

Odum, E.P. 1971. Fundamentals of ecology. W.B. Saunders and Co., Philadelphia.

Oliver, D.R., P.S. Corbet and J.A. Downes. 1964. Studies on arctic
    insects: the Lake Hazen project. Can. Ent. 96: 138-139.

Osgood, C.E. 1971. An oviposition pheromone associated with egg rafts
    of *Culex tarsalis*. J. Econ. Ent. 64: 1038.

Pielou, E.C. 1966. The measurement of diversity in different types
    of biological collections. J. Theoret. Biol. 13: 131-144.

Porsild, A.E. 1955. The vascular plants of the western Canadian Arctic
    Archipelago. Can. Dept. North. Aff. Nat. Res., Nat. Mus. Can.
    Bull. 135, Ottawa.

Porsild, A.E. 1957. Illustrated flora of the Canadian Arctic
    Archipelago. Can. Dept. North. Aff. Nat. Res., Nat. Mus. Can.
    Bull. 146, Ottawa.

Provost, M.W. 1974. The zoogeography of mosquitoes in Florida. Proc.
    California Mos. Control Assoc. and Am. Mos. Control Assoc.

Reed, D.E. 1959. Mosquito light trap captures without benefit of
    light. Proc. Calif. Mos. Control Assoc. 27: 63-66.

Rempel, J.G. 1950. A guide to the mosquito larvae of western Canada.
    Can. J. Research, D, 28: 207-248.

Rempel, J.G. 1953. The mosquitoes of Saskatchewan. Can. J. Zool.
    31: 433-509.

Ross, H.H. 1964. The colonization of temperate North America by
    mosquitoes and man. Mos. News. 24: 103-113.

Rowe, J.S. 1972. Forest regions of Canada. Dept. of the Environment
    Canadian Forest Service Publ. No. 1300, Ottawa.

Salt, R.W. 1961. Principles of insect cold-hardness. Ann. Rev. Ent.
    6: 55-73.

Sanderson, E.D. and L. Peairs. 1913. New Hampshire Agr. Exp. Sta.
    Tech. Bull. No. 7.

Shannon, C.E. and W. Weaver. 1963. The mathematical theory of
    communication. Univ. of Illinois Press, Urbana.

Shemanchuk, J.A. 1965. On the hibernation of *Culex tarsalis* Coquillett,
    Culiseta inornata Williston, and *Anopheles earlei* Vargas, (Diptera:
    Culicidae) in Alberta. Mos. News. Vol. 25, No. 4: 456-462.

Shemanchuk, J.A. 1969. Epidemiology of western encephalitis in Alberta: Response of natural populations of mosquitoes to avian host. J. Med. Ent. Vol. 6, 3: 269-275.

Shemanchuk, J.A. 1978. Biological control of mosquitoes. Canada Agriculture. 23: 25-26.

Smith, S.M. and R.A. Brust. 1970. Autogeny and stenogomy of *Aedes rempeli* (Diptera:Culicidae) in Arctic Canada. Can. Ent. 102(2): 253-256.

Surtees, G. 1959. Influence of larval population density on fluctuations in mosquito numbers. Nature. 183: 269-270.

Tauber, M.J. and C. Tauber. 1976. Insect seasonality: diapause maintenance, termination and post-diapause development. Ann. Rev. Ent. 21: 81-107.

Taylor, M. 1975. The Canadian Agricultural Insect Pest Review. 53: 28.

Teed, L.M. and J.S. Rowe. 1973. Saskatchewan Trees. Tri-Leaf Publ., Saskatoon.

Twinn, C.R. et. al. 1948. A preliminary account of the biting flies at Churchill, Manitoba. Can. J. Res. (D)26: 334-357.

Twinn, C.R. 1950. Studies on the biology and control of biting flies in northern Canada. Arctic. 3: 14-26.

Vockeroth, J.R. 1950. Specific characters in tarsal claws of some species of *Aedes* (Diptera:Culicidae). Can. Entomol. 82: 160-162.

Vockeroth, J.R. 1954a. Notes on the identities and distribution of *Aedes* species of northern Canada, with a key to the females (Diptera:Culicidae). Can. Entomol. 86: 241-255.

Vockeroth, J.R. 1954b. Notes on northern species of *Aedes*, with descriptions of two new species (Diptera:Culicidae). Can. Entomol. 86: 109-116.

Wilde, S.A. 1954. Floristic analysis of ground cover vegetation by a rapid chain method. J. For. 52: 499-502.

APPENDIX A

Notes on the species.

Aedes campestris Dyar and Knab - This species was common to the dry grassland region where it has been reported to have a wide distribution (Rempel, 1953; McLintock, unpubl.); it is found sparingly as far north as the treeline (Vockeroth, 1954). It has been taken at Whitehorse, Y.T. and Churchill, Manitoba, in moderate numbers but, despite intensive collecting, it has not been found in the region between these points. In the present study area it has been recorded as far north as Prince Albert National Park.

The larvae were found in alkaline, semi-permanent or permanent pools, rich in organic matter. The pools usually had mud and grass bottoms with roadside ditches being a favoured habitat. For this reason the species may be restricted in overall distribution although extremely abundant in a particular area. There appears to be only one generation a year.

Aedes canadensis (Theobald) - This was a common woodland species in the study area being most abundant near the northern edge of the aspen grove region. Happold (1965a) recorded similar results from the aspen grove region of northern Alberta. On a North American scale, this is one of the most widespread mosquitoes, its distribution blanketting the larger part of the United States and southern Canada (Carpenter and LaCasse, 1955).

The larvae were found in permanent and semi-permanent pools usually protected by trees or shrubbery. The adults attacked readily

and were most annoying in dense poplar bluffs. There was only one
generation a year with the larvae appearing in late May - early June.

Aedes cataphylla Dyar - In the study area this species was
found commonly in the aspen parklands of central Saskatchewan
extending north into the coniferous forest zone. Its range extended
as far north as Ennadai Lake, N.W.T., wherever relict patches of forest
occurred.

Larvae were found in grassy habitat, sheltered by trees; the
larvae appeared in late May and adults emerged by early June.
A. *cataphylla* appears to be a short-lived species with few adults ever
caught in July. There was only one generation a year.

Aedes cinereus Meigen - This was a predominately woodland species
and was one of the last *Aedes* species to emerge. The larvae seemed to
prefer a variety of habitats, having being taken from permanent, semi-
permanent and temporary locations. Other authors have found them in
open and wooded pools (Haufe, 1952), in pools under alder, willow and
dogwood (Jenkins and Knight, 1952), in ditches at the borders of lakes
in Scandinavia (Natvig, 1948) and in open, grassy habitats (Happold,
1965a). Although *Aedes cinereus* adults generally remained in the
forests or in shaded valleys, they were commonly found in the
transition area between forest and tundra. There was only one
generation a year.

Aedes communis (de Geer) - This species has an exceptionally wide
geographic distribution throughout North America, Europe and Asia. In

the study area it was not encountered on the prairie, it was rare in the aspen parklands, but extremely abundant in forested regions. In the study area, larvae were found abundantly in clear, mossy pools shaded by spruce trees, and occasionally in grass or sedge habitats overhung by willows. The immature forms tolerated a wide range of ph (4.3 to 7.5) of water in the breeding pools. This was an early species with only one generation a year. Larvae appeared soon after the snow began to melt and adults emerged before the end of May. In Prince Albert National Park it formed over 30% of the mosquito population in 1974 and 1975.

Aedes diantaeus Howard, Dyar and Knab - This was an extremely rare species in the study area. A few larvae were found in a forest pool at MacDowall, Saskatchewan in 1975. Happold (1965a) recorded this species from northeastern Alberta in 1962 in sedge and semi-permanent habitats. According to Rempel (1953), only one other adult has been collected in Saskatchewan, at Waskesiu, May 18, 1929. This appears to be an early species with only one generation a year.

Aedes dorsalis Meigen - In the study area, this was a common grassland mosquito. The larvae were found in a variety of temporary pools where the water was quite alkaline (pH 7.3 to 8.4). Adults were taken from early summer till the end of August. Generation followed generation all summer, sometimes as close as two weeks apart, depending on weather conditions. This species was not recorded in the study area north of MacDowall, Saskatchewan.

Aedes eudes Howard, Dyar and Knab - As a member of the *Aedes stimulans* group of mosquitoes (Table 4.4), this species exhibited the same habitat preference and seasonal history as A. *fitchii* and A. *excrucians*. It had a widespread distribution in the southern boreal forest but its range did not extend as far north as A. *excrucians*.

The larvae seemed to prefer the relatively open, semi-permanent pools at the edges of aspen groves, but it was also found in spruce pools, in association with A. *communis*. There was only one generation.

Aedes excrucians (Walker) - This species has an extremely wide distribution. In North America it is found in the northern States and generally throughout most of Canada (Carpenter and LaCasse, 1955). In the study area its distribution extended from the grasslands through the aspen grove and forested region into the tundra.

The larvae were frequently collected in small woodland pools in late May. Happold (1965a) recorded this species from shaded regions of sedge, grass, and forest pools. Rempel (1953) also recorded this species in shaded areas. In 1975, however, this species was observed breeding in extremely exposed tundra pools at Ennadai Lake, N.W.T.. These pools were invariably on the southern slopes of eskers, with sandy or gravelled bottoms. Temperatures in these pools often exceeded 25°C in the daytime. Natvig (1948) has also found this species in open habitats in Scandinavia. There was only one generation. In early

summer this species, together with A. *eudes* and A. *fitchii*, were often the main species encountered in aspen-grove or mixed-wood forest situations. In June and July, these species formed 45-50% of the mosquitoes in the aspen forest.

Aedes fitchii (Felt and Young) - Like *Aedes excrucians*, this species was found in the more open areas of the aspen forest early in the summer, where it was one of the most abundant species. It was also fairly common in the coniferous forested areas, but was not found as far north as *Aedes excrucians*.

Aedes fitchii preferred woodland pools for breeding although they have been reported developing in a wide variety of habitats, including temporary pools in railway ditches or in the open surrounded by shrubbery (McLintock, 1944). In the study area, larvae were found mainly in wooded swamps and in open sphagnum bogs. There was only one generation.

Aedes flavescens Müller - This was an abundant species on the open prairie but has also been recorded from northerly locations, such as Churchill, Manitoba and Wollaston Lake, Saskatchewan. Its distribution on the prairies is not consistent, being closely associated with level and poorly drained land covered by extensive areas of sedge and slough grass. McLintock (1944) for example, found this species to be of little importance in the Winnipeg area, and Shemanchuk (1959) recorded similar results from southern Alberta.

Larvae were found in early June in semi-permanent water.

Like Rempel (1953), the writer collected the larvae consistently in small sloughs overgrown with sedge (*Carex* spp.), rushes (*Scirpus* spp.) and slough grass (*Beckmannia* spp.) in water which was stagnant, organically rich and alkaline (pH 6.7-8.0). At Wollaston Lake, Saskatchewan, the larvae were found in a semi-permanent marshy area, overgrown with sedge. There was only one generation a year; the females survived until late in the season.

Aedes hexodontus Dyar - This was primarily a species of the arctic tundra, but its range apparently may extend southward in the high mountains where its immature stages are found in alpine meadows (Vockeroth, 1954a). The extent of the range of this species is not known at this time, since it has been confused with *Aedes punctor*. The two species are distinquishable only in the larval form.

The larvae of *Aedes hexodontus* were found in various types of small pools on the tundra, usually the temporary type caused by melting snow. At Rankin Inlet, it was also found in rock pools lined with lichens and mosses. This species appeared to be very abundant at the treeline, and was less abundant in the rest of the tundra locations.

Aedes impiger (Walker) - This was chiefly an Arctic species, although it occurred locally far south of the treeline. Rempel (1953) recorded it from Waskesiu, Saskatchewan, and its range is known to extend southward to Utah and Colorado where it is found in alpine meadows of mountains (Carpenter and LaCasse, 1955). Farther north,

Aedes impiger was almost replaced by *Aedes nigripes*, although *Aedes impiger* apparently occurs throughout the arctic. In 1951 adult females were collected at Alert, Ellesmere Island (82° 30'N); this is the most northerly record for any species of mosquito (Vockeroth, 1954a).

The larvae of *Aedes impiger* were found in clear pools of water formed by melting snow and bog-type pools but were found on a few occasions in rock pools containing vegetation. Like all arctic mosquitoes, there was only one generation a year.

Aedes implicatus Vockeroth - This species has a boreal distribution; it occurs in the forested regions of Canada and the northern United States. It does not extend north to the treeline, and it is seldom abundant. In the study area, a large series of larval specimens were reared at MacDowall, Saskatchewan, and larvae were also collected at Saskatoon, Saskatchewan. This was an early species but was also short-lived. Larvae were found in semi-permanent grass habitats at the edge of mixed-wood tree stands.

Aedes nigripes (Zetterstedt) - This species was restricted to the arctic region, where it was the most abundant mosquito. The northern limit of its distribution is not known, although it probably occurs farther north than present distribution records indicate, (Oliver et. al., 1964). The southern limit of its range in the mountainous areas of western North America is unknown.

In the study area, the larvae of *Aedes nigripes* developed in

early spring pools formed from melting snow and ice. The larvae were found primarily in shallow, exposed snow water pools. Occasionally, larvae were taken from more permanent marshy areas dominated by sedges or grasses. As with most arctic mosquito species, adult emergence occurred with a heavy burst around the middle to the end of June and was largely completed during the first week of July. There was then a marked decline in abundance of adults after mid-July, usually initiated by extremes in temperature or a heavy rainfall.

Aedes nigromaculis (Ludlow) - This species was found in the grassland areas. No larvae were found and only a few adults were collected at Weyburn, Saskatchewan in 1974 and 1975. According to Rempel (1953) and McLintock (1969) this species is common in southern Saskatchewan. The reason for the low incidence in this area since 1969 is not known.

McLintock (1944) states that this species breeds in shallow pasture depressions and weedy ditches. There may be a second generation in a summer.

Aedes pionips Dyar - In the study area this species was rare in the aspen parkland, but common in the coniferous forest region from MacDowall-Prince Albert north. It did not occur at the treeline.

This was one of the later developing species and was more restricted in its breeding places. The larvae were only found in cold, clear pools in small depressions at the bases of spruce trees. The emergent vegetation, if any, was usually mosses. A loose, mucky

bottom of black humus and wood appeared to be characteristic. The pools were always shallow, usually small, and of a semi-permanent nature. There was only one generation.

Aedes punctor (Kirby) - *Aedes punctor* occurred throughout most of the forested regions of the study area. Its northward range extended far into the tundra area, where it was one of the four most abundant species.

It bred in a wide variety of habitats; larvae were found abundantly in semi-permanent, open grass and sedge marshes and also in wooded pools. On the tundra it was also found in rock pools with little or no accompanying vegetation. The species showed less tolerance for a wide range of pH (4.5-5.9) than other *communis* group species. The adults emerged in late May and in 1974 formed approximately 3% of the total population in the aspen-forest, 9% in the mixed-wood forest and 70% in the northern coniferous-northwestern transition forest. Together with *Aedes hexodontus*, it formed 35-60% of the mosquito population in tundra areas.

Aedes rempeli Vockeroth - Most authors consider this to be the rarest of all the Canadian species of *Aedes*. There are only five known distribution records, Great Whale River, Quebec; Padlei, N.W.T.; Ennadai Lake, N.W.T.; Baker Lake, N.W.T.; and Rankin Inlet, N.W.T.. The larvae were almost exclusively found in small, unshaded rock-crevice pools underlain with permafrost (average water temperature 4.3°C). These rock pools were formed by frost-initiated, macro-riving of exposed bedrock and appeared common near the treeline. Brust

hypothesized that this species would be more common in areas where there are more extensive macro-riven formations. Studies at Ennadai Lake, N.W.T. revealed this to be true. *Aedes rempeli* larvae were common in rock-crevice pools wherever they occurred in the Ennadai Lake area. They formed 9% of the total larval population.

Aedes riparius Dyar and Knab - This was another rare species in the study area; one adult was taken at MacDowall in 1974 and one larvae was collected at Moose Mountain, in southern Saskatchewan in 1975. This species is primarily found in the southern part of the boreal forest and in the aspen grove region. Rempel (1953) reported it in abundance at Lac La Ronge and Happold (1965a) reported that it formed 8-10% of the total mosquito population in the aspen forest of northeastern Alberta. The larvae was found in a semi-permanent grass habitat in the neighborhood of an aspen poplar stand.

Aedes spencerii (Theobald) - This was one of the early spring mosquitoes in the southern grassland area. It's range extends in steadily decreasing numbers north through the aspen grove area and into the boreal forest; it has been recorded as far north as Churchill, Manitoba. (Rempel (1953) considered this to be the earliest, most widespread and most abundant species on the prairies. In 1974 and 1975 this species was common in the grassland areas but it was not as abundant as A. *vexans*, A. *flavescens*, A. *campestris*, A. *dorsalis*, C. *tarsalis* or C. *inornata*.

The larvae were found in temporary exposed pools left by

the melting snow, the water being as cold as 12°C. Larvae were common during the latter part of April or May and by the middle and end of May, adults were present in sufficient numbers to constitute a problem. In the Weyburn area a second brood was observed in late July 1974, due to heavy rainfall submerging additional numbers of eggs.

Aedes sticticus (Meigen) - This was another rare species in the study area, although it does apparently have a wide distribution in the United States, southern Canada, Siberia and northern Europe (Rempel, 1953). In 1974, adult females were caught in heavy spruce stands at Prince Albert National Park and Wollaston Lake, Saskatchewan. None were caught in 1975. Happold (1965a) recorded this species as larvae from semi-permanent, sedge and forest habitats.

Aedes stimulans (Walker) - This species has a wide distribution in the northern United States and Canada. According to Matheson (1944) it is the most abundant and annoying woodland species in the north-eastern States. In the study area it was rare and localized. Single females were captured at Weyburn, Saskatoon and MacDowall in 1974; only one was caught in 1975, at Saskatoon. The bionomics of this species closely resembles that of Aedes fitchii.

Aedes triseriatus (Say) - Only two females of this species were caught in the study area, both at Wollaston Lake in 1974. According to Carpenter and LaCasse (1955) this species is the most abundant of the tree-hole breeders in North America and is found throughout the

deciduous forests and across the great plains in the north. In 1943, J.G. Rempel collected a female specimen in a wooded valley eight miles northwest of Regina, Saskatchewan. The larvae are found in the water of tree holes of a long series of deciduous trees. They have also been found in the pitcher plant and artificial containers. It is not known where the breeding habitat would be at Wollaston Lake, since the area is largely covered by black spruce forest.

Aedes vexans (Meigen) - This is usually one of the most abundant and widespread species in the prairie area (Rempel, 1953; McLintock et. al., 1966). In the study area, the species was found in three main zones, the grassland, the aspen parkland, and the mixed-wood forest. Rempel (1953) considered this species to have two forms in this area; a small northern one found in the aspen grove and mixed-wood forest regions which is on the wing from mid June to early July, and a larger prairie form which is common during late July and August. The latter may have a second generation in early September.

The larvae were found in exposed, semi-permanent grass habitats although more permanent marshy areas were also a favorite habitat. They were one of the last *Aedes* species to emerge; adult females were not encountered until the end of June at MacDowall, and did not reach any significant level of abundance at Weyburn until mid-July. In 1974 and 1975, cool temperatures throughout the study area tended to retard the development of this species. It never reached its usual abundance level in either year, nor were there more

than two generations.

Anopheles earlei Vargas - In the study area this species was encountered on the open prairie, in the aspen grove region and in the northern wooded areas as far north as Prince Albert National Park and La Ronge.

This species overwinters as the adult female in sheltered places like buildings or rodent burrows. Larvae were generally found in more permanent habitats such as the edges of lakes and slow-moving streams or permanent marshy areas. There may be several generations in a year, although 1974 and 1975 were generally too cold to permit rapid development of larvae.

Culex restuans Theobald - This species was extremely rare in the study area with only one female caught at Weyburn, Saskatchewan in 1974. The larvae are said to prefer small dirty pools and artificial containers. In Manitoba, where this species is more common, rain water barrels appear to be a favorite breeding place (McLintock, 1944). The adult hibernates; there may be more than one generation in a year.

Culex tarsalis Coquillett - This species is very common on the prairies of the western, central and southern United States. Its range also extends south to Mexico (Carpenter and LaCasse, 1955). In the study area, *Culex tarsalis* reached significant levels of abundance only in southern Saskatchewan, its northern limits located at Saskatoon.

The larvae were found in clear or foul water in a variety of habitats including ditches, irrigation run-off systems, ground pools,

marshes, pools in slow-moving streams, rain-water barrels, and hoof-
prints. Foul water in cattle hoof-prints were a favorite habitat.
Larval production commenced in early summer and continued until fall,
with several generations being produced, although few in comparison to
other years. The maximum adult population in the study area was
reached in mid-August.

Culiseta alaskaensis Ludlow - Rare in the study area, this large
species of mosquito has a wide distribution throughout the boreal
forest or taiga region of Europe and Asia. It is common in Alaska
(Frohne, 1954). Adult females were collected from Prince Albert
National Park, Wollaston Lake and Stony Rapids, Saskatchewan.
Females overwinter (Frohne, 1954) and are flying by mid-May. No
larvae were found in the course of this investigation, although they
have been found in open, semi-permanent or permanent sedge marshes
(Rempel, 1953; Carpenter and LaCasse, 1955).

Culiseta impatiens (Walker) - This species does not seem to have
a very wide distribution in the study area, although it is supposedly
widespread in the coniferous forest areas of northern North America
(Matheson, 1944). Rempel recorded the species from Waskesiu in late
May, but did not find larvae. In 1974, 88 adult females were
collected at Wollaston Lake. The larvae are said to prefer shaded,
permanent forest pools but Happold (1965a) found twelve larvae in open
grass marsh.

Culiseta incidens (Thomson) - This was another rare species in the

study area. In 1974, 14 adult females were collected early in the season at Wollaston Lake, Saskatchewan. The larvae breed in sedge and grass marshes and there may be several generations (Happold, 1965a). The adult female hibernates (Frohne, 1954).

Culiseta inornata (Williston) - In 1974 and 1975 *Culiseta inornata* was the most abundant species in the grassland region and was the fourth most abundant species in the entire study area. This species is found throughout the United States and is common on the prairies of Manitoba, Saskatchewan and Alberta (Shemanchuk, 1959). Its most northerly distribution in the study area was Prince Albert National Park.

The species overwintered as females, usually in the basements of abandoned buildings and rodent burrows. The larvae of the first generation appeared early in the season and were found in ground pools, ditches, culverts and marshy areas, often overgrown with bullrush, slough grass, sedge or wild barley. Polluted or brackish water (pH 6.0-8.3) was preferred. There may be several generations in a year, as was the case in the study area in 1974 and 1975. Both larvae and adults developed quickly and were more active during cooler weather. Often, adults of *Culiseta inornata* were the only insects flying on cold nights.

Culiseta sylvestris minnesotae Barr - Only one female specimen of this species was obtained in 1974 or 1975, at Saskatoon, Saskatchewan. C. *minnesotae* was reported by McLintock and Rempel (1963) as one of

19 species of mosquitoes taken in Saskatchewan in the summer of 1962.
Males or females of *C. sylvestris minnesotae* have been taken in light
traps in Saskatchewan each year since 1962 and an occasional female
has been taken in a ramp trap (Gilles, 1969) at Saskatoon and by
aspirator from resting sites, in several other localities. Although
not numerous, this species appears to be widely distributed in
southern Saskatchewan having been taken in 13 localities from Estevan
(Lat. 49°04'N) in southeastern Saskatchewan, northwest to Paynton
(Lat. 53°01'N). According to McLintock (1976), the earliest females
were taken on May 26 (Saskatoon, 1966) and the latest females on
September 27 (Melfort, 1963; Saskatoon, 1970; Outlook, 1971).
According to McLintock (1976) *C. s. minnesotae* reaches its greatest
abundance in Saskatchewan late in the season. These collection
dates are consistent with the occurence of a species that overwinters
as adult females and emerges in late May or early June to produce the
first generation of the current season early in July. The species was
unknown when Rempel (1953) made his study of Saskatchewan mosquitoes
so it is unlikely that some of the *Culiseta morsitans* seen by him were
actually *C. s. minnesotae*. The larvae of this species have not yet
been found in Saskatchewan.

Culiseta morsitans (Theobald) - Four adult females were caught
at Saskatoon, Saskatchewan in 1974, and distribution of this species is
largely restricted to the grassland areas. Occasional specimens have
been recorded in aspen grove or mixed-wood forest areas (McLintock,

unpubl.). The larvae breed predominantly in habitats containing sedges (Rempel, 1953; Happold, 1965). In Europe, *C. morsitans* overwinters as a full-grown larva under ice.

Mansonia perturbans (Walker) - This species was not common in the study area, although it consistently showed up in many localities. In 1974 and 1975, females of this species were caught in four localities, from Weyburn through to Prince Albert National Park.

The larvae of this species were difficult to collect as they quickly dropped to the bottom of a pool whenever they were disturbed. The larvae and pupae are known to attach themselves to the submerged stems of plants where they remain throughout development (Rempel, 1953). The winter is passed as immature or mature larvae. The adults emerged in late spring or summer, with only one generation a year.

APPENDIX B

Description of larval habitats encountered in the study area.

(1) *Semi-permanent snowmelt pools*

(a) *Open grass or sedge pools*. These were usually medium-sized pools about 20-40 cm deep with a bottom of muck, grasses, and sedges, and long grass, sedges or willow around the margins. Common grass species included marsh reed grass, *Calamagrostis canadensis* (Michx.) Beauv.; fowl manna grass, *Glyceria striata* (Lam.) Hitchc.; or slough grass, *Beckmannia syzigachne* (Steud.) Fern.. Sedge species included *Carex rostrata* Stokes in southern areas and *Carex supina* (Willd.) Wahl. var. *spaniocarpa* (Steud.) Baivin in northern areas. In more northerly tundra areas, substrate vegetation included various mosses, usually *Drepanocladus* spp.

In early spring there was usually no emergent vegetation in these pools except for clumps of dead vegetation but, by late May or early June the grass or sedges were over 1 m tall and little of the water surface was visible. This rendered the habitat unsuitable for many mosquito species.

(b) *Wooded pools*. The wooded habitats varied from the type partially shaded by willows or aspen trees to the type found in the totally shaded spruce forest. Most forest habitats had practically no vegetation growing in the water. The water was clear, but leaves in all stages of decay covered the surface. In the mixed-wood or aspen

forest, willow, birch or aspen trees formed a canopy over the water
although diffused sunlight filtered through. Surrounding vegetation
was extremely abundant including prickly rose, *Rosa acicularis* Lindl.;
low-bush cranberry, *Viburnum edule* (Michx.) Raf.; red osier dogwood,
Cornus stolonifera Michx.; bunchberry, *Cornus canadensis* L.; wild
strawberry, *Fragaria glauca* (S. Wats.) Rydb.; horsetails, *Equisetum*
spp.; twinflower, *Linnaea borealis* L. var. *americana* (Forbes) Rehder;
wild sarsaparilla, *Aralia nudicaulis* L.; goldenrod, *Solidago canadensis*
L. var. *salebrosa* (Piper); and fireweed, *Epilobium angustifolium* L.

The vegetation accompanying pools in the spruce forest was less
diverse than in the southern forests. Mosses, *Drepanocladus* and
Sphagnum spp. predominated but sedges, *Carex* spp., horsetails,
Equisetum spp., labrador tea, *Ledum decumbens* (Ait.) Lodd. and *Ledum*
groenlandicum Oeder, cottongrass, *Eriophorum angustifolium* Honck, and
lichens, *Cladonia* and *Setraria* spp., were also present along pool
margins.

(2) *Temporary floodwater pools*

These were found mainly in the prairie portion of the study
area and included roadside ditches, hoof prints, or vehicle tracks
that were temporarily filled with water after a rainstorm, or by runoff
from rivers and creeks that had temporarily flooded their banks. These
extremely shallow and very temporary pools often dried up before
mosquito larvae could complete their development and emerge as adults.

The vegetation varied with the type of habitat but grasses such as smooth bromegrass, *Bromus inermis* Leyss, red fescue, *Festuca rubra* L., wild barley, *Hordeum jubatum* L., and crested wheatgrass, *Agropyron cristatum* (L.) Gaertn., were quite common. The roadside habitats contained many weedy species as well, including dandelion, *Taraxacum officinale* Weber, sow thistle, *Sonchus oleraceus* L., hawksbeard, *Crepis tectorum* L., lady's-thumb, *Polygonum persicaria* L., and curled dock, *Rumex crispus* L..

(3) *Permanent marshy pools*

The emergent vegetation was varied but scanty and included: beaked sedge, *Carex rostrata* Stokes, rush, *Juncus* spp., buckbean, *Menyanthes trifoliate* L., tall cottongrass, *Eriophorum angustifolium* Honch., two species of horsetails, *Equisetum* spp., and sometimes a moss species. Also included in this habitat group were the larger roadside sloughs fringed with hairy wild rye, *Elymus innovatus* Beal, northern reed grass, *Calamagrostis inexpansa* A. Gray, timothy grass, *Phleum pratense* L., and bromegrass, *Bromus inermis* Leyss.. Sedges also grew in the shallower water but the deeper water remained open with patches of duckweed, *Lemna minor* L., floating on the surface.

(4) *Artificial pools*

Included in this group were all pools found in artificial containers (rain-barrels, culverts, bridges and old tires) and extremely specialized larval habitats such as the cavities in tree

trunks or the pitchers of the pitcher plant, *Sarracenia purpurea* L..
One habitat type, the roadside culvert, was encountered quite
frequently in the southern part of the study area and figured
significantly in the life cycle of one mosquito species, *Culiseta
inornata*.

The preferred culverts or bridges were large in size (2 m
diameter) with about 20 cm of standing water at the bottom. Larvae of
C. *inornata* were in the pools and the adult female mosquitoes were
resting in the cool interiors of the culverts or bridges, near the top.
Vegetation in the pools was scanty but near the mouth of the culverts
or bridges were sedges, *Carex* spp., cattails, *Typha latifolia* L., and
rushes, *Scirpus* spp., were found. Adjacent to the pools were
representatives of bromegrass, *Bromus inermis* Leyss., Canada thistle,
Cirsium arvense (L) Scop., Russian thistle, *Salsola pestifer* A. Nels.,
dandelion, *Taraxacum officinale* Weber, and sweetclover, *Melilotus
officinalis* (L.) Lam..

In more northerly subarctic and arctic areas, rock pools
must be considered. Rock pools have been described in detail by Smith
and Brust (1970).

(5) *Rock pools*

Located in tundra areas, these were of two types. The first
were rock crevice pools located in a boulder terrain several hundred
m^2 in size. Extensive, deep, macro-riving of the exposed bedrock by

frost action has produced a series of large rock pools which interrupt the vegetation cover at irregular intervals. Crevices between the heaved bedrock reached depths of 1 m or more and much of the frost heaved zone lay below the surface level of the surrounding terrain. During winter, these crevice pools become completely filled with snow which melts to produce semi-permanent pools of water of varying sizes, shapes, depths and exposures. The second type of rock pool is formed when melting snow collects in the depressions of high-lying bedrock outcrops.

Some pools had marginal vegetation consisting of *Salix* spp., *Betula glandulosa* Michx., *Ledum decumbens* (Ait.) Lodd., and *Empetrum nigrum* L.. Much of this vegetation is submersed in June immediately after snowmelt. An alga encrusts rock surfaces in many pools.