QUAESTIONES ENTOMOLOGICAE

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CONTENTS

OBSERVATIONS ON THE BIOLOGY OF THE ADULT FEMALE MOSQUITOES (DIPTERA:CULICIDAE) AT GEORGE LAKE, ALBERTA, CANADA

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The seasonal distribution of the more important mosquito species is discussed. No species was found to be particularly abundant inside buildings and mosquitoes did not appear to enter buildings to digest their blood meals, but appear to digest these near the feeding site. A significant difference was found between the occurrence of certain species at the lake shore and in the forest. Mosquitoes were found to be relatively inactive when in stages II-IV of Christophers and 3-5 of Sella of the gonotrophic cycle. Retention of eggs by parous females was found to be widespread and to occur in 7% of the parous females.

A key to the adult female mosquitoes of central Alberta is given.

During studies comparing the effectiveness of different mosquito sampling methods at the George Lake field site, in 1965, 1966 and 1967, a number of observations on the biology of the adult female mosquitoes was made. As these observations were incidental to the main study, they are somewhat superficial, but I believe they are worth recording as relatively little is known about the biology of mosquitoes in this area.

The methods of collection and the study area are described elsewhere (Graham, 1969).

NOTES ON THE IDENTIFICATION OF AND KEY TO THE ADULT FEMALES OF CENTRAL ALBERTA SPECIES OF MOSQUITOES

No key to mosquitoes was found to be completely satisfactory for the identification of the adult female mosquitoes taken at George Lake. I, therefore, constructed a key, based largely on the works of Barr (1958), Carpenter and LaCasse (1955), Rempel (1953) and

Vockeroth (1954b), which includes all species of mosquito recorded from Edmonton, George Lake and Flatbush. It includes most if not all species of mosquito likely to be found in the parkland and boreal forest regions of the province. Fig. 1 illustrates characteristics used in the key. This key may prove useful until such time as a complete taxonomic study of Alberta species of mosquitoes is carried out. Such a study is required before a full understanding of this mosquito fauna can be achieved.

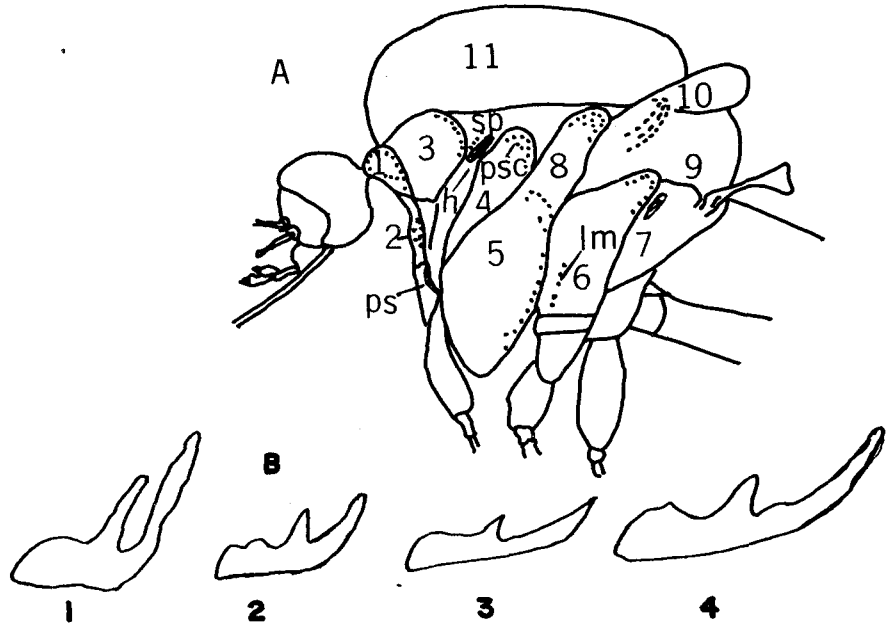

FIG. 1. A. Lateral view of a generalized mosquito thorax. (After Steward and McWade, 1961).
B. Claw characters of *Aedes* species (from Vockeroth, 1954b).

KEY A.

1.	Pronotum	7.	Metepisternum
2.	Proepisternum	8.	Prealar area
3.	Post pronotum	9.	Postnotum
4.	Mesanepisternum	10.	Scutellum
5.	Sternopleuron	11.	Mesonotum
6.	Mesepimeron		
h.	Hypostigial scale patch	lm.	Lower mesepimeral bristles
ps.	Post coxal scale patch	psc.	Post spiracular bristles
sp.	Spiracular bristles		

KEY B.

1. *Aedes excrucians*
2. *A. fitchii*
3. *A. riparius*
4. *A. flavescens*

Keys to the adult female mosquitoes of central Alberta

Key to Genera. –

1. Palps almost as long as proboscis; scutellum rounded ... *Anopheles earlei*, p. 316
– Palps short, less than 1/3 length of proboscis; scutellum trilobed 2
2. (1) Spiracular bristles present ..... *Culiseta*, p. 316
– Spiracular bristles absent 3
3. (2) Post spiracular bristles present; tip of abdomen pointed ..... *Aedes*, p. 322
– Post spiracular bristles absent; tip of abdomen rounded 4
4. (3) Wings with many pale scales, wing scales broad ..... *Coquillettidia perturbans*, p. 322
– Wing scales all dark and narrow ..... *Culex*, p. 322

Key to Culex species (from Rempel, 1953)

1. Tarsal segments ringed with white ..... *tarsalis*, p. 322
– Tarsal segments not ringed with white 2
2. (1) White bands on apices of abdominal terga ..... *territans*, p. 322
– White bands on bases of abdominal terga ..... *restuans*, p. 322

Key to Culiseta species

1. Hind tarsal segments ringed with white 2
– Hind tarsal segments not ringed with white 5
2. (1) Wing scales forming conspicuous spots 3
– Wings without conspicuous spots 4
3. (2) Tarsal white rings broad; very large species ..... *alaskaensis*, p. 316
– Tarsal white rings narrow ..... *incidens*, p. 320
4. (2) Abdominal pale bands on bases of terga only, white in color ..... *C. morsitans dyari*, p. 321
– Abdominal pale bands on both apices and bases of terga, usually pale yellow brown in color ..... *C. sylvestris minnesotae*, p. 321
5. (1) Costa of wing with mixed pale and dark scales ..... *inornata*, p. 320
– Costa with dark scales only ..... *impatiens*, p. 320

Key to Aedes species (based on Vockeroth, 1954b)

1. Hind tarsal segments ringed with white 2
– Hind tarsal segments not ringed with white 11
2. (1) Tarsal white rings on both apices and bases of tarsal segments 3
– Tarsal white rings on bases of tarsal segments only 5
3. (2) Wings with both dark and light scales on most veins 4
– Wing scales entirely dark ..... *canadensis*, p. 325
4. (3) Dark and light scales equally distributed on veins ..... *campestris*, p. 324
– Third vein (R4+5) with more dark scales than 2nd (R2+3) or 4th(M) ..... *dorsalis*, p. 325
5. (2) Tarsal white rings very narrow, ¼ or less than length of segment ..... *vexans*, p. 324

– Tarsal white rings broader, at least 1/3 of length of segment 6
6. (5) Large yellow species; abdominal terga almost completely yellow scaled; tarsal claw as in Fig. 1B 4 ..... *flavescens*, p. 326
– Not as above, abdominal terga with abundant dark scales 7
7. (6) Tarsal claw large, main claw almost parallel to accessory tooth and slightly sinuate, Fig. 1B 1 ..... *excrucians*, p. 325
– Tarsal claw smaller, not sharply bent beyond tooth 8
8. (7) Mesonotum with some contrasting markings; tarsal claw with long accessory tooth, Fig. 1B 2 9
– Mesonotum almost uniform yellow brown; tarsal claw with short accessory tooth, Fig. 1B 3 ..... *riparius*, p. 327
9. (8) Palps and torus with some white scales; lower mesepimeral bristle 1, 2 or absent ..... *fitchii**, p. 325
– Palps and torus usually without white scales; lower mesepimeral bristles 3 or more 10
10. (9) Palps lacking hairs on basal half of apical segment at inner edge ..... *increpitus**, p. 326
– Palps with hairs on basal half of apical segment at inner ventral edge ..... *stimulans**, p. 327
11. (1) Fore coxa with a patch of brown scales on anterior surface; small species ..... *cinereus*, p. 324
– Fore coxa with patch of white scales on anterior surface 12
12. (11) Wing scales distinctly bicoloured 13
– Wing scales all dark or with pale scales restricted to base of costa 14
13. (12) Wings with pale and dark scales intermixed, dark predominating; lower mesepimeral bristles usually present ..... *niphadopsis*
– Wing veins alternating black and white scaled; lower mesepimeral bristles absent ..... *spenceri*, p. 327
14. (13) Post-coxal scale patch present 15
– Post-coxal scale patch absent 21
15. (14) Hairy species, postpronotum with setae scattered over posterior half ..... *impiger*
– Less hairy species, postpronotal setae restricted to a single or irregular double row along posterior margin 16
16. (15) Sides of mesonotum silvery grey; base of costa with numerous white scales in a conspicuous patch 17
– Sides of mesonotum yellow or dark; base of costa with only a few or no white scales 19
17. (16) White scales on costa covering basal 1/7 ..... *cataphylla*, p. 325
– White scales on costa restricted to extreme base 18
18. (17) Sternopleuron with scales extended to anterior angle; mesonotum with numerous white scales giving a "frosted" appearance, medium strip indistinct ..... *trichurus*, p. 327
– Sternopleuron with scales extending half way to anterior angle; mesonotum with distinct median brown stripe ..... *implicatus*, p. 326

*Adult females of these species cannot be distinguished with certainty.

19. (16) Bristles of scutellum and mesonotum black; postmetasternal membrane with 15 or more scales ..... *pionips*, p. 326
– Bristles of scutellum and mesonotum yellow or bronze; postmetasternal membrane bare or with less than 12 scales 20
20. (19) Base of costa with distinct patch of white scales ..... *hexodontus*, p. 326
– Base of costa with no or few scattered white scales at most ..... *punctor*, p. 327
21. (14) Hypostigial scale patch present ..... *pullatus*, p. 327
– Hypostigial scale patch absent 22
22. (21) Scales on sternopleuron extended to anterior angle; mesepimeron scaled to near lower margin; mesonotum with contrasting dark lines 23
– Scales of sternopleuron extended half way to anterior angle; lower 1/3 of mesepimeron bare; mesonotum usually uniform yellow brown ..... *intrudens*, p. 326
23. (22) Bristles of scutellum and mesonotum bright yellow; abdominal white bands indistinct or absent ..... *diantaeus*, p. 325
– Bristles of scutellum and mesonotum black or bronze; abdominal white bands distinct 24
24. (23) Lower mesepimeral bristles present ..... *communis*, p. 325
– Lower mesepimeral bristles absent ..... *sticticus*, p. 327

Notes on identifications of adult females. – The characters given in the key should enable most specimens of adult female mosquitoes from central Alberta to be identified, provided they are not badly rubbed, but some qualifications and explanations are necessary.

Central Albertan species of *Anopheles, Culex,* and *Coquillettidia* present no problems and even badly rubbed specimens of these genera can usually be determined. The only confusion likely in *Culiseta* is that rubbed specimens of *C. sylvestris minnesotae* Barr may be mistaken for *C. morsitans dyari* (Coquillett). However, a close examination will usually reveal a few pale scales on the apices of the terga.

The genus *Aedes* presents most of the identification problems and all specimens unidentified in this study were in this genus. *Aedes cinereus* Meigen is best distinguished by the brown patch of scales on the fore coxa. A character often given in keys, the absence of white bands on the abdominal terga is unreliable in central Alberta; Carpenter and LaCasse (1955: 266) state that the abdomen of this species is as follows: "First tergite with a median patch of brown scales, a few pale scales intermixed; remaining tergites brown without pale bands or with narrow partial or complete bands"; the specimen they figure has complete bands. Forty four specimens of *A. cinereus* collected at George Lake in 1965 and 1966 were examined. Of these 14 had complete bands, 14 had no bands, and 16 had incomplete bands. Specimens of *A. cinereus* are likely to be confused with small specimens of *Aedes intrudens* (Dyar) which have white fore coxal scale patches, and specimens of *Aedes vexans* (Meigen) which have pale bands on the tarsi.

In the subgenus *Ochlerotatus* the species with pale bands on both apices and bases of the tarsal segments are no problem. The "*stimulans*" group, those with bands only on the bases of the tarsal segments, are difficult to separate. Claw characters distinguish *A. excrucians* (Walker) and *A. riparius* Dyar and Knab from the others. *A. flavescens* (Muller) can only be

confused with *A. riparius* and then only when rubbed. Specimens of *A. fitchii* (Felt and Young), *A. stimulans* (Walker) and *A. increpitus* Dyar are easily separated from other band-legged species by claw characters, but are impossible to distinguish from each other with any certainty. The characters in the key are all unreliable. In this study all doubtful specimens were referred to *A. fitchii* since larval surveys and other work (Happold, 1965a and 1965b; Wada, 1965) have shown this to be by far the most abundant species of the three in central Alberta and the larvae of *A. fitchii* only have been found at George Lake.

Black legged *Ochlerotatus* are a difficult group. *A. punctor* (Kirby) and *A. hexodontus* Dyar occur in two forms: "tundra" type with uniform yellow brown mesonota and "*punctor*" type which have contrasting lines on their mesonota. Wada (1965) considered the best way to distinguish these two species was the presence of a white spot on the base of the costa of *A. hexodontus*, but Jenkins and Knight (1950) state that *A. punctor* "tundra" type may also have a few white scales on the costal base. The criterion I used was – a conspicuous white spot on the base of the costa – *A. hexodontus;* none or only a few scattered white scales on the base of the costa – *A. punctor.*

Vockeroth (1952, 1954b) has discussed the separation of *A. pionips* Dyar from *A. communis* (De Geer). The presence of a postcoxal scale patch in *A. pionips* appears to be the best character. I could find no completely satisfactory way of distinguishing *A. pionips* from *A. punctor* or *A. hexodontus*. The black mesonotal bristles are usually adequate but some specimens of *A. punctor* and *A. hexodontus* have dark bronze bristles. These may be separated with difficulty by the characters given by Beckel (1954).

Specimens of *A. intrudens*, *A. communis*, and *A. sticticus* (Meigen) present some problems of differentiation. *A. intrudens* is the only species whose members lack postcoxal scale patches which normally lack contrasting lines on the mesonotum, but a few individuals have indistinct lines on the mesonotum and closely resemble *A. communis*, and a few of these may lack lower mesepimeral bristles and resemble *A. sticticus.* The scale patch on the sternopleuron which only reaches half way to the interior angle in *A. intrudens* will distinguish these. The presence of lower mesepimeral bristles distinguishes specimens of *A. communis* from those of *A. sticticus* and the bright yellow mesonotal bristles and incomplete abdominal bands distinguish specimens of *A. diantaeus* Howard, Dyar and Knab from other species without a postcoxal scale patch.

DIVERSITY

Twenty nine species of mosquitoes have been recorded from the George Lake field site. Nineteen species were taken in 1965, 27 in 1966 and 25 in 1967. The species found and their relative abundance are shown in Table 1. Pucat (1965) records 38 species of Culicinae from Alberta.

Seven species made up 80% of the 1966 collections. These were: *Culiseta inornata* (Williston), *Aedes excrucians, A. fitchii, A. communis, A. punctor, A. riparius* and *A. vexans*. This preponderance of a few species was expected from the work of Williams (1964) and has been recorded in northern mosquitoes by Happold (1965a, 1965b) in Alberta, and by Skiersca (1965) in Poland, as well as by other authors elsewhere.

Table 1. Mosquito species collected at George Lake in 1965, 1966 and 1967, with their relative abundance.

Genus *Anopheles* Meigen, 1818
- *A. earlei* Vargas, 1943 c

Genus *Culiseta* Felt, 1904
- Subgenus *Culiseta* Felt, 1904
  - *C. alaskaensis* (Ludlow), 1906 fc
  - *C. inornata* (Williston), 1893 a
- Subgenus *Culicella* Felt, 1904
  - *C. sylvestris minnesotae* Barr, 1957 fc
  - *C. morsitans dyari* (Coquillett). 1901 p

Genus *Culex* Linnaeus, 1758
- Subgenus *Culex* Linnaeus, 1758
  - *C. tarsalis* Coquillett, 1896 p
- Subgenus *Neoculex* Dyar, 1905
  - *C. territans* Walker, 1856 c

Genus *Coquillettidia* Dyar, 1905
- *C. perturbans* (Walker), 1856 c

Genus *Aedes* Meigen, 1818
- Subgenus *Aedes* Meigen, 1818
  - *A. cinereus* Meigen, 1818 c
- Subgenus *Aedimorphus* Theobald, 1903
  - *A. vexans* (Meigen), 1830 Va
- Subgenus *Ochlerotatus* Lynch Arribalzaga, 1891
  - *A. canadensis* (Theobald), 1901 r
  - *A. cataphylla* Dyar, 1916 p
  - *A. communis* (De Geer), 1776 c
  - *A. diantaeus* Howard, Dyar & Knab, 1913 p
  - *A. dorsalis* (Meigen), 1830 p
  - *A. excrucians* (Walker), 1856 Va
  - *A. fitchii* (Felt & Young), 1904 a
  - *A. flavescens* (Muller), 1764 fc
  - *A. hexodontus* Dyar, 1916 r
  - *A. implicatus* Vockeroth, 1954 c
  - *A. intrudens* Dyar, 1919 fc
  - *A. pionips* Dyar, 1919 fc
  - *A. pullatus* (Coquillett), 1904 r
  - *A. punctor* (Kirby), 1837 a
  - *A. riparius* Dyar & Knab, 1907 c
  - *A. spencerii* (Theobald), 1901 p
  - *A. sticticus* (Meigen), 1838 fc
  - *A. stimulans* (Walker), 1848 p
  - *A. trichurus* (Dyar), 1904 p

Key

Va – Very abundant	fc – Fairly common
a – Abundant	r – Rare
c – Common	p – Present

The coefficient of diversity (Fisher *et al.*, 1943) was 5 ± 0.04 in 1966 and 3 ± 0.02 in 1967, even though the number of species found was almost the same. It appears that this coefficient is a function of sample size as well as population size in a population with a large number of individuals, but a limited number of species. The coefficient of diversity is of use in comparing different areas or traps sampled at the time, as has been shown by Williams (1964) for mosquitoes taken in light traps in several cities in Iowa. It is also useful for comparing captures in the same trap in different years, provided the samples are similar in size or the number of possible species is very large, as in the Lepidoptera studied by Williams (1964).

Genus Anopheles Meigen, 1818

Anopheles earlei Vargas, 1943. – One species of *Anopheles* is recorded from Alberta. This is a member of the widespread "*Anopheles maculipennis*" complex and until recently was confused with a Pacific Coast species, *A. occidentalis* Dyar and Knab. It is distributed over much of the northern U. S. A. and Canada north to Labrador and Alaska. Probably all records of *A. occidentalis* from east of the mountains refer to this species. It is fairly common at George Lake.

There is believed to be only one generation per year in Alberta (Happold, 1965a). Overwintering appears to be by nulliparous females, which hibernate in basements and animal burrows (Shemanchuk, 1965). They leave their hibernation sites in early spring and oviposit soon after. At George Lake adults emerged in late July in 1966 but in late June in 1967. The adult females are long lived and overwintered females could still be found in late July 1966. Dissections for parity rate confirmed the presence of only one generation in 1966 (Fig. 2) but the situation in 1967 was not clear as nullipars predominated in late June. Fig. 3 shows the parity rate in 1967 compared with *Culiseta alaskaensis* (Ludlow) which has only one generation. No hibernation sites were found at George Lake but a series of females taken at animal burrows by Shemanchuk at Rimbey, Alberta in October, 1966, were all nulliparous.

Larvae of this species were found in a sedge meadow along with those of *Aedes vexans* in August 1966 at George Lake.

Genus Culiseta Felt, 1904

This genus is often referred to as *Theobaldia* Neveu-Lemaire, 1902, but this name was not available for this group of insects.

Culiseta alaskaensis (Ludlow), 1906. – This circumboreal species is a typical mosquito of the boreal forest. It overwinters as an adult female and is one of the earliest species to leave hibernation, becoming active as soon as the snow thaws. Though Happold (1965a) states "It is common in Alaska . . . but rare in Alberta and Saskatchewan" it is far from rare at George Lake, and was numerous enough to be a nuisance in May of both 1966 and 1967. In 1966 the emerging generation was seldom encountered, only two adults being taken in July and August. The overwintered generation had disappeared by late June. The females which leave hibernation are voracious biters, but there is no information on whether the newly emerged females bit or not.

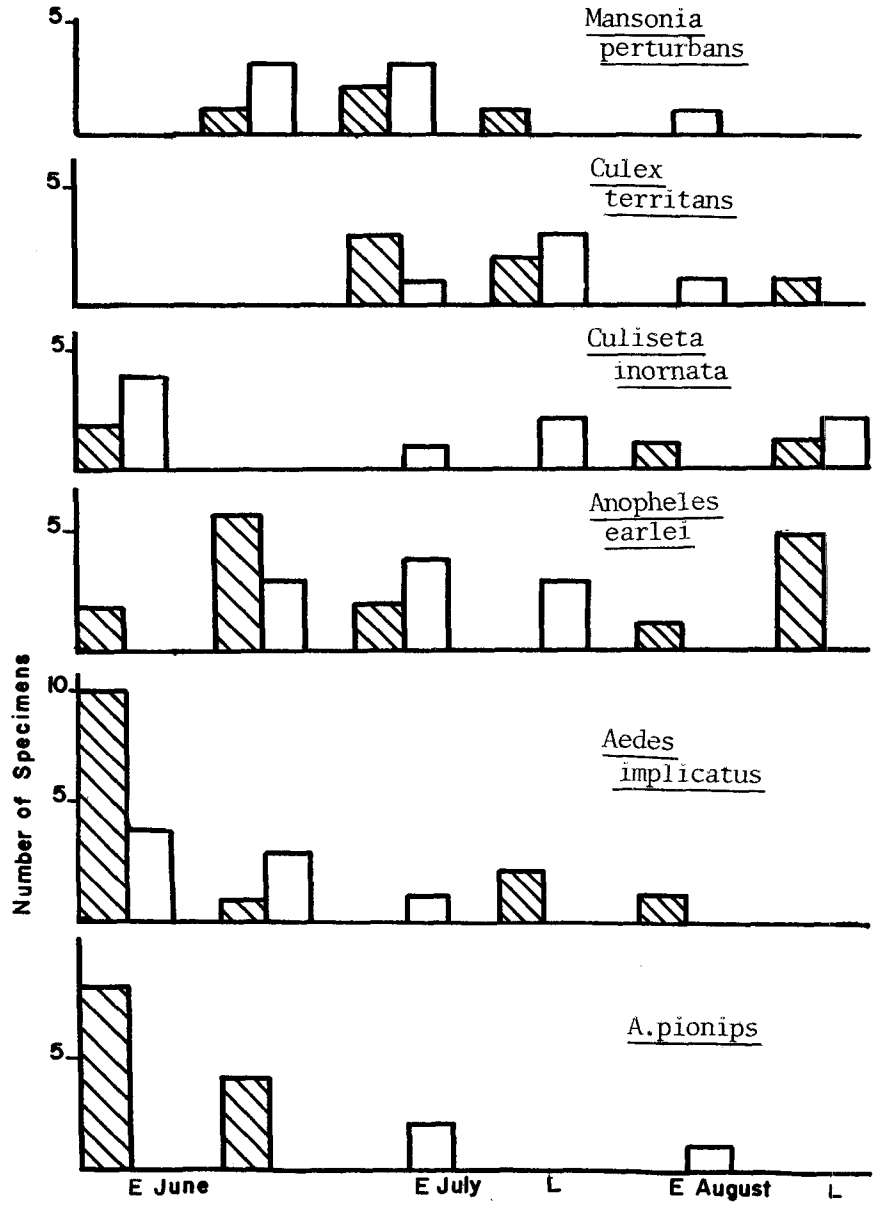

Fig. 2. Seasonal changes in the numbers of parous and nulliparous female mosquitoes at George Lake. June to August 1966.

Shaded area = no. nulliparous E = early; L = late

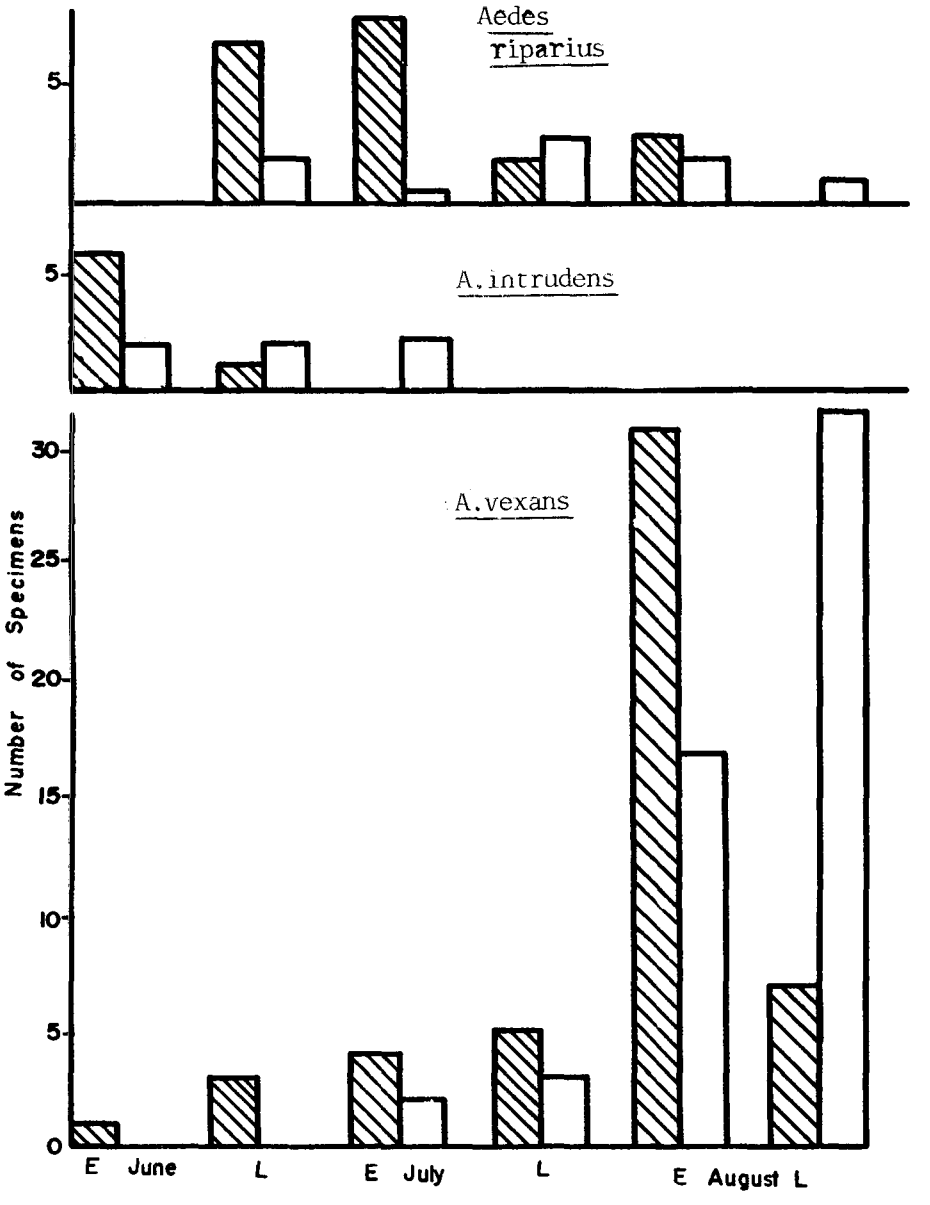

Fig. 2. Continued

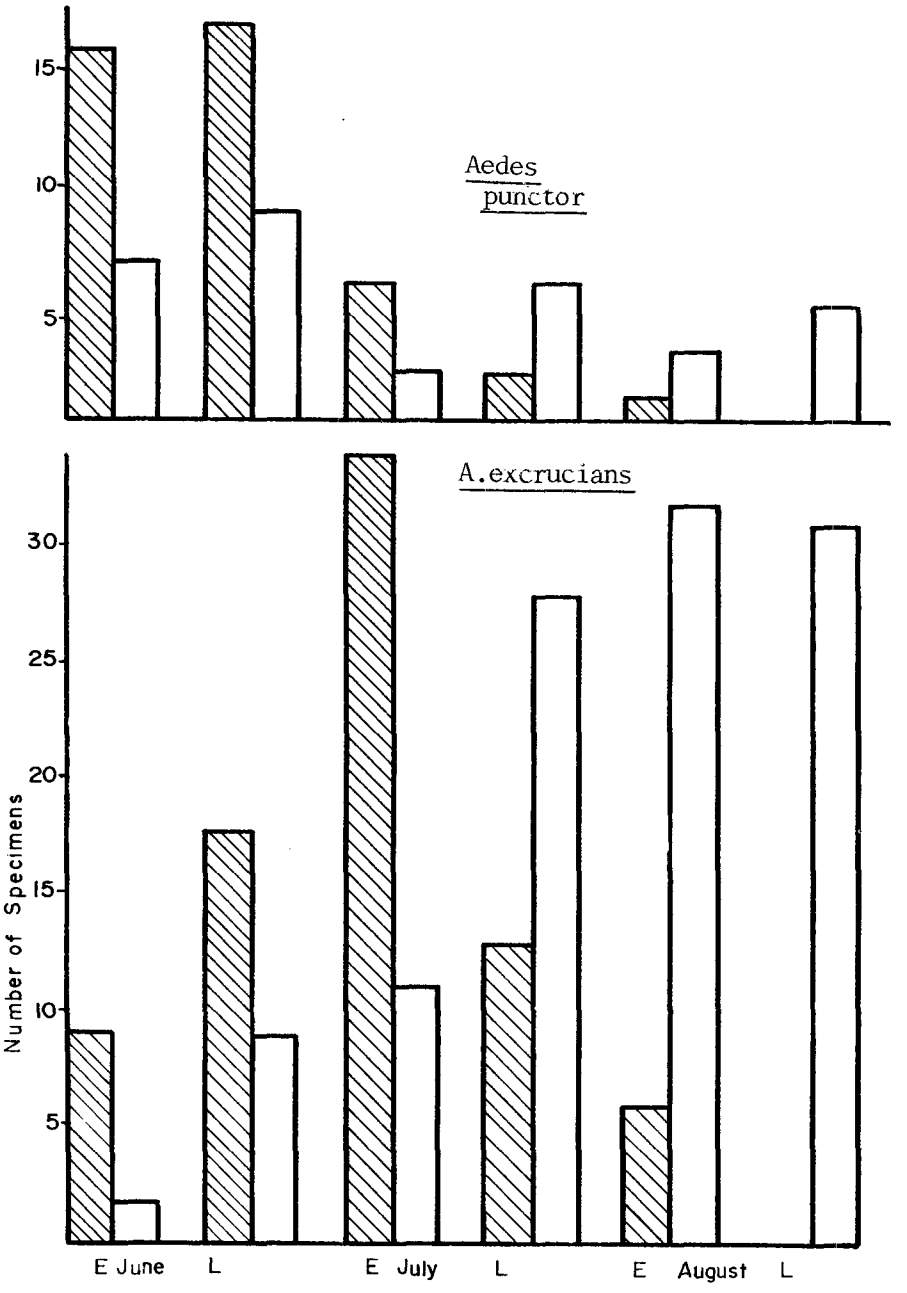

Fig. 2. Continued

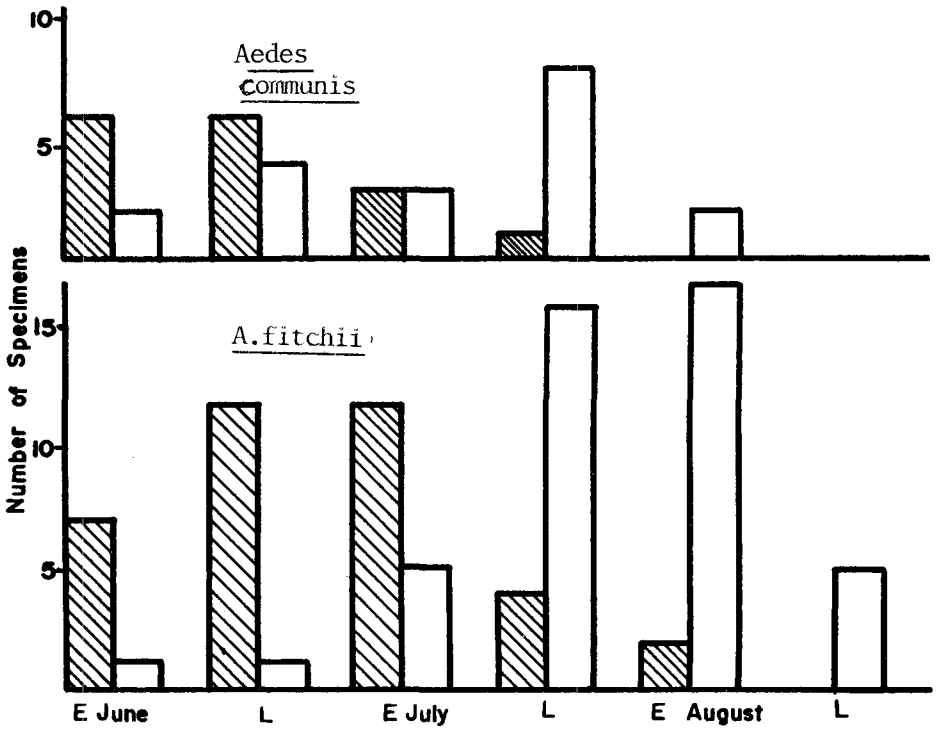

Fig. 2. Continued

Culiseta impatiens (Walker), 1848. – This species has not been found at George Lake, though it occurs at Flatbush (Happold, 1965a).

Culiseta incidens (Thompson), 1869. – This is a western North American species. It has not been found at George Lake but occurs at Flatbush.

Culiseta inornata (Williston), 1893. – Unlike the other Central Albertan species of *Culiseta* this species, which is confined to North America, appears to be a southern rather than a northern or mountain form. It occurs in both forest and open country and has successfully adapted to urban conditions, forming a large proportion of the mosquitoes breeding in Edmonton. It was common at George Lake in 1966, when it was most abundant near the lake shore, but was not taken after the second week in May in 1967. Happold found it to be rare at Flatbush; he found no larvae and very few adult females.

This species overwinters as an adult female, but has several generations in a summer. Wada (1965) found that oviposition in Edmonton continued into mid August. Unfortunately most of the females taken at George Lake were gravid so no confirmation of generation number was possible. Malaise trap captures in 1966 show three peaks, which suggests two generations: one peak in early May, when overwintered females leave hibernation sites, one peak in early August, when the adults resulting from eggs laid by the overwintered females emerge and one in September, which may represent a second generation. Larvae have been found in woodland pools in Edmonton but none have been found at George Lake.

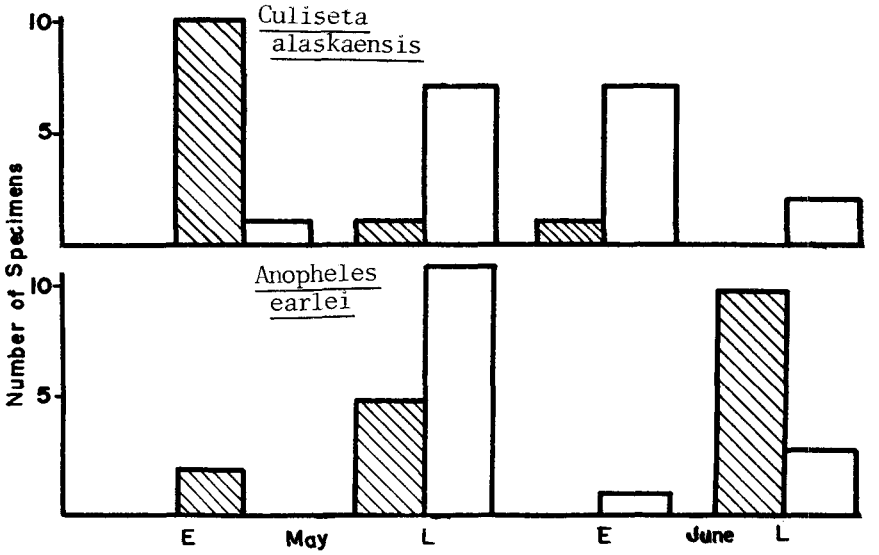

Fig. 3. Changes in the number of parous and nulliparous females of *Culiseta alaskaensis* and *Anopheles earlei* during the spring and early summer of 1967 at George Lake.

Shaded area = no. nulliparous E = early; L = late

Culiseta sylvestris minnesotae Barr, 1957. – Specimens of this species are often confused with specimens of *C. morsitans dyari* (Coquillett). I did not distinguish between the two species in 1965. All 1966 specimens which I preserved were *C. sylvestris minnesotae* but it is possible that a few *C. morsitans dyari* (Coquillett) may have been taken.

C. sylvestris minnesotae hibernates as an adult female, which leaves winter quarters early in the spring, being recorded in the first week of May 1967, before *C. alaskaensis*. The distribution of this species is not yet well known. Stone (1965) records it from Minnesota, Utah, Ontario, New Jersey and Massachusetts. Curtis (1967) states it has been recorded from the borders of British Columbia but not yet in that province. Probably many records of *C. morsitans dyari* (Coquillett) will prove to be *C. sylvestris minnesotae*. Barr (1958) states that females of *C. sylvestris minnesotae* do not appear to take human blood.

Culiseta morsitans dyari (Coquillett), 1901. – This is a holarctic species with a more or less northern distribution. It is not common at George Lake, where only five specimens have been definitely identified. Elsewhere in Alberta I have seen specimens of this species from the Cypress Hills, Edmonton, and Flatbush.

Very little is recorded of the biology of this species in North America. In Europe, Marshall (1938) and Wesenberg-Lund (1921) found that it overwinters as a larva, and unlike other *Culiseta* species it oviposits on wet mud, laying eggs singly instead of in rafts. Howard *et al.* (1915) considered it hibernated as an egg in North America but this does not seem to be so, and there is no study of its life history. Stone *et al.* (1959) suggest that the North American form may be different from the palearctic one. At George Lake in 1967 females appeared in late June, and one dissected was nulliparous.

Genus Culex Linnaeus, 1758

Culex restuans Theobald, 1901. – This species has not been found at George Lake but was taken by Klassen (1959) in Edmonton.

Culex tarsalis Coquillett, 1896. – Two specimens of this common prairie species were taken in 1966. They had probably migrated into the field site from surrounding open lands. This species may be extending its range north in Alberta. Hocking (pers. comm.) informs me that it has increased in abundance in Edmonton in the last ten years.

Culex territans Walker, 1856. – This is a holarctic species which until 1949 was confused with *C. apicalis* Adams in North America. It is probable that all records of *C. apicalis* east of the mountains and north of Utah refer to *C. territans*. Possibly because it rarely bites man, it is recorded as rare in most regional mosquito records (Happold, 1965a, 1965b; Curtis, 1967; Steward and McWade 1961). It is believed to feed mainly on cold blooded vertebrates but Means (1965) has recorded it feeding on man. It was fairly common at George Lake in 1966 and 1967, and was one of the first mosquitoes to leave winter quarters. In 1967 *C. territans* was the first mosquito taken, one specimen being taken in a Malaise trap in April before the snow had completely melted.

From seasonal distribution data it appears that there were two generations in 1966 (Fig. 4), but dissections were too few to confirm, though they do support this.

Genus Coquillettidia Dyar, 1905

This is a mainly tropical genus; two species penetrate into northern regions, one in Eurasia and one in North America.

Coquilettidia perturbans (Walker), 1856. – This widespread North American species was first taken in Alberta at Flatbush by Happold in 1961, (Happold, 1965a) and this is still the only published locality (Pucat, 1964, 1965). I have seen specimens from Edson, and P. Shera (unpublished report) recorded it from Elk Island National Park. At George Lake it was not found in 1965, but was fairly common in 1966 and had just appeared in 1967 when work was stopped. It is probably common and widespread over the forested parts of Alberta. There appears to be only one generation per year and this is the only Canadian mosquito definitely known to overwinter as a larva (Happold, 1965a). As yet no larvae have been found in Alberta.

Adult females of this species are reputed to be fierce biters, but were not numerous enough to be a nuisance at George Lake. Happold (1965a) at Flatbush and Burgess and Haufe (1960) in Ontario found this species abundant in the forest canopy.

Genus Aedes Meigen, 1818

This is the predominant mosquito genus in Alberta and in most northern regions. It includes 70% of the species and 80% of the specimens caught at George Lake. The genus is distributed from the equator to the limit of land in the north and is found on many oceanic islands.

Three subgenera, *Aedes* Meigen, *Aedimorphus* Theobald, and *Ochlerotatus* Lynch Arribalzaga, are found in Alberta.

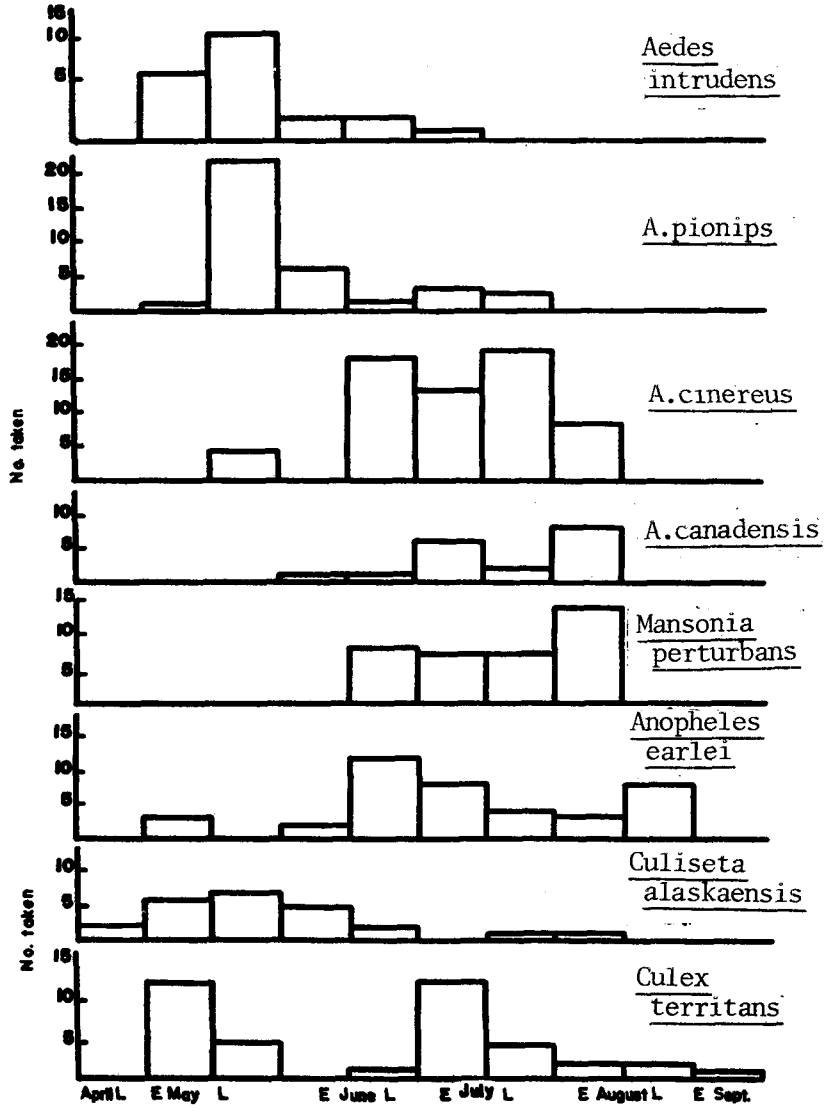

Fig. 4. Seasonal changes in the numbers of some of the less common mosquito species taken by all methods at George Lake. 21 April to 29 September 1966.

E = early L = late

All Alberta *Aedes* species overwinter as eggs and with the possible exceptions of *A. vexans* and *A. dorsalis*, there is only one generation per year. Brust (pers. comm.) informs me that diapause is not obligatory in the eggs of *A. sticticus*, so this species may also be multivoltine if the season permits.

Aedes (Aedes) cinereus Meigen, 1818. – This small holarctic species is common in central Alberta. It is a woodland species which is also common in Poland (Skiersca, 1965). It is common at George Lake, where it is a late-appearing species reaching an adult population peak in July and early August in 1966. I noticed that it is a low flier and bites mainly below the knee and around the ankles.

Aedes (Aedimorphus) vexans (Meigen), 1830. – This appropriately-named species has one of the widest and most unusual ranges of any mosquito, being found in the Palearctic, Nearctic, and Oriental regions and also in the Transvaal, Fiji, Samoa and New Caledonia (Stone *et al.*, 1959). It was very common at George Lake in 1965 and 1966 but was not found there in 1967, though it may have appeared after work stopped. It was taken in June 1966.

Rempel (1953) suggested there were two forms of *A. vexans* in Saskatchewan, a large form in the prairies and a smaller one in the parklands and forest.

A. vexans is a migratory species, capable of flying long distances. Horsfall (1955) records many instances of migration in temperate regions and de Meillon and Khan (1965) have recorded a large migration in Burma. A result of this migratory tendency is that this species is often a major pest species in cities like Edmonton with efficient control programs, as it migrates in from breeding sites which may be several miles from the city. Clark and Wray (1967) have studied the influx of *A. vexans* into Des Plaines, Illinois, and provided a method of predicting invasions.

A. vexans is a late emerging species with a 1966 population peak in late summer. The adult females continued well into September 1966 and larvae were taken in late August. Stage *et al.* (1938) recovered a marked female 55 days after release.

In the southern part of its range the species is multivoltine, but the number of generations in northern parts is not clear, as the eggs do not hatch simultaneously. Some may require several floodings before hatching (Horsfall, 1955), giving rise to broods. Gjullin *et al.* (1950) found that eggs remained viable for three to four years if kept moist.

Nullipars were found from June to the end of August 1966 and predominated up to late August, indicating that emergence took place in June, July, and early August, but there was no evidence of more than one brood.

Subgenus Ochlerotatus Lynch Arribalzaga, 1891

This is the dominant subgenus in northern regions, but also occurs in the tropics. In North America this subgenus extends further north than any other culicid. Two species, *A. nigripes*, and *A. impiger*, occur within 500 miles of the pole. Nineteen species have been recorded at George Lake, and Pucat (1965) records 25 from Alberta.

Aedes campestris Dyar and Knab, 1907. – This species has been recorded at Edmonton (Klassen, 1959; Wada, 1965), but not yet at George Lake.

A. canadensis (Theobald), 1901. – This species is widespread in the forested parts of North America. It is not common at George Lake. Rempel (1950) found it to be fairly common in the aspen grove parkland of Saskatchewan. It is a late emerger. At George Lake it appeared at the end of June in both 1966 and 1967.

Aedes cataphylla Dyar, 1916. – This holarctic species is confined to western Northern America in the Nearctic Region (Stone, 1965). It is not common at George Lake, but is often a major pest species in Edmonton (Klassen, 1959; Klassen and Hocking, 1963). It is one of the first species to emerge and Klassen found emergence completed by 19 May, 1958, at Edmonton.

Aedes communis (De Geer), 1776. – This is an important woodland species with a circumboreal distribution and is a well known pest species in Europe and North America. Chapman and Barr (1964) have described a subspecies *A. communis nevadensis*, from the western U. S. A. and two larval forms of the typical subspecies. All larvae examined from Alberta belonged to the eastern form. Hocking (1954) described an autogenous form from Churchill on Hudson Bay in which autolysis of the flight muscles takes place. The species is common at George Lake.

It is a fairly early emerging species; in 1966 a population peak of adult females occurred in early June. Nullipars predominated to late June, indicating that some emergence took place up to then.

Aedes diantaeus Howard, Dyar and Knab, 1917. – This species has a wide distribution in the boreal forests of the old and new worlds, but it is seldom abundant (Vockeroth, 1954b). In Alberta it has only been recorded from Flatbush (Happold, 1965a; Pucat, 1964). A single specimen was found at George Lake in 1966.

Aedes dorsalis (Meigen), 1830. – This species occurs in the grasslands of the Palearctic and Nearctic regions. It is abundant in southern Alberta but uncommon north of Edmonton. One specimen was taken at George Lake in 1965.

Khelevin (1958) has shown that diapause in the egg of this species is facultative and it can have several generations per year. Like *A. vexans* it is a migratory species (Horsfall, 1955).

Aedes excrucians (Walker), 1856. – This is a holarctic woodland species with a somewhat more southerly distribution than *A. communis*. Together with *A. vexans*, it was one of the two most abundant species at George Lake in 1965 and 1966. It was also abundant in 1967, but work stopped before it reached population peak. It is a fairly early emerger, first appearing in the last week in May 1966 but not till the second week in June 1967. The emergence period appears to be prolonged as nullipars predominated until mid July and could still be found in early August 1966. The adult females were found up to the end of August but none were taken in September 1966. Matheson (1944) records a single instance of larvae being found in September in New York. It is a persistent biter, and is a major pest species in central Alberta.

Aedes fitchii (Felt and Young), 1904. – This species is confined to North America, where it has the same range as *A. excrucians*. It is common in central Alberta. At George Lake it appeared in early June 1966. Nullipars predominated until mid July and were found till mid August, indicating a prolonged emergence period. Adult females were taken up to the end of August but were not taken in September either in 1965 or in 1966.

It is an important pest species in central Alberta.

Larvae were found in a pool in a spruce grove on the western fence of the George Lake field site along with those of *A. implicatus* in May 1966.

Aedes flavescens (Muller), 1764. – This species occurs in grassland areas of Eurasia and North America. It is common in central Alberta and fairly common at George Lake. Specimens taken on the field site had probably migrated in as it is an open country species. Hearle (1929) considered it to be the most numerous mosquito on the Canadian prairies. Happold (1965a) did not find it in the forest at Flatbush but found it common in an alfalfa field.

Adult females were taken from early June to mid August 1966 at George Lake. Nullipars were found till early July. A single male was taken in June 1967, when females were more abundant than in 1966.

Aedes hexodontus Dyar, 1916. – This tundra and open country species was first recorded from Alberta by Wada in 1964 at Edmonton (Wada, 1965). It was not common at George Lake. It is an early species and was not found after June in either year.

Aedes implicatus Vockeroth, 1954. – This is a boreal forest species, confined to North America, and occurs north almost to the tree line. It is locally common in central Alberta, being common at George Lake but rare at Flatbush. In late May and early June 1967 this species was the most abundant *Aedes* at George Lake.

It is an early emerger, the adult females reaching a population peak in mid June in both 1966 and 1967. There was some indication that a second brood occurred in late July 1966, as pars predominated in late June and early July, but the three specimens dissected in late July and early August were nulliparous. In 1967 only nullipars were taken in May but pars predominated in late June and the numbers taken began to decline in mid June. Nielsen and Rees (1961) believed this to be a short lived species; if so, then second broods are needed to account for nullipars occurring in late summer.

In early May 1966 larvae were found in pools in ruts in the road near the campsite and in a pool on the western boundary along with those of *A. fitchii*.

Aedes increpitus Dyar, 1916. – This species has been taken at Edmonton by Klassen and Wada, but has not yet been found at George Lake.

Aedes intrudens Dyar, 1919. – Another species with a circumboreal distribution, it was common at Flatbush and relatively rare at George Lake in 1966, but common there in 1967.

It is an early species, with a population peak in late spring and only pars were taken in July 1966. Happold recorded it as the most important *Aedes* species in buildings at Flatbush. At George Lake only one specimen was taken in the trailer in 1966 but it was prominent indoors in spring 1967. Matheson (1944) writes of *A. intrudens*: "Dyar states that this species readily invades houses, but I have never taken them in houses though I have found them abundantly in wooded areas throughout the season."

Aedes pionips Dyar, 1919. – This Nearctic species is found in Canada and the western U. S. A. It is rare at George Lake.

It is generally considered to be a late emerger (Carpenter and LaCasse, 1955) but at George Lake in 1966 the population peak appeared to be in early summer, adult females continued into August, nullipars were found in late July.

Aedes pullatus (Coquillett), 1904. – This species is confined to the western mountains and to the Ungava peninsula and South Baffin Island in North America. It also occurs in Europe, where it is not a mountain species. In Alberta it is common in the Rocky Mountains. Klassen and Wada did not find it at Edmonton but in some years it is common there (Hocking, pers. comm.). It was rare at George Lake, and only found there in late May and early June.

Jenkins and Knight (1950) found it to be one of the most abundant species at Great Whale River on the east coast of Hudson Bay and Vockeroth (1954b) states that the eastern forms may be different from the western, though no morphological differences could be found.

Aedes punctor (Kirby), 1837. – This is an important woodland species with a holarctic distribution. It is a major pest species in both North America and northern Eurasia. It is common in central Alberta, being the major black-legged *Aedes* species at both George Lake, Edmonton and Flatbush.

In 1966 adult females were taken from late May into September, the population peak being in early June. In 1967 this species reached its peak somewhat later than *A. implicatus,* becoming the most abundant species in the third week in June. In 1966 there was a second peak in August, which may have signified a second brood, but the few dissections done at this time did not confirm this, the individuals examined being mainly parous. Nullipars predominated until early July and were found until mid August; probably some emergence took place in each summer month in 1966.

Aedes riparius Dyar and Knab, 1907. – This species occurs in western North America and northern Eurasia. It is mainly an open country species but also occurs in woodlands. It is common in central Alberta.

In 1966 it was not found until late June when it occurred in fairly large numbers, which possibly indicates it did not breed in the area. Nullipars predominated in June and July and some were found in August. In 1967 this species was taken in late May and was the most abundant band-legged *Ochlerotatus* species till the end of June when *A. excrucians* began to reach peak emergence.

Aedes spencerii (Theobald), 1901. – This is a prairie species, confined to western North America; it is among the most numerous species in southern Alberta but rare north of Edmonton. One specimen was taken at George Lake in August 1966 and several in late May 1967.

A. sticticus (Meigen), 1838. – This is a holarctic species which extends its range south to the Gulf of Mexico in North America. It is locally common in central Alberta being fairly common at George Lake and rare at Flatbush.

Adult females were taken from late May to the end of July and nullipars to mid July in 1966.

Aedes stimulans (Walker), 1848. – This species has much the same range as *A. fitchii*. It is common over much of the forest country of Canada, but appears to be rare in central Alberta. Only four specimens have been definitely identified at George Lake and Happold did not find it at Flatbush.

Aedes trichurus (Dyar), 1904. – This is a woodland species found in the northern U. S. A. and southern Canada. In Alberta it occurs as far north as Beaverlodge (Rempel, 1950). It was rare at George Lake.

SEASONAL DISTRIBUTION

Happold (1965b) discussed the seasonal distribution of mosquitoes at Flatbush, where most of the important species found at George Lake occur, and the George Lake findings are in agreement with his.

Fig. 5 shows the 1966 distribution of the commoner species in Malaise trap catches corrected to 100 hours running time.

The mosquito population showed three peaks in 1966: the first in early May when the overwintering females left hibernation; one in early July, representing the peak population of *Aedes* species; and the third in early August formed by the emergence of those females which enter hibernation and second broods of *Aedes*. This peak was probably much more pronounced in 1965, when weather conditions favoured second broods.

In 1965, adults of *Anopheles intrudens* and pars of *Anopheles earlei* were taken in August. This was almost certainly the result of weather conditions in 1965. Happold (1965a) noted that in 1961 adults of *Anopheles earlei* survived for a longer period than in 1962. During 1961 the weather conditions were like those in 1965. The adults of other species may exhibit increased longevity as a result of favorable climatic conditions.

In all three years *Aedes* mosquitoes became abundant each spring approximately at the same time as the poplars flushed.

MOVEMENT INTO BUILDINGS

Unlike tropical areas where disease transmission inside human dwellings is important, there is relatively little information from North America on the movement of mosquitoes into buildings. Matheson (1944) mentions a few species as persistent house enterers and Happold (1964b) has recorded the species he collected indoors at Flatbush.

During June, July, and August 1966 and in May and June 1967 special captures were carried out in a partially screened trailer at George Lake. In 1966, 112 specimens of 16 species and in 1967, 96 specimens of 12 species were taken in this trailer (Table 2).

In 1966 70% of the indoor catch was composed of *A. punctor, A. excrucians, A. pionips* and *A. communis*, while in 1967 *Anopheles earlei, Aedes punctor* and *A. intrudens* made up the body of the catch. *A. hexodontus* and *A. sticticus* were also prominent in both years.

Happold (1965b) found *A. earlei* and *A. intrudens* made up 80% of the indoor catch at Flatbush. In 1967 all *A. earlei* found indoors at George Lake were taken in May. This may indicate that the overwintered females enter buildings to feed but that the trailer did not provide a good hibernation site. Elsewhere individuals of this species are known to hibernate in buildings, especially basements. The most striking difference between the George Lake and Flatbush results was the absence of *A. punctor* from indoor captures at Flatbush, although it was one of the most abundant local species. It formed over 30% of the indoor catch at George Lake.

In central Alberta, the entry of mosquitoes into buildings depends more on the environment rather than on specific innate tendency to enter buildings as has been recorded in the tropics, where exophilous and endophilous genera and species are recognized (Holstein, 1954; Muirhead-Thompson, 1951).

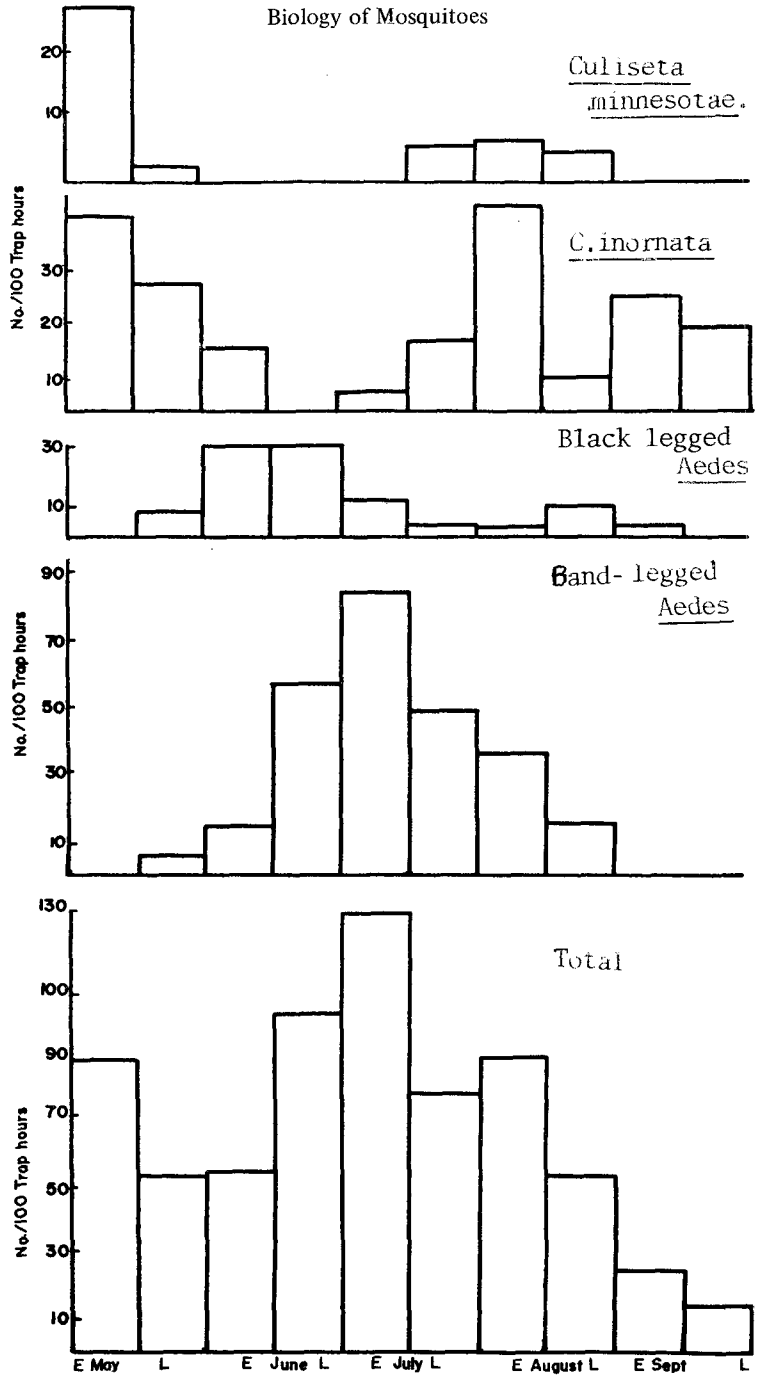

Fig. 5. Seasonal changes in the numbers of mosquitoes caught per 100 trap hours, in Malaise traps, at George Lake. May to September 1966.

E = early L = late

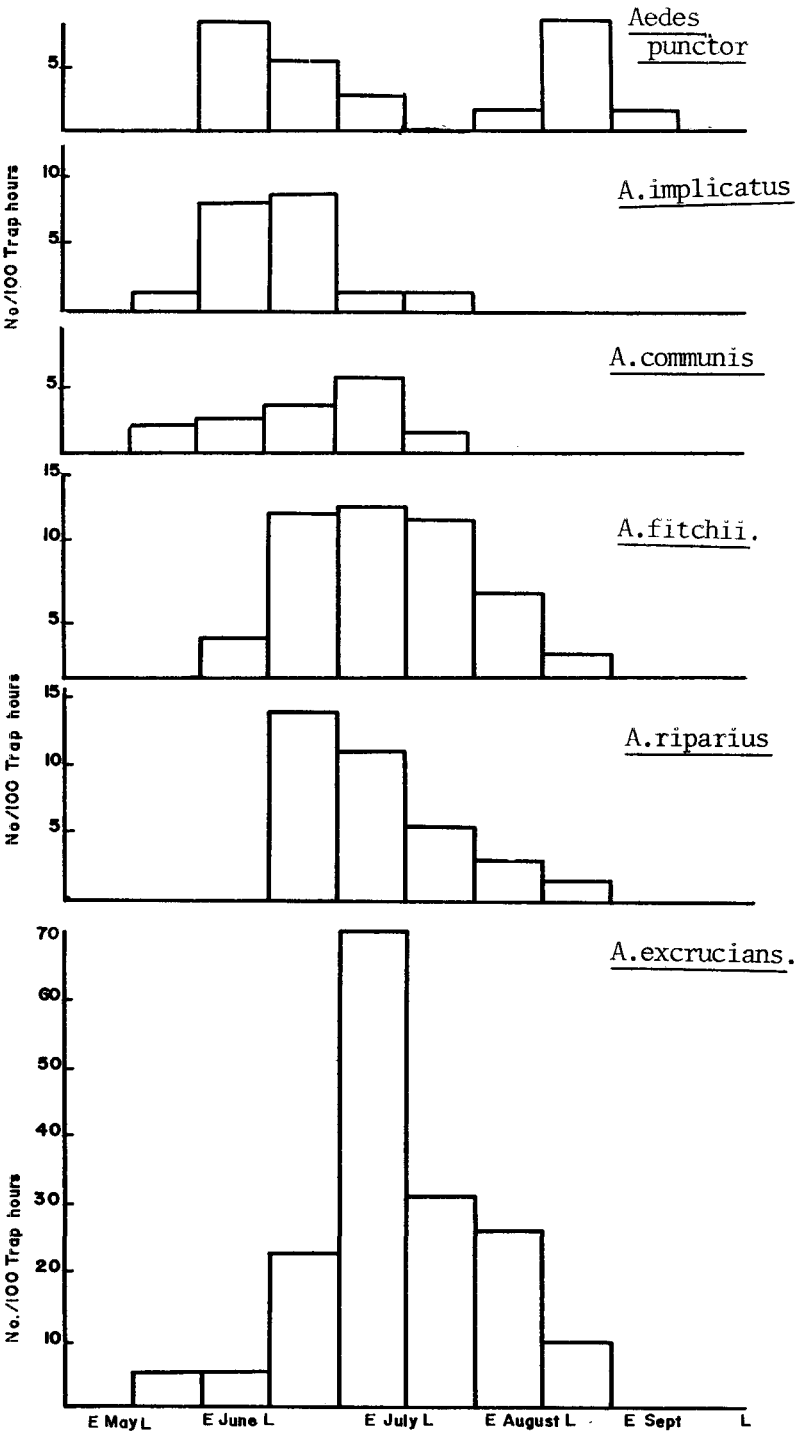

Fig. 5. Continued

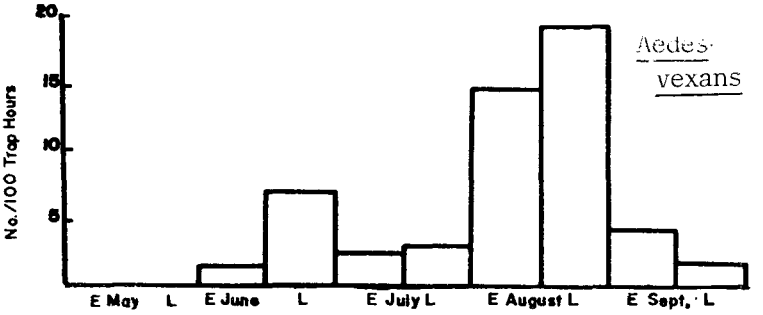

Fig. 5. Continued

Table 2. Mosquito species taken indoors at George Lake in 1966 and in 1967 and numbers taken.

Species	Number Caught			
	1st June – 1st September 1966		16th May – 15th June 1967	
	No.	%	No.	%
Anopheles earlei	1	0.9	25	26.0
Culiseta alaskaensis	0	0	5	5.2
C. inornata	1	0.9	0	0
Culex territans	0	0	3	3.1
Aedes cataphylla	1	0.9	0	0
A. communis	10	8.9	5	5.2
A. diantaeus	1	0.9	0	0
A. excrucians	19	17.0	0	0
A. fitchii	8	7.1	0	0
A. hexodontus	5	4.5	3	3.1
A. implicatus	3	2.7	5	5.2
A. intrudens	1	0.9	9	9.4
A. pionips	14	12.6	2	2.1
A. pullatus	0	0	2	2.1
A. punctor	34	30.4	33	34.4
A. riparius	1	0.9	1	1.0
A. sticticus	9	8.0	3	3.1
A. trichurus	1	0.9	0	0
A. vexans	2	1.8	0	0
Unidentified	1	0.9	0	0
Total	112		96	

DISTRIBUTION WITHIN THE STUDY AREA

Fig. 6 shows the relative abundance of the major species at the lake shore and in the forest in 1966. *Culiseta inornata* and *Aedes vexans* were more abundant in the lake shore traps and *A. excrucians* and *A. fitchii* in the forest traps. The other species were more or less evenly distributed. In 1967 *A. implicatus* was far more abundant in the forest traps.

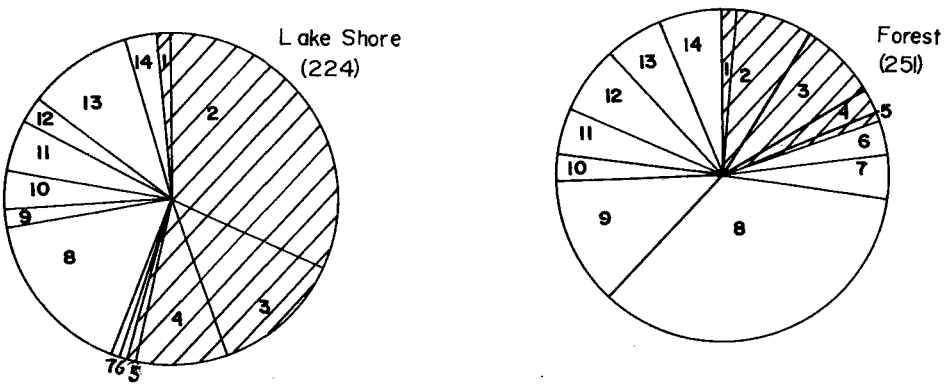

Fig. 6. Relative abundance of mosquito species taken in Malaise traps at the lake shore and in the forest at George Lake in 1966. Shaded – genera other than *Aedes*

1 = *Anopheles earlei*
2 = *Culiseta inornata*
3 = other *Culiseta*
4 = *Culex territans*
5 = *Coquillettidia perturbans*
6 = *Aedes cinereus*
7 = *A. communis*
8 = *A. excrucians*
9 = *A. fitchii*
10 = *A. implicatus*
11 = *A. punctor*
12 = *A. riparius*
13 = *A. vexans*
14 = other *Aedes*

PROPORTION PAROUS

Fig. 2 shows the seasonal distribution of pars and nullipars* in the species taken more abundantly in 1966 and Fig. 3 shows the parity rate for *Culiseta alaskaensis* and *Anopheles earlei*, in the spring of 1967. The distributions in *Aedes excrucians* and *A. fitchii* exactly fit those expected for a univoltine species which overwinters as eggs, i.e. there are two overlapping curves, one in early summer with nullipars predominant and one in late summer with pars predominant. The curve for *Anopheles earlei* in 1966 fits the expected for a univoltine species which overwinters as an adult female, though the number dissected was small. The 1967 curve, however, indicates that considerable emergence took place in late

*Nullipars = those individuals which have not yet laid eggs.
Pars = those individuals which have laid at least one batch of eggs.

June and as this appears rather early for females to enter hibernation it is possible that there was a second generation. The 1967 curve for *Culiseta alaskaensis* is as expected for a species which overwinters as an adult nulliparous female. The picture for the other species is not so clear.

Shelenova (1959) found that in Russia, members of *Aedes* were generally shorter lived than were members of *Anopheles* in the same area, few *Aedes* individuals having passed four gonotrophic cycles, while anophelines often had passed 12 to 29. Carpenter and Nielsen (1965) also found few individuals of *Aedes* with more than four dilations in the ovarian ducts in Utah.

Corbet (1961) and Hamon *et al.* (1964) have studied differences in activity between pars and nullipars, especially with regard to biting activity. Neither found any significant differences, though Hamon *et al.* found a modification of the biting cycle after spraying with insecticide had removed the older portion of the population. They concluded that extrinsic factors, such as light intensity and temperature are more important in controlling activity of adult female mosquitoes than the age of the insect.

OVARIAN DEVELOPMENT AND ACTIVITY

Table 3 shows the stages of Sella and of Christophers in the total catch, in total *Aedes* species and in the commoner species of mosquitoes. By far the greater proportion of all

Table 3. Distribution of the stages in the gonotrophic cycle (stages of Sella and of Christophers) in the more important species of mosquito taken at George Lake in 1966.

	Stage of Sella							
Species	1	2	3	4	5	6	7	% gravid
Anopheles earlei	26	–	–	–	–	–	3	10
Culex territans	12	1	–	1	–	–	3	17
Culiseta inornata	15	1	–	1	2	3	90	80
Coquillettidia perturbans	12	–	–	–	–	–	–	0
Aedes communis	38	–	–	–	–	–	1	2
Aedes excrucians	198	2	3	–	1	1	5	2
Aedes fitchii	95	1	1	–	–	–	–	0
Aedes punctor	83	–	–	1	1	–	–	0
Aedes riparius	36	–	–	–	–	–	–	0
Aedes vexans	120	1	1	1	–	–	7	5
Total *Aedes*	707	13	5	4	3	1	17	2
Total catch	786	18	6	5	4	4	115	12

Table 3. continued.

Species	Stage of Christophers I	II	III	IV	V
Anopheles earlei	16	10	–	1	2
Culex territans	5	7	1	–	3
Culiseta inornata	13	3	–	9	81
Coquillettidia perturbans	–	10	2	–	–
Aedes communis	14	13	–	–	1
Aedes excrucians	51	132	6	1	5
Aedes fitchii	23	57	3	–	–
Aedes punctor	39	33	3	1	–
Aedes riparius	9	22	4	–	–
Aedes vexans	58	53	1	1	7
Total *Aedes*	265	403	22	4	17
Total catch	300	438	27	15	106

females caught were in stages 1 and 7 of Sella and I, II or V of Christophers. Thus they were either unfed or gravid, with few in the intermediate stages. Christophers (1911) and Clement (1963) have shown that the eggs normally develop to stage II of Christophers and then development stops until a blood meal is taken. This agrees with the findings of Carpenter and Nielsen (1965) in Utah, where 89% of the active females examined were in stages I and II of Christophers.

A surprising part of the 1966 findings at George Lake was that very few of the resting older females caught in the trailer were gravid or in intermediate stages. In 1967 rats were kept in unscreened cages in the trailer and many specimens of *Anopheles earlei* as well as *Aedes* species were found in the intermediate stages of Sella and Christophers. This indicates that these mosquitoes enter houses in search of food and if they find it remain to digest their blood meals, but otherwise leave fairly soon. It also indicates their digestion of blood meals is done very close to the feeding site. Carpenter and Nielson (1965) found about half the resting females taken in their study were gravid but found very few intermediates.

These findings indicate that there is very little flight activity during intermediate stages of the gonotrophic cycle. This is most probably because the blood fed or gravid female mosquito is a relatively inefficient flying machine as the weight of the blood meal may exceed the weight of the insect. This little flight activity may apply mainly to woodland species as individuals resting in grassland or tundra are more likely to be disturbed by passing animals. Corbet (1961) found that most individuals engaging in "non-specific activity" were in the early stages of Christophers but Standfast (1965) believed that light trap captures in Australia showed that a considerable part of the population was engaging in "non-specific activity" during the night, interpreted this to mean that there was considerable activity in the intermediate stages of the gonotrophic cycle, but did not record any dissections to support this.

Carpenter and Nielson (1965) report that a fair number of biting mosquitoes had ovaries in stage II of Christophers and were nulliparous. They suggest that this is an indication of autogeny and mention that some of the species in which this occurred have been shown to be capable of autogeny by Chapman (1962).

At George Lake in 1966 and 1967 records were kept of specimens in stage I of Sella and stage III of Christophers. Twenty three were found of which seven were nulliparous, forming 0.007% of all nullipars. These seven consisted of five species: *A. communis, A. fitchii, A. intrudens, A. punctor*, and *A. riparius*. Two of these, *A. communis* and *A. punctor* were included in those found by Carpenter and Nielson (1965) and are mentioned as capable of autogeny by Chapman (1962) but the phenomenon appears to be rarer at George Lake than in Utah where 4% of the biting females had ovaries in stage III of Christophers.

Eighty percent of the females of *Culiseta inornata* taken at George Lake in 1965 and in 1966 were gravid. The reason for this is not known but it could indicate some degree of autogeny. No indication of autogeny in this species had been found in the laboratory.

RETENTION OF EGGS BY PAROUS FEMALE MOSQUITOES AND OTHER OVARIAN ABNORMALITIES

During dissections for parity rate I noticed that several parous females with ovaries of otherwise normal appearance (i.e., they did not have the sac-like appearance of those in females which have just oviposited) had retained eggs in one ovary. The number of eggs retained was usually one but six were found in one *Aedes excrucians*.

Table 4 shows the species and the number in each with retained eggs. This appears to be a widespread phenomenon as it was recorded in ten species of three genera. It is also interesting to note that the percentage of pars with retained eggs in each year was approximately 7%. The slightly higher proportion in August over June, may be due to older multiparous females having a greater tendency to retain eggs over younger pauciparous females; but this will need further study.

In one parous *Aedes punctor* taken in a Malaise trap in late June 1967 there was differential development in the ovaries, one being in stage II and one in stage IV of Christophers.

Table 4. Parous female mosquitoes at George Lake with eggs retained in one ovary.

Species	1965 (August)	1966 (June–August)	1967 (May–June)	Total
Anopheles earlei		1	2	3
Culiseta inornata	2	2		4
C. alaskaensis			1	1
Aedes excrucians		11		11
A. fitchii		1		1
A. flavescens		1		1
A. intrudens	1		1	2
A. punctor		2	3	5
A. riparius		1	2	3
A. vexans	2	5		7
Total	5	24	9	38
Total No. Pars.	67	337	139	543
% Pars. retaining eggs	7.5	7.1	6.5	7.0

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