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THE NATURAL HISTORY OF THE MOSQUITOES OF THE WICHITA

MOUNTAINS WILDLIFE REFUGE

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THE NATURAL HISTORY OF THE MOSQUITOES OF THE WICHITA MOUNTAINS WILDLIFE REFUGE

CHAPTER I

INTRODUCTION

Nature of the Problem

The Wichita Mountains Wildlife Refuge is a semi-natural area composed of rugged, granitic mountains, rounded limestone hills, and extensive intermontane flats. Due to its location, vegetation, physiography, impoundments, unique biota, and semi-arid conditions, it was felt that the area might present a diverse mosquito fauna.

The primary purpose of this investigation was to study the natural history of the mosquitoes of the Refuge. The term natural history as used in this study is in accordance with the views of Bates (1949), who points out that the term denotes a complete fusion of morphology and physiology, in studies which attempt to understand the whole organism.

Studies relative to natural history of mosquitoes are too numerous to list. However, summaries pertinent to mosquito natural history, from various sections of the world, have been presented by such workers as Wesenberg-Lund (1921), Boyd (1927), Bradley and King (1944), Matheson (1944), Seamen (1945), Jenkins and Carpenter (1946), The Tennessee Valley Authority (1947), Natvig (1948), Bates (1949), Jenkins and Knight (1950, and 1952), Haufe (1952), and Horsfall (1955).

Studies relative to the natural history of mosquitoes of the grassland biome are relatively few. Some information relative to the natural history of mosquitoes of the grassland biome has been obtained in connection with studies on species associated with irrigation practices. Such studies have been presented by Keener (1952) who observed the overwintering of Culex tarsalis in western Nebraska, and by Keener and Edmunds (1954) who made observations on the larval growth rates of Aedes dorsalis, Aedes vexans, Aedes nigromaculis, and Culex tarsalis in temporary surface pools on irrigated salt grass pastures in Nebraska. Rapp (1955) showed that Culex tarsalis is a grassland species and is only rarely found in forested areas in Nebraska. Edmunds (1958) presented field observations on the habitats and seasonal abundance of mosquito larvae in irrigated ditches in Scotts Bluff County, Nebraska.

Only a few references have been presented in the literature relative to Oklahoma mosquitoes. The most complete study of the mosquitoes of Oklahoma was made by Rozeboom (1942) who recorded forty species of mosquitoes in the State. Specific reference to the presence of Aedes zoosophus Dyar and Knab and Aedes atropalpus (Coquillett) from the Wichita Mountains Wildlife Refuge was reported in the above study. Roth (1945) reported the occurrence of Psorophora longipalpis in Oklahoma. Griffith (1952) recorded eleven additional species, bringing the total known species for the State to fifty-two.

The study reported herein, began in March, 1958 and continued through February, 1960. Ordinarily several collection trips per month were made to the Refuge, during the course of this study, except during the summer months when full time was devoted to the study. Laboratory facilities were provided in the headquarters area of the Refuge through the courtesy of the director.

Taxonomic studies were prerequisite to other investigations, but the ecology of the larval mosquito habitats, the ecology of adult mosquitoes and the parasites of mosquitoes were given equal attention. Most of the observations presented in this study were made under natural conditions. Only limited laboratory experiments were performed.

Inasmuch as this study was approached from the four distinct facets listed in the above paragraph, it seemes desirable to present each portion of the study as a separate chapter in order to insure coherence and clarity.

Description of the Study Area

By an act of Congress in March, 1907, the Wichita Mountains area became the Wichita National Forest and Game Preserve. In 1935, the area came under the jurisidiction of the Biological Survey of the Department of the Interior, as one of the national wildlife refuges, under the name Wichita Mountains Wildlife Refuge.

The Refuge is a tract of 59,020 acres, embracing the major portion of the Wichita Mountains in southwestern Oklahoma, and lies entirely within Comanche County. This region, which has been described as the "Wichita Mountains Biotic District" by Blair and Hubbell (1938), is distinguished by the presence of interesting ecological mixtures of eastern and western biota, and is an area of transition.

The climate is of the continental type and shows an average yearly temperature of 62.0° F. and an average rainfall of 31.53 inches. The data relative to temperature and precipitation are presented in Table 1 and Figure 1, respectively. Weather data were obtained from Refuge records, prepared in cooperation with the U. S. Weather Bureau.

The mountains are composed of igneous rocks, surrounded by sedimentary formations. The igneous rocks are Pre-Cambrian whereas the sedimentary rocks are mostly Paleozoic. In general, the Proterozoic sediments are overlain by the Cambrian and Ordovician sediments. These are followed by upper Pennsylvanian, which are overlapped by the Permian series. The geology of the Wichita Mountains has been outlined by Harlton (1951) and summarized by Chase et al. (1956)

These are numerous outliers, which are isolated in the plains, reaching heights of as much as 400 to 600 feet above the surrounding terrain. Certain of the higher peaks exceed an elevation of 2,400 feet above sea level, and rise approximately 1000 feet above the plains. The Refuge is characterized by numerous flats or valleys (Map 1).

The Refuge is drained by several creeks which flow to the southeast. The eastern section is drained by Little Medicine and Blue Beaver Creeks. Drainage in the central section is principally by West Cache Creek and its many tributaries. The northwest section is drained largely by Boggy Hollow, Wolf, and Telephone Creeks, whereas the southwestern section is drained by Post Oak and Sandy Creeks. The streams found in the Refuge are intermittent and frequently become pooled during dry periods. Along many of the streams, many small dams have been constructed to form 22 lakes and numerous small pools which comprise approximately 635 acres of the Refuge (Map 1).

Within the Refuge, the grassland is restricted to the valley floors and some of the lower hills. The grasses of the Refuge are typical of the tall grass prairie and the mixed grass plains (Duck and Fletcher, 1945). The dominant species are big and little bluestems (Andropogon gerardii, Andropogon scoparius), Indian grass (Sorghastrum nutans), switch grass (Panicum virgatum), and such short grasses as buffalo grass (Buchloe dactyloides), hairy grama (Bouteloua hirsuta) and blue grama (Bouteloua gracilis).

In the flats along streams there are mesophytic forests in which the dominant species, spotted oak (Quercus shumardii), hackberry (Celtis laevigata var. texana), black walnut (Juglans nigra), American elm (Ulmus americana), wolly buckthorn (Bumelia lanuginosa), and green ash (Fraxinus pennsylvanica var. subintegerrima), are present with other species of less importance.

The lower granitic hills, and most of the south facing slopes of the higher mountains, are covered with an extension of the eastern deciduous forest, which becomes limited by climatic and edaphic factors. The dominant species of this scrubby forest are post oak (Quercus stellata) and blackjack oak (Quercus marilandica). On the north facing slopes the forest appear to be denser and somewhat less xeric. Blair and Hubbell (1938) state that "the post oak-blackjack association is the most extensive association of the Wichita Mountains proper."

The flora of the Wichita Mountains Refuge was studied by Eskew (1938). In this study, Eskew listed 447 species of flowering plants of 248 genera and 75 families.

Penfound (1953) studied the plant communities of a number of Oklahoma lakes. Collections were recorded from five lakes within the Refuge. He pointed out that all of the lakes studied in the Refuge are located in granitic basins and possess excellent plant zonation. The principal aquatic and marsh plants found in the Refuge were cattail (*Typha domingenesis*), pond weed (*Potamogeton nodosus*), lotus (*Neblumbo lutea*), and coontail (*Ceratophyllum dermersum*).

CHAPTER II

TAXONOMY OF THE MOSQUITOES

Materials and Methods

Early in the study, in order to facilitate a survey of the larval habitats and adult resting sites, the Refuge was conveniently divided into four study areas (Map 2). Study Area III is completely restricted to the public, and presented the most nearly natural area at the Refuge.

Larvae were usually collected with the aid of a white enamel dipper. When collecting larvae from tree holes and rock holes, a large pipette equipped with a rubber suction bulb was employed. Except for the larvae of *Anopheles barberi*, which were collected as were the larvae of other tree hole breeders, Anopheline larvae were collected by skimming the surface of the breeding water with a small flat white enamel tray.

In most instances, five dips constituted a sample at each larval site. When collecting the larvae of such species as *Psorophora ciliata* and *Psorophora signipennis*, whose larvae often hide underneath debris or vegetation, larvae were collected with a pipette as they were seen.

After larvae were collected, they were placed in a small, wide mouth bottle, which was labeled and numbered to correspond to a number on a data sheet.

In the laboratory, the larvae were examined in finger bowls and the total number of larvae collected recorded in the appropriate space on the data sheet. A number of larvae were prepared for preservation by placing the larvae in hot (but not boiling) water after which they were placed in screw cap vials in 75% ethanol. A number of the remaining larvae were reared by standard isolation technique. For example, larvae of Aedes triseriatus were generally reared in the water from which they were collected. During rearing larvae were fed small quantities of ground rabbit pellets. Larval and pupal skins were removed from the isolation vials, stretched, and preserved in 75% ethanol. Adults were removed from isolation vials, and pinned approximately 30 hours after they emerged.

Procedures for the mounting of larvae, larval skins, and pupal cases were essentially those of Carpenter and La Casse (1955).

Many of the adult mosquitoes discussed in this study were reared from larvae and pupae in the laboratory. Identifications were frequently confirmed by comparing the larval skin of an isolated larva with the adult which emerged within the same isolation vial.

Resting adults were collected under bridges, in culverts, storm sewers, houses, barns, hollow logs, trees, garages, restrooms, and on several occasions from an abandoned mine tunnel. Resting collections were made with aspirators, chloroform tubes, and an aerial net. On numerous occasions adults were collected by sweeping the vegetation near breeding sites with a standard sweep net.

Biting samples were collected on at least two nights of the week from 7:30 to 8:30 P. M. in the headquarters area of the Refuge, during the summer months. Biting females were also collected whenever encountered in the field.

A standard New Jersey type mosquito light trap was operated in the headquarters area of the Refuge from June 1, 1959 through November 6, 1959. A portable light trap of the same type, which operated on a six volt battery, was operated in various sections of the Refuge where electrical current was not available (Map 4). Operation of this trap began June 1, 1959 and terminated September 1, 1959. On alternate days, the battery used in the operation of this trap was recharged. The portable trap was operated, for the most part, in Area III (Map 3). All adults collected were chloroformed, pinned, labeled, and subsequently identified in the laboratory. Males were identified by mounted terminalia following procedures for the mounting of terminalia which were essentially those of Carpenter and La Casse (1955).

RESULTS

Thirty-three species of mosquitoes, distributed among two subfamilies and ten genera, were recorded for the Wichita Mountains Wildlife Refuge during the course of this study. Species of mosquitoes collected at the Refuge were: (Subfamily Chaoborinae) Chaoborus punctipennis (Say); (Subfamily Culicinae) Anopheles barberi Coquillett, Anopheles crucians Wiedemann*, Anopheles punctipennis (Say), Anopheles quadrimaculatus Say, Toxorhynchites rutilus septentrionalis (Dyar and Knab), Uranotaenia sapphirina (Osten Sacken)*, Culiseta inornata (Williston) Orthopodomyia signifera (Coquillett), Orthopodomyia alba Baker, Mansonia perturbans (Walker)*, Psorophora ciliata (Fabricius), Psorophora howardii Coquillett, Psorophora cyanescens (Coquillett), Psorophora ferox (Humboldt), Psorophora confinnis (Lynch Arribalzaga), Psorophora discolor (Coquillett), Psorophora signipennis (Coquillett), Aedes atlanticus Dyar and Knab or Aedes tormentor D. and K.*, Aedes canadensis canadensis (Theobald)*, Aedes dorsalis (Meigen)*, Aedes nigromaculis (Ludlow), Aedes trivittatus (Coquillett)*, Aedes atropalpus (Coquillett), Aedes triseriatus (Say), Aedes zoosophus Dyar and Knab, Aedes vexans (Meigen), Culex quinquefasciatus Say*, Culex restuans Theobald, Culex salinarius Coquillett*, Culex tarsalis Coquillett, Culex erraticus Dyar and Knab, and Culex territans Walker.

The taxonomic keys are presented here as a ready reference to the mosquitoes of the Refuge. For a more detailed description of the species, the author suggests the use of such taxonomic works as that of Carpenter and La Casse (1955), or of Rozeboom (1942). The morphological structures emphasized for specific identification are unavoidably repetitious in that they appear in keys published by others. It should be pointed out that a number of the key characters are those previously employed by Carpenter and La Casse (1955).

* Species of mosquitoes of which only the adult was recorded.

Taxonomic Keys to the Mosquitoes of the Wichita Mountains Wildlife Refuge

Key to Subfamilies of Culicidae

A. Larvae

A. Antennae prehensile, with long and strong apical spines........... .... Chaoborinae

Antennae not as above .... Culicinae

B. Adults

B. Proboscis absent (Mouth parts not prolonged into proboscis)....... .... Chaoborinae

Proboscis present.................... Culicinae 33

KEY TO LARVAE OF CULICINAE

1. Siphon absent .... (<u>Anopheles</u>)............... 9

   Siphon present 2

2. Distal half of siphon strongly attenuated, adapted for piercing roots of aquatic plants .... <u>Mansonia perturbans</u>

   Distal half of siphon not as above 3

3. Siphon with a pecten 4

   Siphon without a pecten 8

4. Head longer than wide; eighth abdominal segment with a prominent sclerotized plate bearing the comb on its posterior border .... <u>Uranotaenia sapphirina</u>

5. Siphon with a pair of large basal siphonal tufts; comb scales arranged in a single row .... Culiseta inornata

Siphon without a pair of basal siphonal tufts 6

6. Siphon with several pairs of siphonal tufts or single hairs (Culex) 28

Siphon with one pair of median or subapical siphonal tufts 7

7. Anal segment completely ringed by the saddle and pierced on the midventral line by tufts of the ventral brush ..(Psorophora) .. 13

Anal segment not completely ringed by the saddle ..(Aedes) 19

8. Eighth abdominal segment without comb scales, but with lateral plate bearing two spimulose hairs .... Toxorhynchites r. septentrionalis

Eighth abdominal segment with two rows of comb scales; if lateral plate is present, it does not bear hairs ...(Orthopodomyia).... 12

9. Frontal head hair 5-7 small, simple; lateral hair 6 of abdominal segments I-IV plumose .... Anopheles barberi

Frontal head hair 5-7 large,plumose; lateral hair 6 of abdominal segments I-III plumose 10

10. Accessory hair 0 and hair 2 on abdominal segments IV and V both well developed, each with five to nine branches .... Anopheles crucians

Accessory hair 0 absent or rudimentary 11

11. Basal tubercles of inner clypeal hairs 2 separated by at least the diameter of one tubercle .... Anopheles quadrimaculatus

Basal tubercles of inner clypeal hairs 2 separated by less than the diameter of one tubercle .... Anopheles punctipennis

12. Siphonal tuft with 2 to 4 branches and less than three fourths as long as that part of the siphon beyond point of insertion of the tuft. Abdominal segment VIII without a sclerotized plate; pentad hair 3 of eighth abdominal segment, less than half as long as the saddle of the anal segment .... *Orthopodomyia alba*

Siphonal tuft about as long as that part of the siphon beyond point of insertion of the tuft .... *Orthopodomyia signifera*

13. Pecten teeth numerous (about 18 or more), each terminating in a hairlike filament; siphonal tuft represented by a single long hair 14

Pecten teeth few (less than 10), not prolonged into hairlike filaments; siphonal tuft multiple, large, small or obsolete ... 15

14. Lateral hair of anal segment 3 to 4 branched near base .... *Psorophora ciliata*

Lateral hair of anal segment single or forked beyond middle ... . *Psorophora howardii*

15. Siphonal tuft large, multiple, as long as the siphon; siphon small, not inflated .... *Psorophora discolor*

Siphonal tuft small or obsolete, multiple; siphon large, more or less inflated medially 16

16. Upper frontal and lower frontal head hairs 5 and 6 multiple ... . *Psorophora confinnis*

Upper frontal and lower frontal head hairs 5 and 6 single, double or triple 17

17. Upper frontal and lower frontal hairs 5 and 6 with one or more hairs single 18

Upper frontal head hair 5 double, lower frontal 6 double ......
.... <u>Psorophora</u> <u>ferox</u>

18. Antennal and preantennal tufts strongly multiple (antennal tuft usually with 8 to 15 branches) .... <u>Psorophora</u> <u>signipennis</u>

Antennal and preantennal tufts with about 2 to 4 branches, occasionally rebranched toward the tip; sparsely barbed ....
.... <u>Psorophora</u> <u>cyanescens</u>

19. Anal segment completely ringed by the saddle 20

Anal segment not completely ringed by the saddle 23

20. Siphonal tuft with the hairs less than half as long as the basal diameter of the siphon .... <u>Aedes</u> <u>nigromaculis</u>

Siphonal tuft not as above 21

21. Siphonal tuft inserted within the pecten .... <u>Aedes</u> <u>tormentor</u>

Siphonal tuft inserted beyond the pecten 22

22. Comb of the eighth segment with 4 to 9 scales in a row ....
.... <u>Aedes</u> <u>atlanticus</u>

Comb scales not as above .... <u>Aedes</u> <u>trivittatus</u>

23. Pecten with one or more of the distal teeth detached 24

Pecten with all teeth rather evenly spaced 25

24. Siphonal tuft inserted within the pecten .... <u>Aedes</u> <u>atropalpus</u>

Siphonal tuft inserted beyond the pecten .... <u>Aedes</u> <u>vexans</u>

25. Antennae smooth; antennal tuft represented by a single small hair 26

Antennae spiculate; antennal tuft double or multiple 27

26. Lateral hair of the anal segment inserted near the center on posterior border of the saddle; a light colored depression on

either side near the ventral margin of the saddle; larvae light in color .... _Aedes zoosophus_

Lateral hair of anal segment inserted near ventrolateral margin of the saddle, without a light-colored depression on the saddle; larvae dark in color .... _Aedes triseriatus_

27. About 25 comb scales in an irregular double row ... _Aedes dorsalis_

Comb scales in a patch .... _Aedes canadensis_

28. Antennae of nearly uniform shape, with antennal tuft inserted near middle of shaft .... _Culex restuans_

Antennal tuft placed in a constriction near outer third of shaft, the part beyond the tuft more slender 29

29. Siphon with two or three pairs of small sub-dorsal tufts in addition to siphonal tuft; siphon with about eight pairs of siphonal tufts, none of which are more than one-half the length of the siphon .... _Culex erraticus_

Siphon lacking small sub-dorsal tufts 30

30. Upper frontal head hair 5 single (sometimes double), lower frontal 6 usually single; abdominal segments rather evenly pigmented .... _Culex territans_

Upper frontal head hair 5 and lower 6 not as above 31

31. Siphonal tufts inserted in a straight line; lower frontal head hair 6 and upper frontal 5, with 3 or more branches .... _Culex tarsalis_

Siphonal tufts not inserted in a straight line 32

32. Lower frontal head hair 6 usually with five or more branches .... _Culex pipiens_ or .... _Culex quinquefasciatus_

Lower frontal head hair 6 usually with three or four branches

.... _Culex_ _salinarius_

KEY TO ADULT FEMALES

33. Palpi nearly as long as the proboscis ....._Anopheles_............ 41

Palpi much shorter than the proboscis 34

34. Proboscis slender throughout, never curved downward 35

Proboscis stout on proximal half, strongly curved downward on distal half .... _Toxorhynchites_ _r._ _septentrionalis_

35. Wing with the second marginal cell less than half as long as its petiole .... _Uranotaenia_ _sapphirina_

Wing with the second marginal cell at least as long as its petiole 36

36. Spiracular bristles present 37

Spiracular bristles absent 38

37. Post-spiracular bristles present ...._Psorophora_ 52

Post-spiracular bristles absent .... _Culiseta_ _inornata_

38. Post-spiracular bristles present 39

Post-spiracular bristles absent 40

39. Wing scales broad and dense .... _Mansonia_ _perturbans_

Wing scales narrow and not dense .... _Aedes_ 44

40. Mesonotum with narrow longitudinal lines of silvery white scales

.... _Orthopodomyia_ _alba_

or .... _Orthopodomyia_ _signifera_

Mesonotum not as above ....(_Culex_) 58

41. Wings with areas of pale scales 42

Wings with dark scales only 43

42. Wing costa with a pale spot at distal third opposite tip of subcosta; vein 6 with one or two areas of dark scales. Wing veins 3 and 5 entirely dark-scaled; vein 6 with apical half and basal fourth dark-scaled........................ <u>Anopheles punctipennis</u>

Wing costa dark except for a pale spot at the extreme tip vein 6 with three areas of pale scales .... <u>Anopheles crucians</u>

43. Wings without spots of dark scales; setae on scutum at least half as long as width of scutum .... <u>Anopheles barberi</u>

Wings with spots of dark scales; wing with four distinct dark spots .... <u>Anopheles quadrimaculatus</u>

44. Tarsal segments with white rings 47

Tarsal segments without white rings 45

45. Scutum with a pair of broad submedian white or yellowish-white stripes separated by a brown stripe of about the same width ... . <u>Aedes trivittatus</u>

Scutum without a pair of broad submedian white or yellowish white stripes 46

46. Scutum with a broad median stripe of dark brown scales, sides and anterior margin with silver white scales .... <u>Aedes triseriatus</u>

Scutum with a broad median stripe or patch of silver-white scales or pale-yellow scales; occiput dorsally with a median stripe of narrow white scales bounded by a patch of broad dark scales ... . <u>Aedes atlanticus</u>

or .... <u>Aedes tormentor</u>

47. Tarsi with rings only at the base of the segments 48

Tarsi with white rings both apically and bascally 51

48. Hind femur entirely pale scaled on all aspects of basal half .... Aedes zoosophus

Hind femur with basal half of anterior surface all dark or with intermixed dark and pale scales 49

49. Proboscis with broad white ring in middle ..... Aedes nigromaculis

Proboscis without a broad white ring in middle ...... Aedes vexans

50. The second, fourth, and sixth wing veins white scaled, dark and light scales mixed on other veins .... Aedes dorsalis

Wing veins not as above 51

51. Wings with a patch of white scales at base ...... Aedes atropalpus

Wings without a patch of white scales at base ... Aedes canadensis

52. Wing scales mixed dark and white; hind femur with a more or less distinct narrow subapical ring of white scales 53

Wing scales all dark or with only few inconspicuous white scales on costa and sub-costa; hind femur not ringed 55

53. Wing scales black and white mixed, but wings without definite white spots .... Psorophora confinnis

Wings with some of the white scales grouped to form definite white spots 54

54. Costa with a single prominent white spot on the apical half of of the wing .... Psorophora discolor

Costa with two prominent white spots on the apical half of the wing .... Psorophora signipennis

55. Hind legs including part of femora, with long erect scales, very shaggy; very large species 56

Hind legs not as above 57

56. Scutum with a narrow median longitudinal stripe of golden scales; proboscis yellow scaled on distal half, dark at tip .... Psorophora ciliata

Scutum without a median longitudinal stripe; proboscis entirely dark scaled .... Psorophora howardii

57. Hind tarsi entirely dark scaled; abdominal segments with apical submedian triangular patches of golden-yellow scales .... Psorophora cyanescens

Hind tarsi with white on apical segments; abdominal segments with pale-scaling restricted to apicolateral corners or the apical margin (scutum clothed with mixed dark brown and golden-yellow scales in no definite pattern) .... Psorophora ferox

58. Tarsi with conspicuous white rings; proboscis with a white ring in the middle .... Culex tarsalis

Tarsi and proboscis dark 59

59. Pale scales of occiput ashy white; abdominal segment V about one and three-tenths times as broad as long in engorged dried specimens .... Culex territans

Occiput and abdominal segments not as above 60

60. Wing scales slightly or distinctly broaden on wing vein 2; occiput usually with broad appressed scales dorsally, sometimes limited to a narrow border behind the eyes .... Culex erraticus

Wing scales and occiput not as above 61

61. Abdominal tergites without conspicuous transverse bands of white scales .... Culex salinarius

Abdominal tergites with transverse white bands 62

62. Abdominal bands, broadly rounded on posterior margin and constricted laterally, rather narrowly joining or entirely disconnected from the lateral patches; scales of scutum somewhat coarse, golden .... Culex pipiens
or .... Culex quinquefasciatus
Abdominal bands with posterior margin nearly straight and broadly joining the lateral patches (particularly on segments 3 to 5); scales of scutum fine golden brown; scutum usually with a pair of pale scaled submedian spots near middle .... Culex restuans

KEY TO MALE TERMINALIA

ANOPHELES

1. Phallosome without leaflets; small species ..... Anopheles barberi
   Phallosome with leaflets 2
2. Claspette with dorsal and ventral lobes fused forming a single flesh conical lobe on back side .... Anopheles crucians
   Claspette with dorsal and ventral lobes distinct at least apically 3
3. External spine of dorsal lobe of claspette capitate or bluntly rounded at apex; One or more leaflets of phallosome with a few coarse basal teeth .... Anopheles quadrimaculatus
   External spine of dorsal lobe of claspette acuminate at apex; lobe of ninth tergite long and narrow .... Anopheles punctipennis

AEDES

1. Claspette stem crowned with a dense tuft of setae, filament absent;

claw of dististyle subapical in position, arising at apical fifth of the dististyle .... Aedes vexans

Claspette with a distinct filament; claw of dististyle apical in position 2

2. Terminal claw of dististyle one-half as long as the dististyle. 3

Terminal claw of dististyle never more than one-third as long as the dististyle 4

3. Basistyle with a small dense patch of long hairs arising on the inner face at apical third .... Aedes triseriatus

Basistyle without a small dense patch of long hairs on the inner surface at apical third .... Aedes zoosophus

4. Apical lobe of basistyle absent 5

Apical lobe of basistyle present 6

5. Dististyle of equal width throughout, glabrous except for short subapical setae; lobes of ninth tergite inconspicuous without setae .... Aedes atropalpus

Dististyle distinctly broadened, before the middle, pilose; lobes of ninth tergite small but distinct, armed with short spine like setae .... Aedes nigromaculis

6. Claspette stem stout, broad medially, constricted basally and apically .... Aedes atlanticus

Claspette stem slender, not as above 7

7. Basal lobe of basistyle bearing setae but lacking a distinctly enlarged spine .... Aedes canadensis

Basal lobe of the basistyle bearing one or more distinctly enlarges spines 8

8. Basal lobe of basistyle cylindrical and fingerlike, nearly four times as long as its basal width .... Aedes tormentor

Basal lobe of basistyle not as above 9

9. Basal lobe of the basistyle bearing one or two stout spines in addition to the normal long stout spine .... Aedes dorsalis

Basal lobe of the basistyle without differentiated strong spines other than a long one (strong dorsal spine often followed by progressively weaker spines or setae) .... Aedes trivittatus

PSOROPHORA

1. Phallosome with a pair of dorsal submedian longitudinal toothed ridges and a pair of broad lateral thornlike projections on the apical half 2

Phallosome cylindrical or conical, without teeth or broad lateral thornlike projections 3

2. Dististyle stout, with a very large lateral hatchet shaped lobe directed mesad .... Psorophora howardii

Dististyle slender, with a small dorsal angular projection at distal fifth .... Psorophora ciliata

3. Phallosome conical, with a lateral flange on apical half and a basally divaricated carina on dorsal surface .... Psorophora cyanescens

Phallosome conical or cylindrical, without a lateral flange and dorsal divaricated carina 4

4. Claspette slender, about three-fourth as long as basistyle, with

two contorted leaflike filaments and a short blunt filament; basistyle three to three and a half times as long as broad; phallosome pointed at apex .... *Psorophora ferox*

Claspette stem slender, expanded into a broad crown apically not extending beyond middle of basistyle 5

5. Claspette with about five or six setaceous filaments on crowns .... *Psorophora signipennis*

Claspette not as above 6

6. Inner ventral margin of each plate of phallosome with a distinct triangular projection directed ventrolaterally; claspette with five or six blades and a single apically feathered seta .... *Psorophora discolor*

Inner ventral margin of each plate of phallosome with only a narrow rounded part directed ventrad, lacking a distinct triangular projection; claspette with six or seven blades and a single apically feathered seta .... *Psorophora confinnis*

CULEX

1. Tenth sternite crowned apically with a comblike row of blunt teeth 2

Teeth sternite crowned apically with a dense tuft of spines ... 3

2. Dististyle with apical half roundly expanded (never quadrate), bearing minute setae on outer crest .... *Culex erraticus*

Dististyle about half as long as the basistyle, curved; distal half with many setae, two large setae, and a row of membranous lobes (seen at high magnification)...................... *Culex territans*

Dististyle about half as long as the basistyle, curved; distal half with many setae, two large setae, and a row of membraneous lobes seen at high manification .... *Culex territans*

3. Subapical lobe of basistyle with eight or more appendages..... .... *Culex quinquefasciatus*

Subapical lobe of basistyle with five or six appendages 4

4. Leaflike filament of subapical lobe narrow, club like; crown of tenth sternite with outer spines blunt .... *Culex tarsalis*

Leaflike filament of subapical lobe broad; crown of tenth sternite either with all spines pointed or with the outer spines blunt .... *Culex salinarius*

DISCUSSION

Due to the fact that the Refuge is an ecotone, eastern as well as western species were collected during the course of this study. To date there have been fifty-two species of mosquitoes recorded for the State of Oklahoma (Griffith, 1952).

Aedes atropalpus and *Aedes zoosophus* are much more abundant at the Refuge than previously indicated in the literature. The collections of *Anopheles barberi* and *Toxorhynchites rutilus septentrionalis* is a westward extension of the state distribution of these species. The presence of *Orthopodomyia alba* at the Refuge constitutes a new state record, and also the most westward record known for this species.

CHAPTER III

ECOLOGY OF THE MOSQUITO LARVAE

Materials and Methods

The classification of larval habitats was essentially that of Bates (1946). The classification scheme used in this study was largely empirical, being designed to provide a basis for making records of operation; however, the natural aspects relative to mosquito larval habitat classification were not omitted in that ecological aspects were also considered. The following three main habitat divisions were established, based on the location, the length of time water was present in a habitat, and such habitats as presented by containers, which were difficult to include under either of the other two major divisions: Permanent Habitats, Transient Habitats, and Container Habitats.

In order to analyze the water in the various habitats for free carbon dioxide and dissolved oxygen content, a chemistry kit was constructed which facilitated these determination under field conditions. In addition, the kit allowed for the storage of equipment and solutions necessary for the determinations.

Preliminary determinations of the free carbon dioxide and dissolved oxygen of the water in the various larval habitats indicated no significant difference between the concentration of these gases in the permanent and transient habitats. Rock hole determinations varied significantly from the tree hole, but did not differ significantly from those of the permanent and transient type habitats. In order to obtain additional data concerning the significant variation of these gases in the tree hole and rock hole larval habitats, field determinations of the dissolved oxygen and free carbon dioxide were made on ten additional samples from both of these habitats during the months of June and July, 1959. The procedures followed in these determinations were essentially those presented in the manual "Standard Methods for the Examination of Water and Sewage" (American Public Health Association, 1946).

Hydrogen ion concentration determinations were made routinely on the water of the various larval habitats, at the time larvae were collected. During 1958, pH determinations were made with Nitrazine Paper. In 1959-60 the determinations were made colorimetrically with a Hellige Comparator.

During this study, the physical and biotic factors observed in the larval habitats were temperature, the presence or absence of plants, and the amount of light associated with the larval habitats. Water temperature of the various habitats were determined with the aid of a thermometer with a temperature range of 0° to 125° F. The thermometer was equipped with a water retaining cup at the base of the mercury column. Temperatures were recorded on the data sheet at the time larvae were collected.

The presence of plants, the amount of light, and turbidity of the water were estimated and notes made at the time larvae were collected from a particular habitat.

Frequently the larvae of various species were dissected to ascertain their feeding habits. Dissections were made by holding the head of a larvae with a teasing needle and pulling gently at the anal segment with another needle until the intestine was pulled out of the body wall. The intestine was then opened and its contents observed and identified.

Results

The data concerning the percent of collections by the month is presented in Figure 3. On the basis of these data, the greatest percentage of larvae were collected during June, July, and August.

Figure 4 summarizes the percent of larvae collected from specific larval habitats. The most numerous larval collections were made from the tree hole, isolated pooled stream, and rock hole type larval habitats respectively.

Figure 5 summarizes the data relative to the total larval collections from the various habitats during June, July, and August of 1958, and 1959.

I. Permanent Habitats

This major class of larval habitats includes those which normally contain water throughout the year.

A. Shores of Lakes - Shallow Coves of Lakes - Impounded Streams. Characteristically the water of these larval habitats was fresh, clear, alkaline (ph range 7.3 to 9.6), quiet, cool, and shaded. Often filaemntous algae (*Spirogyra*, *Oedogonium*, *Rhizoclonium*, and *Mougeotia*) along with a number of species of unicellular algae were present. The predominant species of unicellular algae present were *Closterium*, *Cosmarium*, *Desmidium*, *Navicula*, *Pinnularia*, *Pediastrum*, *Scenedesmus*, and

Ankistrodesmus. Larger aquatic plants often present were Typha domingenesis, Potamogeton nodosus, Potamogeton diversifolius, Ceratophyllum dermersum, Eleocharis acuminata, Neblumbo lutea and Nitella sp. Laboratory dissections of larvae from these habitats indicated that most of the larvae fed on the associated unicellular algae. Floating debris was usually present when larvae were collected. The initial occurrence of larvae in these habitats was during April when the water temperature was 48° F. Temperatures of water associated with these permanent larval habitats varied from 46° F. to 82° F. over the course of this study. Species of mosquitoes recorded here, in the order of prevalence, were Anopheles quadrimaculatus, Culex erraticus, Anopheles punctipennis, Psorophora signipennis, and Culex territans. Larval collections from these habitats constituted only 10.2% of the total larval collections (Figure 4).

B. Open Mine Shaft. One open mine shaft was located adjacent to a stream west of Sunset Campground. This mine contained water throughout the year. In general, the water was shaded and clear. Spirogyra and numerous species of unicellular algae, of which Cosmarium and Desmidium were predominant, were present during the summer months. Species recorded from the mine shaft, in the order of prevalence, were Culex erraticus, Culex tarsalis, Anopheles punctipennis, and Culex territans. Only 2.9% of the total larval collections were made from this habitat.

II. Transient (Semi-Permanent) Habitats

To this class of larval habitats were assigned sites in which water was present for varying periods of time lasting from three days to as long as two months, depending upon the amount of precipitation, depth and size of the cavity and the nature of the soil associated with this larval habitat.

A. Seepages. These larval habitats are formed as the results of water oozing or percolating through crevices in rocks or seeping from springs. In general the flow of water was slow, and often puddles formed along the course of the flow. Due to the fact that seepages were relatively rare at the Refuge, the data recorded were not extnesive. Seldom if ever was large vegetation observed, although algae such as Ocillatoria, Spirogyra and Cosmarium, were present on occasions. These habitats were usually in direct sunlight and during July a water temperature of 92° F. was recorded. The lowest temperature recorded was 52° F. in September. Larvae first appeared in this habitat during the month of May. The larvae of Aedes atropalpus, Culex tarsalis, Anopheles punctipennis, Anopheles quadrimaculatus, Culiseta inornata, and Psorophora ciliata were recorded for seepages during the course of this study. The data presented in Figure 4 indicate that only 2.9% of the total larval collections were made from seepages.

B. Open Ground Pools. This designation was assigned to depressions encountered in open fields. These pools were usually several feet in diameter and contained water from six to twenty-four inches in depth. Usually grasses, sedges, and other component prairie plants typical of the tall grass prairie and the mixed grass plains was present. The presence of vegetation appeared to favor the development of mosquitoes normally found breeding in these open ground pools. These pools were most frequently found in direct sunlight and contained turbid water. The pH ranged from 6.9 to 10.8. Temperatures ranged from 42° F. in

November, to 91.2° F. during August. Larvae were first collected here during the month of May. Species recorded from open ground pools, in the order of prevalence, were Aedes vexans, Psorophora discolor, Aedes nigromaculis, Culex tarsalis, Psorophora signipennis, Culiseta inornata Psorophora cyanescens, Psorophora confinnis, and an unusual record for Aedes atropalpus. As indicated in Figure 3, 8.7% of all larval collections were made from these pools.

C. Borrow Pits. This term was assigned to ditches which result from the normal construction and grading of road beds for the purpose of elevating the road surface and providing drainage. In general, the ecological features of this habitat were similar to those presented for the open ground pool. The pH determinations, ranged from 7.3 to 9.4. They were usually found in direct sunlight and contained prairie vegetation, protozoans, crustaceans (Daphnia, Cyclops, and Diaptomus), and rotifers. The maximum and minimum temperatures recorded were 88.3° F. in July and 32° F. in February. Species recorded from borrow pits, in the order of prevalence, were Psorophora signipennis, Aedes nigromaculis, Culiseta inornata, Aedes vexans, Culex tarsalis, Culex erraticus, Psorophora discolor, Psorophora confinnis, and Aedes atropalpus. The data illustrated in Figure 4 indicate that 8.1% of all larval collections were made from this type of habitat.

D. Drainage Ditches. This term was assigned to ditches which facilitate the removal of surface water or the lowering of the ground water table. The ecological data were quite similar to those recorded for borrow pits and those of the open ground pools. The species present were somewhat different and the order of their abundance sufficiently different to justify the separation of habitats. Immediately after a rain these ditches were often filled with fast flowing water, but after the major flow had passed the water often became pooled in low places, The pH determinations ranged from 7.8 to 9.8. The maximum and minimum temperatures when larvae were collected were 86.3° F. in August, and 36° F. in February.

The following species, in the order of prevalence, were collected from these drainage ditches: Psorophora signipennis, Culex tarsalis, Aedes nigromaculis, Psorophora discolor, Psorophora ciliata, Culiseta inornata, Anopheles punctipennis, Psorophora howardii, Psorophora ferox, Psorophora confinnis, and Culex territans. While drainage ditches had the richest species fauna, only 7.6% of the total larval collections were made from drainage ditches.

E. Woodland Pools. This larval habitat consisted of pools of varying size and depth found in wooded areas. The relatively rare occurrence of these pools at the Refuge is probably attributable to the topography and scrubby nature of the forest present. Several semi-permanent woodland pools were located some two and one-half miles southwest of Mount Scott adjacent to the main highway. These pools were formed after a small dike was constructed across an old road to prevent the flooding of a camp site. The water was dark brown and usually contained decaying leaves most of the year. Plants were not observed in these pools although a large number of rotifers, water fleas, fairy shrimp, and nematodes were seen. The pH determinations of the water found in these pools, ranged from 6.9 to 7.3. The maximum and minimum temperatures at which larvae were collected were 72° F. and 32° F.

respectively. Larvae first appeared here during the month of June. Species collected here, in the order of prevalence, were Psorophora ferox, Chaoborus punctipennis, Culiseta inornata, Psorophora ciliata, Psorophora confinnis, and Psorophora discolor. A total of 4.9% of the total larval collections were made from this type of larval habitat (Figure 4).

F. Pooled Streams. This larval habitat includes the small pools which form in creek and stream beds during dry periods away from the main current flow. The waters found herein were usually clear, and invariably alkaline (pH 7.4 to 9.2). These pools were usually partially shaded, with intermittentlight, although some isolated pools were encountered in direct sunlight. The maximum and minimum temperatures at which larvae were collected were 82° F. during August, and 48° F. during October. The first appearance of larvae was recorded during the month of May. These pools were especially common during 1958, when the total precipitation was some eight inches below the fifty year average precipitation. The filamentous algae Spirogyra was present in 80% of these pools when larvae were collected. The following larvae, in the order of prevalence, were collected from the pooled stream habitat: Anopheles quadrimaculatus, Culex erraticus, Anopheles punctipennis, Culiseta inornata, Culex tarsalis, Culex territans, Culex restuans Psorophora discolor, Aedes atropalpus, and Aedes vexans. A total of 19.6% of the total larval collections were made from these pools (Figure 4).

III. Container Habitats

This major category includes all natural and man-made containers which hold water long enough to become a suitable habitat for mosquitoes.

A. Tree Holes. A tree hole has been defined by Park et al. (1950) as "any extrinsically produced tree cavity that is in direct contact with the external environment at some point in its development." In the event that a tree hole can receive and retain water for extended periods of time, an aquatic microsere develops. During the past few decades, there has been a noticeable increase in the number of studies of the tree hole microhabitat as a site for the development of mosquito larvae and as resting sites for certain adults. The larvae of all species of mosquitoes recorded from tree holes during this study have been collected from oak trees (*Quercus marilandica*, *Quercus stellata*, *Quercus shumardii*), with the exception of *Orthopodomyia alba*. The sole collection of the larvae of *Orthopodomyia alba* was made from an American Elm tree (*Ulmus americana*). The maximum and minimum temperature under which larvae were collected here ranged from 32° F. during February to 76° F. during July. The pH determinations ranged from 6.8 to 7.2. The tree holes usually contained brown turbid water in which decaying leaves were present. The size and height of the tree holes varied. The habitats were often dry during August and the hibernal period, depending although on the amount of precipitation. The dissolved oxygen and free carbon dioxide determinations made from ten samples of water from tree holes indicated a high percentage of free carbon dioxide (.9 to 8.4 parts per million) and a low percentage of dissolved oxygen (1.0 to 2.7 parts per million). These data suggest the presence of a large amount of decaying material.

The following larvae, in the order of prevalence, were collected from the tree hole habitat: Aedes triseriatus, Orthopodomyia signifera, Toxorhynchites rutilus septentrionalis, Aedes zoosophus, Anopheles barberi, Orthopodomyia alba, Culex tarsalis, and Aedes atropalpus. The data presented in Figure 4 indicate that the tree holes were the most numerous of all collecting sites during the course of this study (22.6% of the total collections.)

B. Rock Holes. This category included holes which have been formed in rocks as the result of water erosion. The water present in these holes may be derived either from streams during flooding or from rainfall. The pH ranged from 7.2 to 10.4. Dissolved oxygen and free carbon dioxide determinations ranged from 0.7 to 1.3 and 6.2 to 8.8 respectively. These values appear to be significantly different from those found in tree holes. In general, the water found in these holes was clear and usually exposed to direct sunlight. Temperatures ranged from 38° F. in November to 96° F. in August. Mosquito larvae were first observed in Rock Holes during late April. Filamentous algae such as Spirogyra, Oscillatoria, and Cladophora were often encountered in these holes, along with the following unicellular algae which also were common in the rock hole habitat: Pediastrum, Gonium, Closterium, Navicular, Gomphonema, Asterionella, Pinnularia, and Scenedesmus. Invertebrates present in the rock hole habitat included several species of rotifers, snails, nematodes, and crustaceans (including Cyclops, water fleas, and fairy shrimps Streptocephalus sp. and Eubranchipus sp.. Larval dissections of Aedes atropalpus, the most abundant species found in rock holes, indicate that they prefer algae, although a few invertebrates were often ingested.

The species collected from rock holes, in the order of prevalence, were Aedes atropalpus, Culiseta inornata, Anopheles quadrimaculatus, Culex tarsalis, Culex erraticus, and Anopheles punctipennis. A total of 13% of the total larval collections were made from this type of habitat.

During the spring months, Culex tarsalis and Anopheles punctipennis were the dominant species, but during the summer months, the dominant species was Aedes atropalpus. During the late fall months the larvae of Culex tarsalis, Culiseta inornata, Anopheles punctipennis, and Anopheles quadrimaculatus were the most abundant larvae in rock holes. During the winter months, larvae were not collected from these holes. On the basis of these observations, there appears to be a type of seasonal succession present.

C. Artificial Containers. This type of larval habitat was rare at the Refuge. During November, 1959 twenty-eight fourth instar larvae of Orthopodomyia signifera were collected from an old tractor tire in the Headquarters area. In the order of prevalence, the larvae collected from artificial containers were rare collections of Aedes atropalpus, Orthopodomyia signifera, and Aedes triseriatus, which were collected from several cans, tractor tires, and a bottle, respectively. As the data in Figure 4 indicate, only 1.6% of the total larval collections were made from this type of habitat.

Discussion

The breeding sites of each species of mosquitoes are usually characteristic and in some cases restricted to a single peculiar type of larval habitat although certain species are not so rigid in their selection of breeding sites. According to Bates (1949) the classification of larval breeding sites involves two somewhat different though related problems: first, that of the terms or characteristids to be stressed in describing or defining the habitat of a particular species; and second, that of the criteria to be used in studying the relationship among habitats.

The major divisions of mosquito breeding places were based primarily on the permanent and transient accumulation of water. The third major division represented was the container type of habitat.

The permanent type of habitat is perhaps the most generalized of larval habitats, and is occupied in every part of the world by many species of Anopheles and Culex (Bates, 1949). The permanent type habitats comprised only 10.5% of the total larval collections at the Refuge.

The transient type of habitat included sites located in the open as well as pools enclosed by forest. In general larvae of Aedes and Psorophora were usually found here. Species are found in these habitats which usually require desiccation of the eggs before hatching (Horsfall, 1955). The immature forms of the species associated with transient waters develop at an accelerated pace, compared to the species generally occurring in permanent waters. This would seem to be another adaptation necessary for the survival of the species because often these pools dry up in 3 to 5 days. As indicated in Figure 4, 51.8% of the total larval collections were made from transient waters.

The container type of larval habitats usually contained their peculiar species of mosquitoes. Species from a variety of natural habitats were recorded from these habitats on rare occasions. Aedes atropalpus was usually restricted to rock holes and seepages. During the spring and fall months, Culex tarsalis, Anopheles punctipennis and Culiseta inornata were collected in association with Aedes atropalpus (Table 3).

Orthopodomyia signifera, Orthopodomyia alba, Aedes triseriatus, Aedes zoosophus, Toxorhynchites rutilus septentrionalis, and Anopheles barberi inhabited the tree hole habitat.

At the Refuge the larvae of Aedes zoosophus was collected from tree holes in post oaks (Quercus stellata) and spotted oak (Quercus shumardii) trees. It should be pointed out that according to Jenkins and Carpenter (1946) the only kind of tree from which the larvae of Aedes zoosophus had been previously collected was willow (Salix sp.) trees.

As indicated in Figure 4, 37.2% of the total collections were made from the tree hole habitat.

A preliminary check of the pH of the various larval habitats indicated that most of the waters were alkaline, with a pH range of 6.8 in a tree hole to a high of 10.8 in an open ground pool.

The water temperature in early March varied from 34° F. to 56° F. at which time early spring species appeared. There was a gradual increase in most water temperatures until an average temperature of 68° F. was reached in late spring, at which time summer species appeared such as Aedes nigromaculis, Culex erraticus, Anopheles quadrimaculatus and Aedes atropalpus appeared. The summer species reached their peak during July and August when water temperatures averaged 79° F. During late October temperatures averaged 46° F. and a noticeable decreases in larvae in all habitats was observed.

During the winter period, cold resistant larvae of such species as Toxorhynchites rutilus septentrionalis, Orthopodomyia signifera.

Orthopodomyia alba, Aedes triseriatus, and Culiseta inornata were present. These larvae were collected when temperatures were as low as 30° F. in February. In general, the cold resistant species appeared when the average minimum temperature fell below 36° F. which occurred in November.

According to Baker (1935) the length of the photoperiod affected the rate of development of Orthopodomyia signifera in that the latent period continued until days became longer in the spring. Since that time, Jenkins and Carpenter (1946) have pointed out that no such relationship was presented when larvae of Orthopodomyia signifera were brought into the laboratory during February and kept in total darkness except for an hour each day. During the present study, similar experiments were performed on hibernating larvae of Orthopodomyia signifera and Orthopodomyia alba, which were collected in February and reared in the laboratory at 22° C. in complete darkness. The results corroborate the findings of Jenkins and Carpenter (1946).

The length of the photoperiod, as it affects the development of larvae in other habitats, has been given but little consideration. There is a possibility that the length of the photoperiod may play a significant rôle in the regulation of the seasonal cycles of mosquitoes in other larval habitats.

The presence of vegetation in certain larval habitats appears to be correlated with the presence of larvae. Larvae were usually collected from the permanent and transient type of habitats when characteristic vegetation was present. For example, the larvae of Anopheles quadrimaculatus were usually collected from larval sites which contained the filamentous algae Spirogyra during the summer months. In general, vegetation is a fairly reliable indicator of the type of larval habitat present.

Species which select the same type of larval habitat, and whose larvae develop at the same rate, are often found in association. Logically, those species which have a wide range of larval habitats would be associated with a large number of other species.

A distinct seasonal succession occurred in most of the transient and container types of larval habitats. Seasonal succession appears to be directly correlated with distinct changes in temperature, rainfall, and photoperiod over extended periods. An example of seasonal succession has been presented in the discussion of the rock hole habitat.

During the rainy seasons, when certain roads were inaccessible, collections were probably somewhat biased, in that areas with good roads were favored. During dry periods, often the only larval habitats which contained larvae were the larger rock holes, deeper tree holes, permanent types of larval habitats, and isolated stream pools.

CHAPTER IV

ECOLOGY OF THE ADULTS

Materials and Methods

Resting adults were collected from a variety of resting sites and in the manner described in Chapter II.

In order to determine the relative abundance of the mosquitoes present during the summer months, a New Jersey type light trap was operated in the headquarters area from June 1, 1959 to September 1, 1959. A portable light trap was operated in Study Area 3 (Map 3), from June 1, 1959 to September 1, 1959 on alternate days. Standard procedures were followed in the operation of the light traps.

Regular biting collections were made on at least two nights of the week from 7:00 to 9:00 P. M. and also whenever encountered in the field as described in Chapter II.

Results

The adults of *Anopheles quadrimaculatus*, *Anopheles punctipennis*, and *Culex erraticus* were often collected from a variety of resting sites during the diurnal period. The majority of the resting adults were collected in the headquarters and Sunset Campground Areas. In the headquarters area, females of *Anopheles quadrimaculatus* and *Culex erraticus* were usually found resting in a stable during the diurnal period. This stable was located adjacent to an impounded stream, where the larvae of these resting species were often collected. The females of all tree hole species, with the exception of Orthopodomyia alba, were collected resting around tree holes during the summer months. Females of Psorophora ciliata, Psorophora ferox, Psorophora signipennis, Psorophora howardii, Aedes nigromaculis and Aedes vexans were collected resting in vegetation near their breeding sites during the course of this study.

The species percent of the total number of mosquitoes collected and the monthly percent of the total number of mosquitoes collected are presented in Figures 3 and 4 respectively. The data relative to the seasonal distribution of the adult mosquitoes recorded at the Refuge are presented in Table 5.

Biting records were recorded for Anopheles punctipennis, Anopheles quadrimaculatus, Mansonia perturbans, Psorophora confinnis, Psorophora cyanescens, Psorophora howardii, Psorophora signipennis, Aedes nigromaculis, Aedes atropalpus, Aedes triseriatus, Aedes zoosophus, and Culex erraticus.

The most numerous biting records made at the Refuge were for Anopheles quadrimaculatus and Culex erraticus, during the summer months, between 7:30 and 8:30 P. M., and in the Headquarters area. It should be pointed out that in the Headquarters area conditions were especially conducive for the breeding of the two species indicated above because of the presence of the impounded streams and nearby lakes.

Species of the Genus Psorophora were often collected in biting samples during the diurnal period. Psorophora cyanescens fed readily during the diurnal period, when vegetation in which they were resting was disturbed. This species was especially active in this respect. Biting specimens of Aedes atropalpus and Aedes nigromaculis were collected during the early evening in various sections of the Refuge. Aedes triseriatus and Aedes zoosophus were often collected while biting during the diurnal period, especially in forested areas. The most abundant biting records for tree hole mosquitoes were recorded at dusk in wooded areas. Mansonia perturbans was collected while biting at Lost Lake during June, 1959 at dusk.

The unpublished light trap records of Dr. Melvin E. Griffith, who ran light traps in the Headquarters area during 1946, are presented along with the data from this study relative to the total number of adults collected in Table 5. A comparison of Griffith's data with data collected during this study indicates that the abundance of Anopheles quadrimaculatus has increased considerably in this area since 1946 and the prevalence of Culex tarsalis has fallen sharply.

Mosquitoes were not as attracted to the battery operated light trap as they were to the light trap which was operated by regular current. It should be pointed out, however, that Aedes nigromaculis and Psorophora signipennis were the most abundant species in the big game area (Study Area 3) whereas Anopheles quadrimaculatus and Culex erraticus were predominant in the Headquarters area, where the total mosquito population was much higher. Aedes nigromaculis and Psorophora signipennis were only rarely collected in the Headquarters area.

Discussion

Bates (1949) indicated that it is quite common to describe the larval habitat of a given species of mosquito, but that it is difficult to think of the adult as having a characteristic habitat. In general, most of the observations presented in this study relative to the adults concerns biting and resting habits.

The females of most mosquitoes, after taking a blood meal, spend the period during which the ovaries are developing in a stage of inactivity. The resting place is thus herein considered as a part of the adult habitat. Numerous studies have been made relative to the resting sites of Anopheles, but relatively little attention has been paid to the resting sites of other mosquitoes.

The study of seasonal distribution was important in this study since characteristics of the environment change in time as well as in space. The data presented in Table 5 are only an index, since there is no way of making a census of the actual number of individual mosquitoes present in a given area. Presumably the index fluctuations correspond directly to fluctuations in the absolute populations.

CHAPTER V

HIBERNAL OBSERVATION ON MOSQUITOES

Materials and Methods

In general, the methods utilized in the collection of larvae were the same as those presented in Chapter II. With the aid of a flashlight, an aspirator, and a small net, a few specimens of adult mosquitoes were collected from restrooms, hollow logs, a tunnel, and culverts during the winter months.

The larvae of several species of mosquitoes were placed in glass containers and exposed to a temperature of 21.5° F. for a period of two hours. The larvae were observed and then placed back into the freezing unit for an additional forty-eight hours. These experiments were performed in order to determine if the species could survive complete freezing. The laboratory procedures followed were essentially those of Baker (1936).

Results

During the hibernal season, larvae of the following species were collected: *Aedes triseriatus*, *Orthopodomyia signifera*, *Orthopodomyia alba*, *Toxorhynchites rutilus septentrionalis*, and *Culiseta inornata*. The larvae of *Orthopodomyia signifera*, *Toxorhynchites rutilus septentrionalis*, and *Aedes triseriatus* were collected from several tree holes under thin layers of ice during February, 1960. Field observations indicated that these tree hole species can survive during the hibernal season provided water is present in tree holes.

Several females of Anopheles punctipennis and Anopheles quadrimaculatus were collected during the hibernal months from several hollow logs and a culvert. Gravid females of the above species along with females of Culex erraticus, Culex tarsalis, and Culiseta inornata were also collected during the hibernal period from an abandoned mine tunnel. All specimens were collected while the mosquitoes were in a state of inactivity.

Laboratory observations on the larvae of Orthopodomyia alba, Orthopodomyia signifera, Culiseta inornata, and Aedes triseriatus suggest that these species can not survive complete freezing. Larvae of these species have been observed in the laboratory swimming sluggishly beneath layers of ice in finger bowls which had been exposed to a temperature of 21.5° F. for a period of two hours. When the above larvae were subjected to the latter temperature for 48 hours, they were completely frozen and did not revive after thawing.

Five larvae of Toxorhynchites rutilus septentrionalis revived upon thawing after being subjected to a temperature of 21.5° F. for a period of 48 hours.

Identical laboratory freezing experiments, such as those presented above, were conducted to determine whether the larvae of Culiseta inornata could withstand complete freezing. Upon thawing the larvae of this species did not revive. The entire experiment was repeated, and the same results were obtained.

In an attempt to corroborate the results of Jenkins and Carpenter

(1946) regarding the question of whether the larvae of Orthopodomyia signifera (which overwinters in this area as fourth instar larvae) would pupate if the temperature was elevated, eighteen fourth instar larvae of this species were isolated (in tree hole water) and reared in total darkness at a temperature of 70° F.. Normal adults appeared on the 16th day after the beginning of this experiment. All of the larvae had pupated and emerged as adults by the end of 21 days.

Larvae of Orthopodomyia alba, which were collected in February, were reared to adults in the laboratory at a temperature of 71 °F..

Discussion

Bates (1949) has indicated that in the temperature zone seasonal changes are primarily related to the cold period, whereas in the tropics these changes are more closely related to periods of dry weather. It seems only reasonable to assume, that in order for a species to survive, it must be able to adapt itself during the unfavorable period. Different species have adapted themselves to cope with the unfavorable period in a variety of ways. In general, the unfavorable period in the temperature zone is the hibernal period. Mosquitoes at the Refuge show hibernation adaptations in the egg, larvae or adult stage, but never the pupal stage.

Wesenberg-Lund (1921) described the seasonal distribution of mosquitoes found in Denmark. These data on Danish mosquitoes have also been presented by Bates (1949) with comments. Due to the fact that four distinct types of seasonal cycles were recognized, it seemed convenient to name the different types of seasonal cycles after well known species which illustrated each particular type of cycle. The three types of seasonal cycles represented at the Refuge were the Aedes capius, Anopheles claviger, and Culex pipiens types.

In the Aedes capius type seasonal cycle (which is represented by such mosquitoes as the Genus Psorophora, Anopheles barberi and such species of Aedes as Aedes atropalpus, Aedes nigromaculis, and Aedes zoosophus), hibernation is in the egg stage but, in general there is an indefinite number of generations per year. Usually with this type of seasonal cycle, the species tend to appear in great numbers quite abruptly, several times a season, depending on the distribution of rain and floods.

In the Anopheles claviger type seasonal cycle (represented at the Refuge by such species as Toxorhynchites rutilus septentrionalis, Orthopodomyia signifera, and Aedes triseriatus), hibernation is in the larval stage. Species with this type of seasonal cycle may be either single or many brooded, and in more southern latitudes they tend to show an early spring peak of adults (Bates, 1949).

In the Culex pipiens type of seasonal cycle (represented at the Refuge by members of the Genus Culex and the Genus Anopheles with the exception of Anopheles barberi), hibernation is in the adult stage and there are usually many broods. The species population is at a minimum level during the winter months, building up by successive generations during the period of favorable temperatures (Bates, 1949).

The larvae of most species of mosquitoes are killed when frozen. However, on the basis of laboratory observations it appears that most tree hole species can overwinter as larvae provided water is present, or the larvae do not become completely frozen.

During 1959, when precipitation was greatly reduced, many of the tree holes became dry during the hibernal period. It seems logical to assume that species with the Anopheles claviger type of seasonal cycle may be able to overwinter in the eggs stage, since these same tree holes, which were dry during the hibernal season, had larvae in abundance after flooding during the spring of the next year.

In the north, Culiseta inornata is considered a summer species, whereas in the south it is active in the spring, winter and fall; in intermediate regions, this species is abundant during the spring and fall (Horsfall, 1937; Rozeboom, 1942; Owens, 1937). Laboratory experiments suggest that the larvae of Culiseta inornata possibly survive freezing temperatures provided they are not completely frozen. Rozeboom (1942) observed the larvae of this species during the winter months, although the larvae did not seem to be able to withstand freezing. Carpenter (Carpenter and La Casse, 1955) has collected the larvae of Culiseta inornata from pools covered with ice in Arkansas.

Culiseta inornata is active at the Refuge from January through May, after which it disappears until early November. Wilkins and Breland (1951) suggest the possibility of the summer being spent in the egg stage in the southern part of its range in the United States. On the basis of observations made during this study, it appears that this species overwinters as fecund or fertilized females in protected sites. On warm days these females are believed to leave their hibernation sites to oviposit, thus presenting a possible explanation for the sporadic occurrence of egg rafts and larvae during the hibernal period. Rees (1943) collected Culiseta inornata during the hibernal period in basements, cellars, potato pits, and similar sites in Utah. Owens (1937) observed females of Culiseta *inornata* overwintering in sheltered sites during the hibernal period in Minnesota.

Laboratory results relative to the question of whether the larvae of *Orthopodomyia signifera* would pupate if the temperature was elevated, suggest that the activity of this species appears to be directly related to temperature, which is the same conclusions reached by Jenkins and Carpenter (1946). The absence of light did not prevent the development of the larvae, thus, perhaps the active season of this species can be attributed to thermoperiodicity rather than photoperiodicity.

CHAPTER VI

Mosquito Parasites

Materials and Methods

According to Horsfall (1955), the parasites of mosquitoes are numerous and are often associated with more than one developmental stage.

Larval and adult mosquitoes were examined routinely for parasites with a stereoscopic microscope under 60X magnification. A few larvae, with parasitic water mites attached, were observed for several days in isolation vials in the laboratory. Data were recorded on the rate of infection of water mites on *Anopheles quadrimaculatus*, by examining all adults of this species for mites and recording the results.

Results

Parasitic water mites were recorded from females of *Aedes zoosophus* and *Anopheles quadrimaculatus*. Water mites were also found on the larvae of *Anopheles punctipennis* and *Anopheles quadrimaculatus* during the summer of 1958. The water mites parasitic on these species were *Arrenurus* sp.. During 1958, when precipitation was some 10 inches below normal, water mites of the Genus *Arrenurus* were observed a number of times on resting females of *Anopheles quadrimaculatus* near an impounded stream in the

Headquarters area. It is interesting to note that during the summer of 1959, when precipitation was much greater, the mite population became much smaller.

The data relative to the rate of infestation of the water mite Arrenurus sp. on the adults of Anopheles quadrimaculatus are presented in Table 6.

The water mite Thyas stolli Koenike 1895, was recorded from several adult females of Aedes zoosophus during July, 1959, members of the Genus. Thyas are in general dipteran parasites (Mitchell 1957). During this study Thyas stolli was observed only on the adults of Aedes zoosophus, but never on the larvae. As far as can be determined this is the first occurrence of Thyas stolli on Aedes zoosophus.

Discussion

It is a generally accepted fact that nearly all members of the Animal Kingdom are parasitized by other groups of organisms, and mosquitoes are no exception. Mosquitoes are parasitized by a variety of fungi (Empusa, Entomopthora, Trichophyton, Aspergillus, Coelomaomyces, Polyscytalum, and Saprolegniales), spirochaetes (Spirochaeta and Turchiniella), flagellates (Leptomonas, Crithidia, and Herpetomonas), microsporidia (Nosema, Thelohania, and Stempellia), gregarines (Lankesteria, Diplocystis, and Caulleryella), ciliates (Rhabdostyla, Epistylis, Scyphidia, Tetrahymena,and Vorticella), filarial worms, mermithid nematodes, trematodes, and numerous species of hydrachnid mites (Horsfall, 1955). The field of the relation between mosqui toes and their parasites has been reviewed at length by Steinhaus (1946).

The most abundant parasites encounted on mosquitoes during this study were hydrachnid mites (water mites), and it was observed that mosquito larvae were apparently not parasitized by these mites as often as the adults.

The reduction in mites during 1959, when precipitation was much greater, was probably attributable to the flushing of the stream during periods of heavy precipitation.

According to Mitchell (1957) the typical life cycle of the members of the superfamily Arrenurae begins with the hatching of the eggs, after which the larvae swim swiftly through the water in an erratic and undirected path. If a mosquito pupa is encountered, the larvae attach. It appears that the larvae are not directed or attracted to the host from any great distance. When the host imago emerges, the larvae again become active and crawl onto the adult host and attach themselves, often at a specific location. Later engorgement follows and distention of the integument occurs posteriorly and lateroposteriorly to the third coxae. It is believed that these mites, at the emergence of the adult mosquitoes, seek the soft parts of the adult hosts to which they cling (Uchida and Miyazaki, 1935). Observations made during this study suggest that the attachment of these mites to emerging adult mosquitoes is perhaps a matter of chance since none of the adults mosquitoes which were isolated and reared from parasitized larvae had mites attached upon their emergence.

According to Mitchell (1957) larvae of the Genus Thyas swim actively upon the surface of the water. Later the larvae locate the host pupae and attach themselves near the breathing horns of the pupa. When the imago emerges, the larval mites climb onto the adult host and dig in with their mouthparts before the cuticle is fully hardenend. Engorgement follows and the distention of the body occurs both anteriorly and posteriorly to coxae III.

Thyas stolli was recorded from adults of Aedes vexans, by Dr. R. M. Crowell (personal communication) in Wayne County, Ohio, during June and July, 1955.

Uchida and Miyazaki (1935) have presented similar observations upon water mites of the same genue in Japan; Arrenurus madaraski Daday was reported with a 57% infection rate when 219 Anopheles adults were examined.

In general the water mite belonging to the Genus Arrenurus was quite host specific on species of Anopheles, even though larvae of Culex erraticus were present in the same habitat. It is interesting to note that even though the Culex mosquitoes were often very abundant, these mites were never observed on the Culex larvae.

CHAPTER VII

GENERAL DISCUSSION

Mosquitoes larvae often form part of relatively simple communities, such as those found in tree holes, rock holes, temporary rain pools, and in a number of special situations associated with growing plants (Bates, 1949). It would seem that in such micro-communities, mosquito larvae are likely to be the dominant species due to their abundance and total bulk.

The most abundant larval mosquitoes collected were Aedes triseriatus and Aedes atropalpus, whereas the most abundant species of adult mosquitoes collected were Culex erraticus and Anopheles quadrimaculatus. It is significant to note that the permanent type habitats, in which the larvae of Culex erraticus and Anopheles quadrimaculatus were often collected, comprised only 10.5% of the total larval collections made during this study.

Regarding the habitats of the most abundant larvae (Aedes triseriatus and Aedes atropalpus) it should be pointed out that these species were most often collected from the tree holes and rock holes respectively. The reduced surface area, as compared to the lake and stream types of larval habitats, would seem to allow for a greater concentration of larvae per unit area.

The most numerous larval collections were made from the tree hole (22.6%), pooled stream (19.6%), and rock hole (13.6%) larval habitats, respectively, which was probably attributable to the fact that often during dry periods (especially during late summer) these larval habitats were the only ones which contained water.

Although Culex erraticus and Anopheles quadrimaculatus were found to be the most abundant adult species, it should be noted that a large percentage of these mosquitoes were resting adults which were collected during the diurnal period in the Headquarters area. My observations indicate that adults of species of Psorophora and Aedes were probably just as abundant as adults of species of Culex and Anopheles. The obscurity of the former species was probably attributable to the fact that resting sites are more dispersed and hidden; the latter species rest in a number of sites near their breeding sites during the diurnal period thus making adult collections relatively easy. Some species of Aedes and Psorophora are quite active during the diurnal period.

Regarding the larval associations, it has been observed that species which select the same types of habitats and whose larvae develop at the same rate, are often found associated (Table 3). Those which have a wide range of larval habitats would naturally be associated with the greatest number of other species. According to Senior-White (1926) the association of species in a particular habitat is determined by certain ecological factors of an obscure nature, but nevertheless fundamental to the problem of occurrence of larvae and even their distribution. It appears that larval associations represent the product of the interaction of all the physical and chemical factors associated with the larval habitats. In this study, the most abundant larval associations were recorded for Psorophora signipennis, Psorophora discolor, and Anopheles punctipennis collectively (Table 3).

The mosquito population found at the Refuge consists of those normally found in the grassland and deciduous forest biome. This is probably due to the fact that the area is an ecotone. Likewise since the winter is the unfavorable season for most species of mosquitoes and the summer the unfavorable season for other species such as Culiseta inornata and Culex tarsalis, several types of seasonal cycles were found which allowed for seasonal succession of larvae in specific larval habitats.

The selectivity of the oviposition site or the restricted occurrence of mosquito larvae in specific larval habitats was especially obvious in the case of the tree hole species (Aedes triseriatus, Aedes zoosophus, Toxorhynchites rutilus septenrionalis, Orthopodomyia alba, and Orthopodomyia signifera) and, to a less extent, the rock hole mosquito, Aedes atropalpus.

One of the most interesting problems remaining to be solved in the study of mosquitoes is the selection of oviposition sites by the female of the species. According to Rozeboom (1942), the concentration of larvae in definite water types can not be explained only on the basis of a survival of larvae in favorable water, for laboratory experiments have shown a rather delicate selectivity in oviposition by females offered several dishes of water differing only in their organic or inorganic content. On the other hand Bates (1949) has pointed out that laboratory experiments with oviposition behavior have, in general, given unsatisfactory results. The reactions of mosquitoes in the restricted and highly simplified environment of a cage often seems quite unrelated to the reactions that we know or suspect in nature; thus, almost all mosquitoes will lay eggs in almost any substrate containing water under specific cage conditions. Although selection from a series of oviposition sites can be demonstrated, the basis of the selection may be difficult to demonstrate, and the result may seem quite unintelligible. Laboratory experiments using varying amounts of chemicals in breeding water and variation of temperature of breeding water have not presented positive results relative to the selection of the oviposition site. The most clear-cut results in laboratory experiments concerning the selection of the oviposition site have been obtained with light and background color, suggesting that visual stimuli may play an important role in this reaction (Bates, 1949). It is conceivable that adult mosquitoes might disperse their eggs in all types of water, but the distribution of the larvae may be the result of a differential mortality in different types of breeding places.

Aedes atropalpus is much more abundant in the Wichita Mountains Wildlife Reufge than previously indicated in the literature. During the summer of 1958 and 1959, on numerous occasions 100 or more larvae were counted in a single dip from shallow rock holes.

The collection of such species as Anopheles barberi and Toxorhynchites rutilus septentrionalis extends westward the known State distribution of these species. Due to the large collection of adults and a few larvae of Aedes zoosophus, it appears that this species is much more abundant at the Refuge than previously indicated in the literature.

The occurrence of Orthopodomyia alba Baker constitutes a new State record and is the most westerly record known for this species in the United States. The recording of this species brings the total list of known species of mosquitoes in Oklahoma to fifty-three.

SUMMARY

The natural history of the mosquitoes of the Wichita Mountains Wildlife Refuge (Comanche County, Oklahoma) was studied from March 1, 1958 through February 29, 1960. A total of thirty-three species, distributed among two sub-families and ten genera was observed.

The following three types of larval habitats were designated: Permanent Habitats; Transient Habitats; Container Habitats. The transient and container types of larval habitats presented the largest number of larvae. Species associated with the transient type larval habitats usually completed their larval development in relatively short periods of time. However, Psorophora discolor was an exception to this statement. Perhaps the accelerated development can be attributed to the fact that these larval habitats are usually exposed to direct sunlight, which would directly affect the temperature of the water thus directly accelerating the rate of development. Larvae associated with the transient type of larval habitat were nearly always isolated or associated species of Aedes or Psorophora.

Only moderate numbers of Culex and Anopheles larvae were collected from the permanent types of larval habitat. Larvae were usually collected from these larval habitats when aquatic vegetation and intermittent shade were present. Collections from impoundments were fewer than anticipated. A comparison of Griffith's data (unpublished) with the data collected

during this study, suggests a marked decline in the abundance of Anopheles quadrimaculatus.

Hydracarina of the Genus Arrenurus were observed on larvae and adults of Anopheles quadrimaculatus, Anopheles punctipennis and on one female of Culex erraticus during this study. These mites were most abundant on females of Anopheles quadrimaculatus. The water mite, Thyas stolli was observed on females of Aedes zoosophus on a few occasions.

Laboratory experiments were performed on the pre-adult stages of several species of mosquitoes. The larvae of Orthopodomyia signifera, Orthopodomyia alba, Aedes triseriatus, Toxorhynchites rutilus septentrionalis, and Culiseta inornata were completely frozen. Of the above species, only the larvae of Toxorhynchites rutilus septentrionalis survived complete freezing at 21.5° F. for 44 hours. Orthopodomyia signifera, Aedes triseriatus, and Toxorhynchites rutilus septentrionalis overwinter as fourth instarllarvae, provided that water is available in tree holes during the hibernal period. During dry hibernal periods such as occurred during 1956, it appears that these species are also adapted to overwinter in the egg stage. Orthopodomyia alba and Culiseta inornata develop through various instars during the hibernal period.

Laboratory experiments suggest that the seasonal periodicity of tree hole species appears to be directly related to temperature; therefore, the effects of photoperiodism as presented by Baker (1935) were not cooroborated.

The occurrence of Orthopodomyia alba Baker constitutes a new State record and is the most westerly record known for this species in the United States. The addition of this species brings the total list of species known for the State of Oklahoma to fifty-three.

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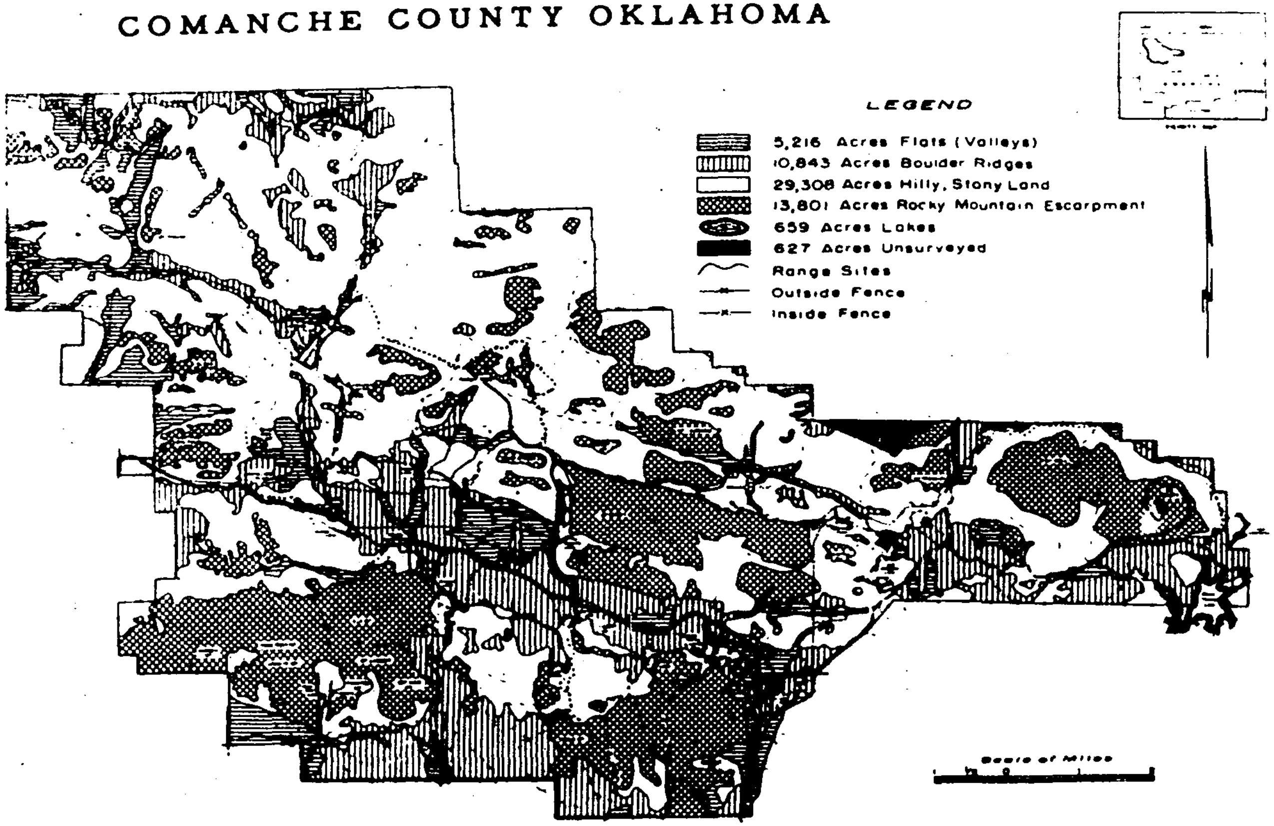
Map 1. RANGE SITES

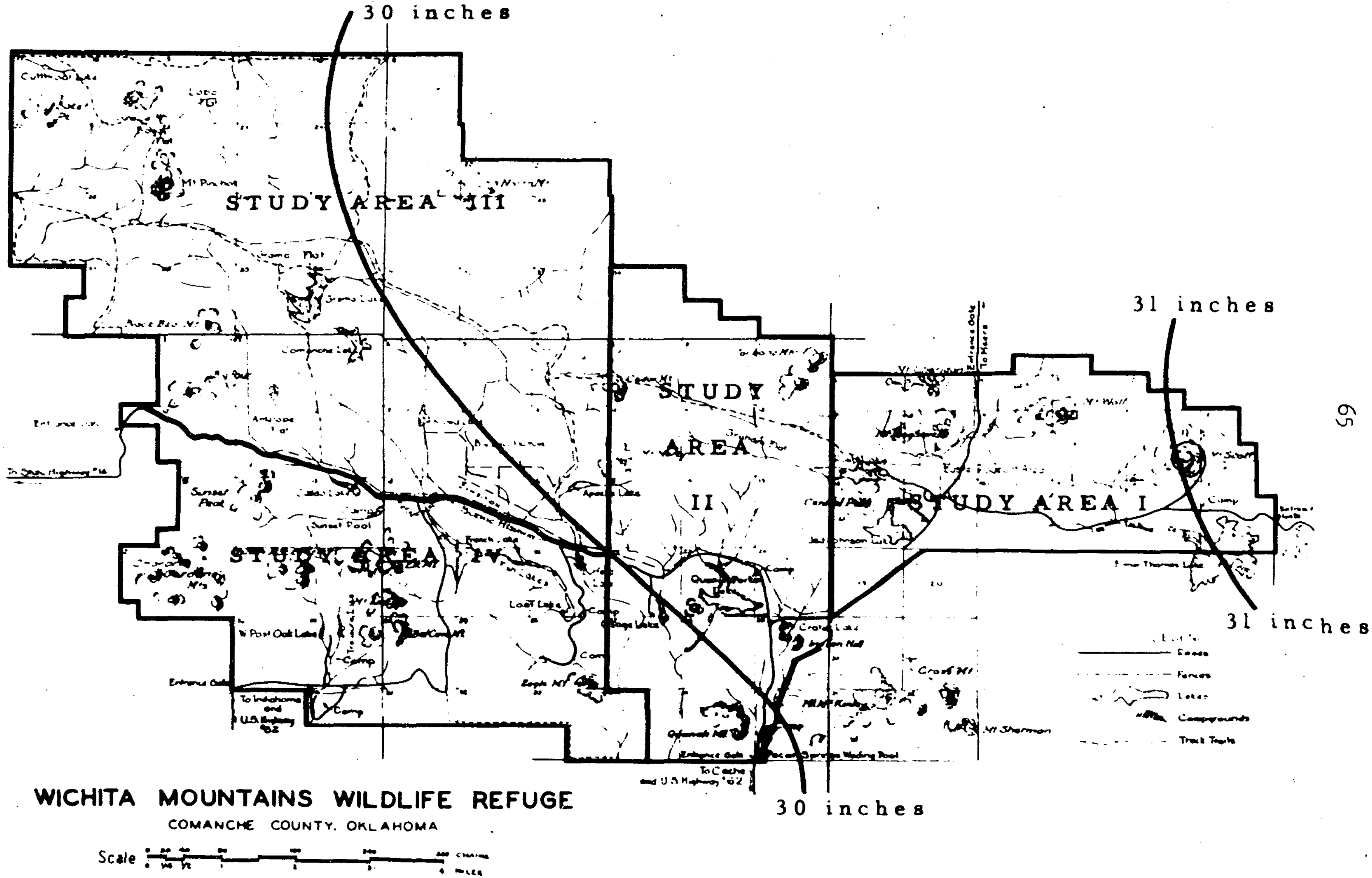
WICHITA MOUNTAINS WILDLIFE REFUGE

COMANCHE COUNTY OKLAHOMA

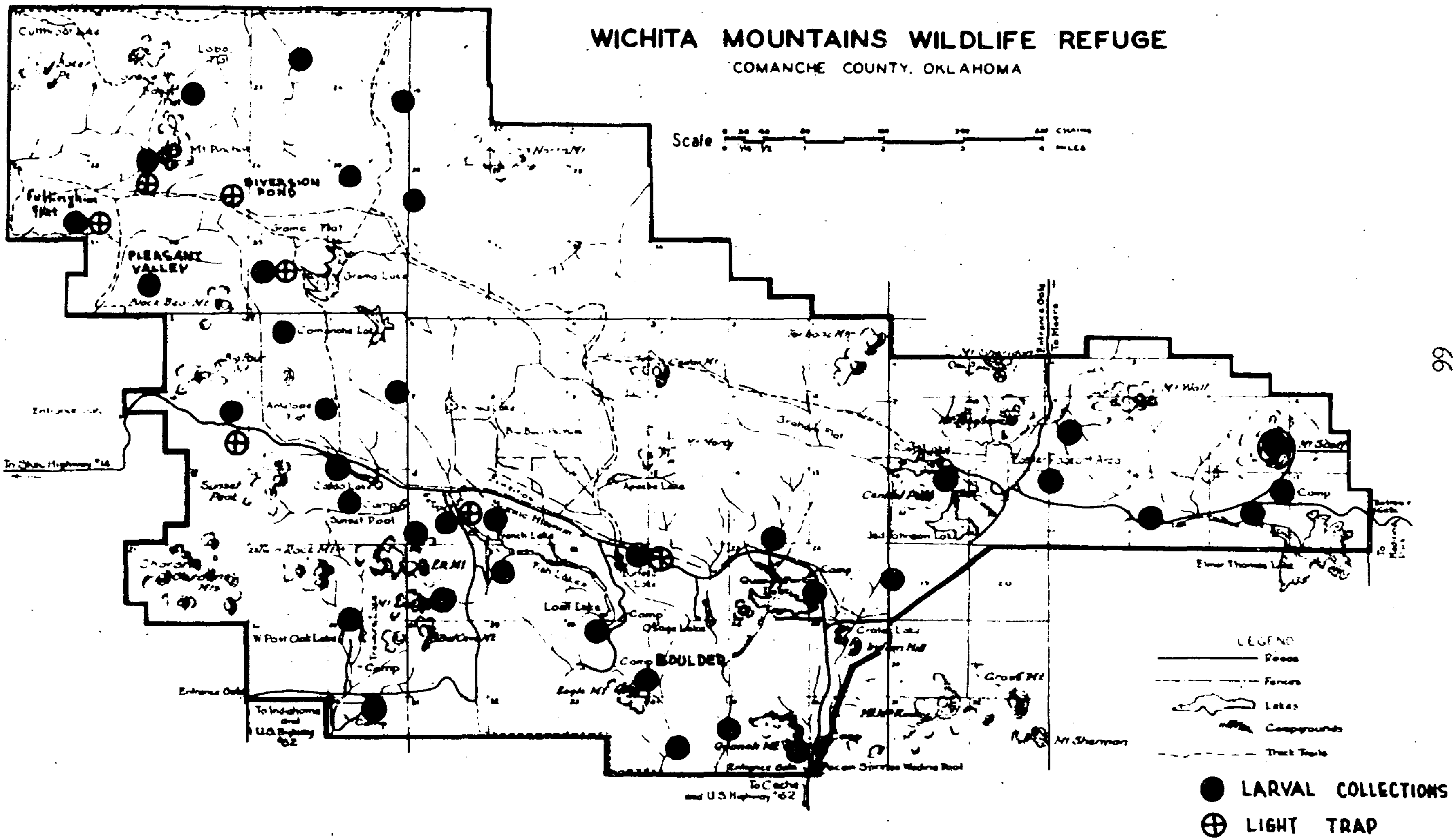


Map prepared by the U. S. Soil Conservation Corp.

Map 2. STUDY AREAS, assigned to facilitate larval survey, with annual precipitation indicated.



Map 3. The Wichita Mountains Wildlife Refuge with collecting sites indicated.*.



* Map prepared by the Branch of Engineering, 1956, for the Fish and Wildlife Service, Dept. of Interior.

Figure 1. Monthly Precipitation

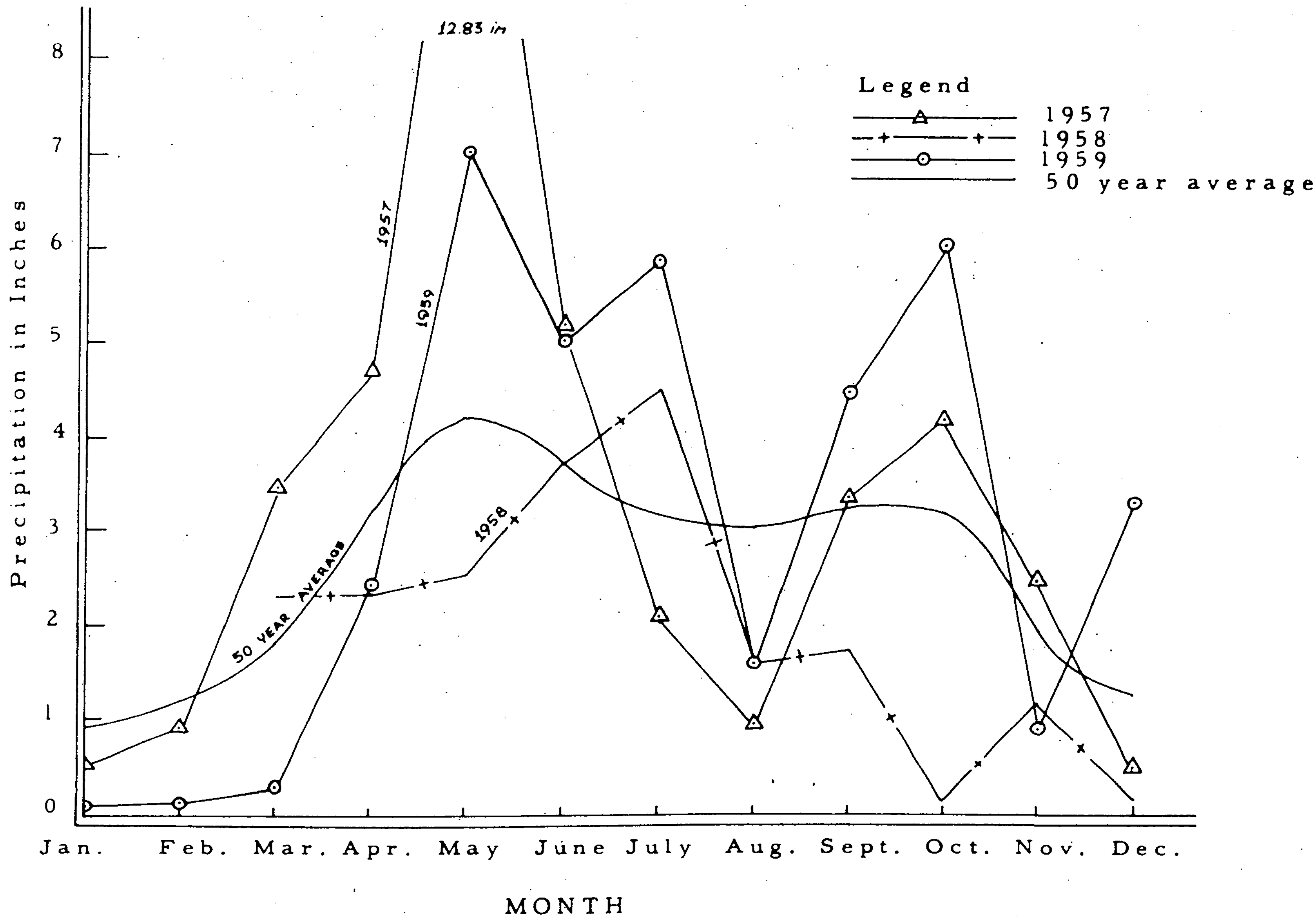
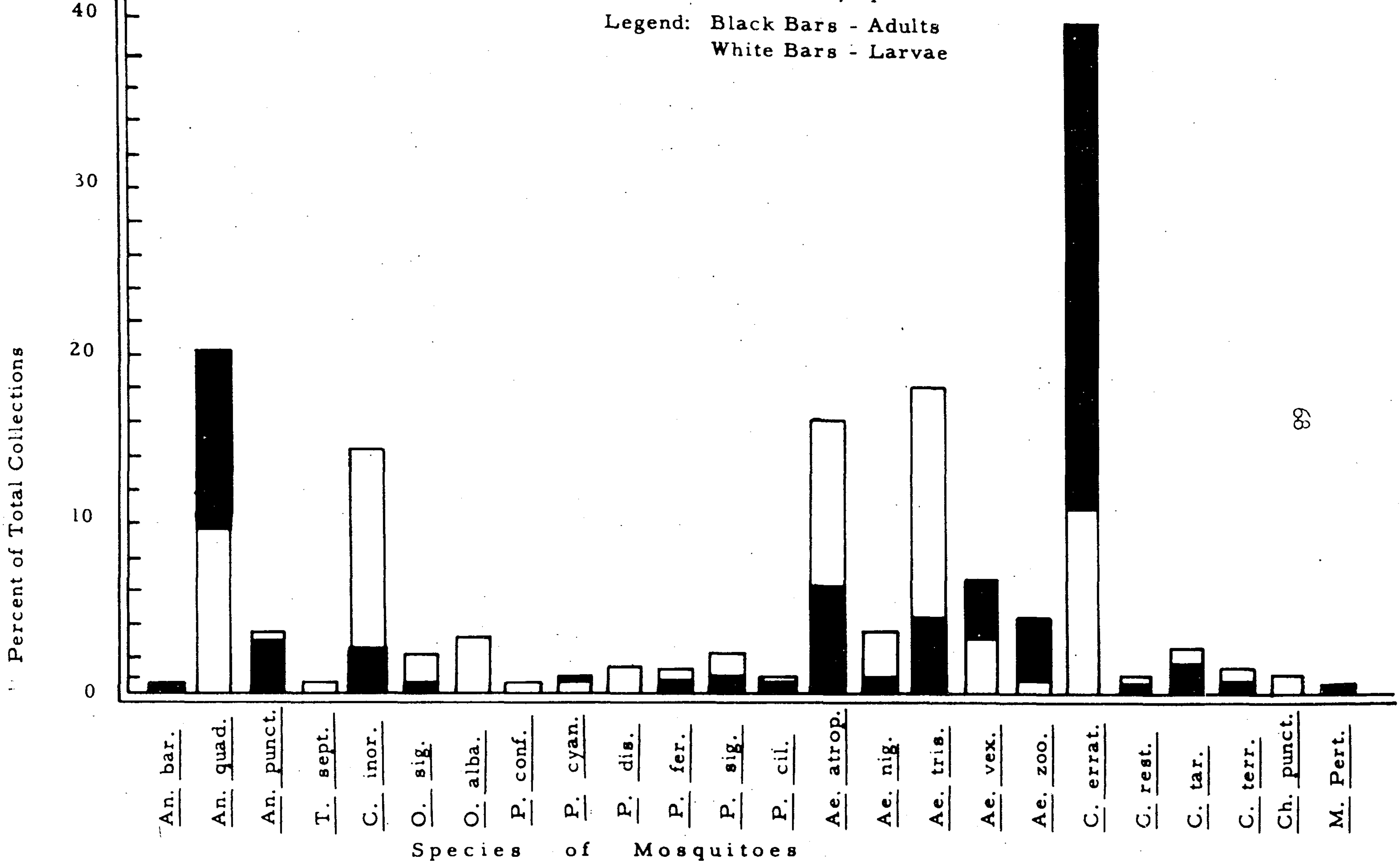


Figure 2. Percent of the Total Mosquitoes Collected by Species



* Relative percent of species collected below 2% of total collection not indicated.

Figure 3.
Monthly percent of the Total Mosquitoes Collected

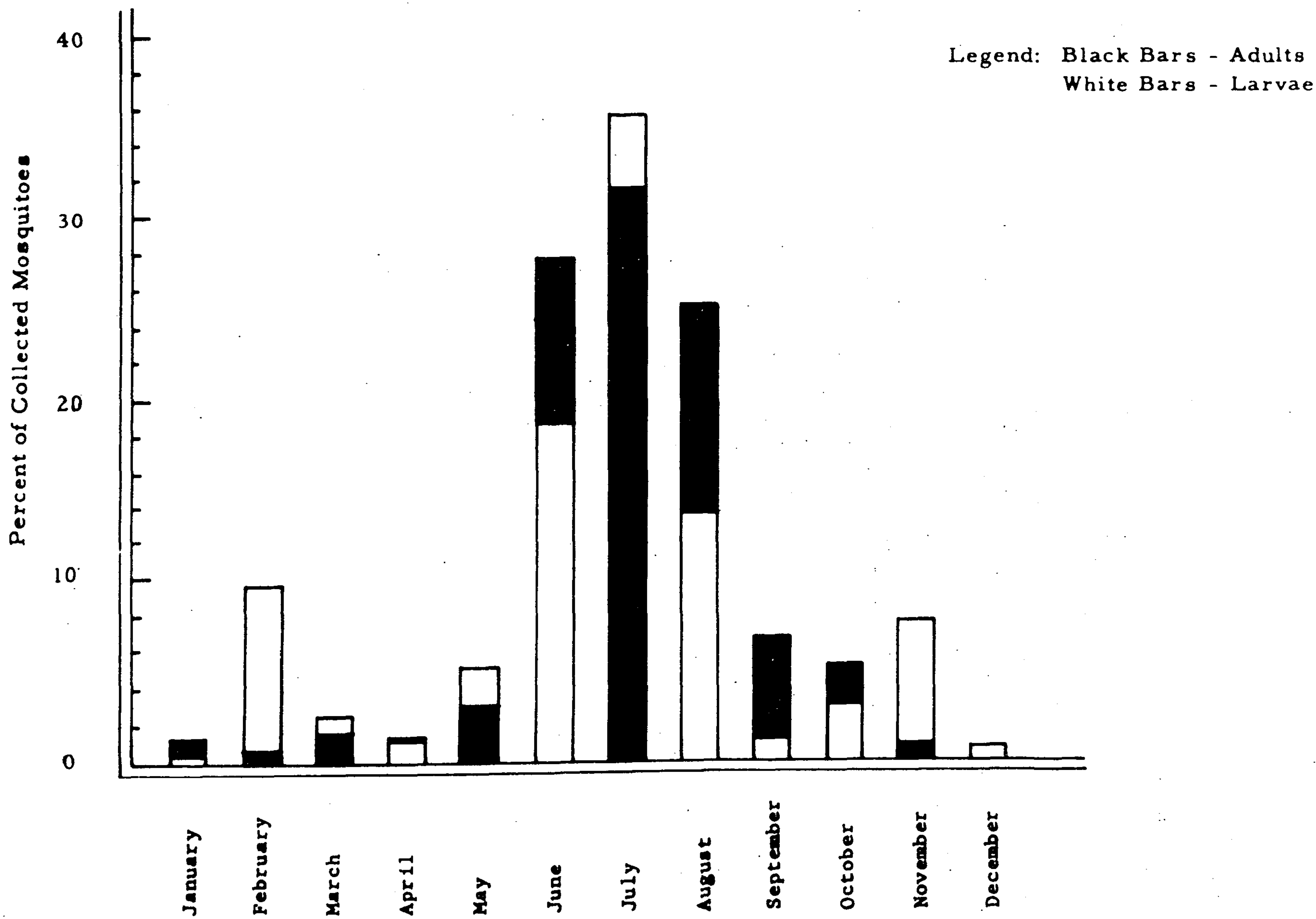
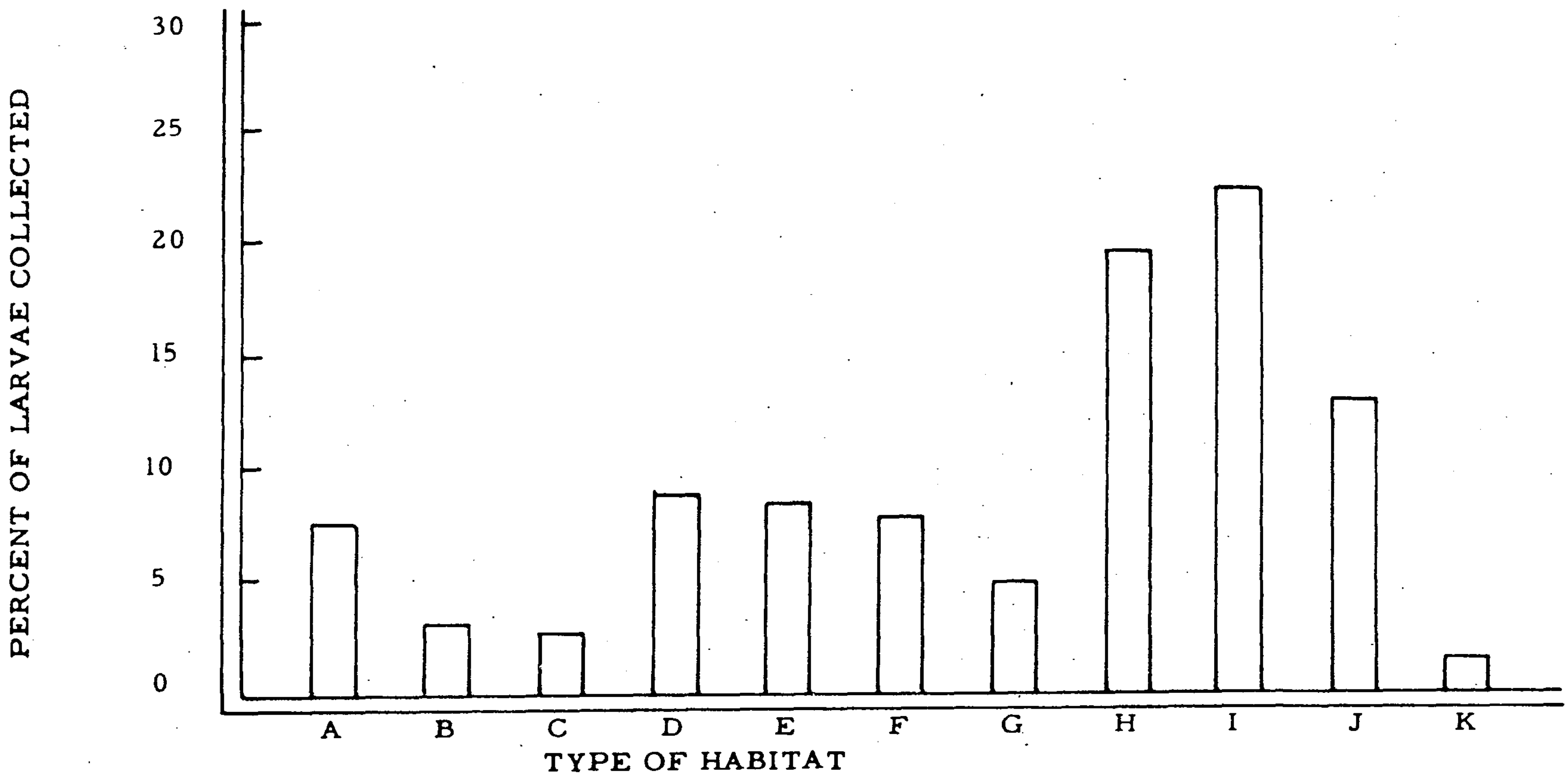
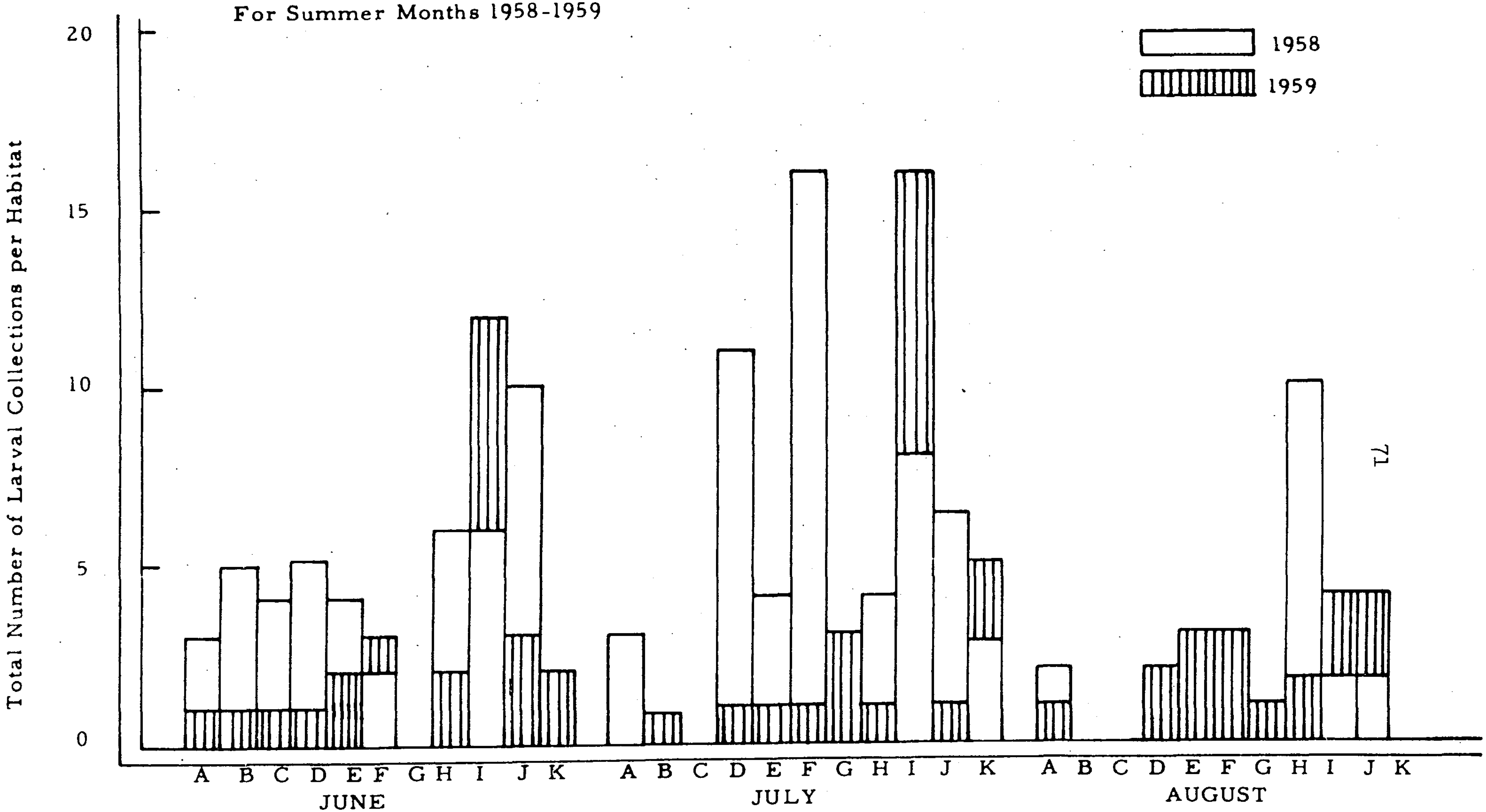


Figure 4.
Percent of Total Larval Collections by Type of Habitat



Legend:
A. Permanent Habitats
B. Open Mine Shaft
C. Seepages
D. Open Ground Pools
E. Barrow Pits
F. Drainage Ditches
G. Woodland Pool
H. Pooled Stream
I. Tree Holes
J. Rock Holes
K. Artificial Containers

Figure 5.
Total Number of Larval Collections from Specific Type Habitats
For Summer Months 1958-1959



Legend:
A. Lakes-streams
B. Mine
C. Seepages
D. Ground Pools
E. Roadside Ditch
F. Drainage Ditch
G. Woodland Pool
H. Pooled Stream
I. Tree Hole
J. Rock Hole
K. Artificial Container

TABLE 1

CLIMATOLOGICAL DATA (Temperature)

	Year												
	1957			1958			1959			1960			
Month	Av. Max.	Av. Min.	Av. Temp.	Av. Max.	Av. Min.	Av. Temp.	Av. Max.	Av. Min.	Av. Temp.	Av. Max.	Av. Min.	Av. Temp.	27 Yr.Av.*
January	48.2	22.7	35.4				49.5	23.6	36.6	48.3	27.4	37.8	39.6
February	57.8	36.2	47.0				56.6	30.2	43.4				43.9
March	58.2	35.5	46.8	53.3	31.2	42.3	68.5	36.1	53.3				51.0
April	68.2	45.2	56.7	68.9	47.1	58.5	78.8	47.7	62.3				61.0
May	76.3	56.2	66.2	81.9	59.2	70.6	83.7	60.3	72.0				68.1
June	86.1	62.7	74.4	92.0	65.6	78.8	83.3	65.0	76.7				77.5
July	98.4	71.6	85.0	93.6	68.6	81.0	89.9	65.9	77.9				82.1
August	95.8	67.5	81.6	96.8	68.1	82.5	95.9	68.6	82.1				82.1
September	86.0	55.2	69.1	86.7	62.9	74.8	87.8	61.9	74.9				74.2
October	69.7	45.9	57.8	77.4	50.3	63.9	72.0	47.0	59.6				63.1
November	56.7	34.8	45.2	66.5	36.7	51.6	58.3	30.7	49.5				49.1
December	58.9	31.0	44.9	52.7	36.2	39.5	55.6	38.5	44.6				41.3

*Long term means 1921 - 1950.

TABLE 2

OCCURRENCE OF LARVAE BY SPECIES AND TYPE OF LARVAL HABITAT

Species	Type of Larval Habitat*											Total Times Collected
	A	B	C	D	E	F	G	H	I	J	K	
Anopheles barberi									1			1
A. punctipennis	5	2	1			2		10		1		21
A. quadrimaculatus	8							22		4		34
Toxo. r. sept.									9			9
Chaoborus punctipennis							3					3
Culiseta inornata			1	2	3	2	3	7		5		23
Orthopodomyia alba									1			1
Orthopodomyia sig.									10		2	12
Psorophora ciliata			1			3	2					6
Psorophora howardii						1						1
Psorophora cyanescens				2								2
Psorophora ferox						1	8					9
Psorophora confinnis				1	1	1	1					4
Psorophora discolor				8	1	3	1	2				15
Psorophora signipennis	1			3	9	7						20
Aedes nigromaculis				4	8	3						15
Aedes atropalpus			6	1	3			1	2	35	3	51
Aedes triseriatus									53	1	1	54
Aedes zoosophus									7			7
Aedes vexans				8	2			1				11
Culex restuans								2				2
Culex tarsalis		2	2	3	2	4		5	1	2		21
Culex erraticus	8	7			1			20		1		37
Culex territans	5	1				1		2				9
Totals	27	12	11	32	30	28	18	72	83	48	6	367

*A. Shores of Lakes-Shallow Coves-Impounded Streams
B. Open Mine Shaft
C. Seepages
D. Open Ground Pools
E. Barrow Pits
F. Drainage Ditch
G. Woodland Pools
H. Pooled Streams
I. Tree Holes
J. Rock Holes
K. Artificial Containers

TABLE 3

LARVAL ASSOCIATIONS

SPECIES	A. barberi	A. punct.	A. quad.	T. r. sept.	C. inor.	O. sig.	O. alba	P. conf.	P. cyan.	P. disc.	P. ferox	P. howa.	P. sign.	P. cil.	A. atro.	A. nigro.	A. tris.	A. vex.	A. zoo.	C. errat.	C. rest.	C. tar.	C. terr.	Ch. punct.
A. barb.																	1							
A. punct.			8		2					1			2					2		8		10	2	
A. quad.		8											1							18			5	
T. r. sept.						3																		
C. inor.		2													8							5		
O. sig.				3													4							
O. alba						1																		
P. conf.										2			3	1				1						
P. cyan.																								
P. disc.	1							2			6		8	1		1				1		1	1	
P. fer.										6						1								2
P. howa.													1	1				1				1		
P. sign.	2	1						3		8	1	1		2	1	2		3		1		1	1	
P. cil.								1		1		1	2			1								
A. atro.					8								1	1			3			2		2		
A. nigro.									1		1		2	1								1		
A. tris.	1			4											3				2					
A. vex.		2						1				1	3								1	2		
A. zoo.																	2							
C. errat.		8	18							1			1		2					3				
C. rest.																		1						
C. tar.		10			5					1	1	1	1		2								3	
C. terr.		2	5							1		1											3	
Ch. punct.											2													

TABLE 4

SEASONAL DISTRIBUTION OF MOSQUITO LARVAE COLLECTED

Species	Month												Total
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Anopheles barberi							3						3
A. quadrimaculatus						83	98	177	5	110			373
A. punctipennis			3		18	30	40	45	5	4	3		148
Toxo. r. sept.	5				3		6				1		15
Culiseta inornata	3	233	67	8	4					4	222	12	553
Orthopodomyia sig.	4	18				12	14			32	3		83
Orthopodomyia alba		118											118
Psorophora confin.						10							10
Psorophora cyan.						22							22
Psorophora disc.						18	45	3		1			67
Psorophora ferox							41	2	8	12			63
Psorophora howardii						1							1
Psorophora sign.						17	64	2		3			86
P. ciliata						3	8						11
Aedes atropalpus			16	25	23	95	334	83	12	18	4		610
A. nigromaculis						20	59	60	2	3			144
A. triseriatus	3	6	11	16	58	156	356	60	2	66	8	2	684
A. vexans					23	63	22	12					120
A. zoosophus						3	18						21
Culex erraticus				3	12	140	203	60	1	2			421
C. restuans					35	8							43
C. tarsalis				8	23	5			3	20	45		104
C. territans			1			28	14	8	2	1			54
Chaoborus punct.							30	12					42
Totals	15	375	98	60	199	714	1305	524	40	116	286	14	3796

TABLE 5

SEASONAL DISTRIBUTION OF ADULT SPECIMENS COLLECTED*

Species	Month												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Anopheles barberi							2	5					7
Anopheles crucians						(3)		3					3
A. quadrimaculatus	9					223	303	99	36	5			675
						(1)	(1)						
A. punctipennis	3					30	43	20	7	2	3		108
					(1)	(108)	(37)		(1)	(1)			
Toxo. r. sept.						3							3
Uranotaenia sapph.										3			3
					(1)		(1)						
Culiseta inornata	3		2	5						71	4		85
				(15)	(2)								
Orthopodomyia sig.						3	7	2					12
				(1)	(3)								
Mansonia perturbans						4	3						7
				(11)	(1)	(17)	(57)	(1)	(1)				
Psorophora ciliata							13			5			18
						(2)							
P. confinnis	3					10	3	6					22
						(1)							
P. cyanescens						22		3					25
					(1))	(1)							
P. discolor								4					4
					(4)	(4)	(15)						
P. ferox						2	1	25					28
						(1)							
P. howardii							5						5
P. signipennis						11	19	2					32
				(4)	(9)	(6)	(35)						
Aedes atlanticus or Aedes tormentor						1							1

TABLE 5 CONTINUED

SEASONAL DISTRIBUTION OF ADULT SPECIMENS COLLECTED

Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Total
Aedes atropalpus				3	12 (5)	82 (1)	80 (16)	28	3	5	8		221
A. c. canadenesis						1	21						22
A. nigromaculis					(12)	19 (2)	17 (16)	1	2				39
A. stictus					(1)								
A. triseriatus				8	33 (17)	58	32 (2)	13					144
A. trivittatus					(7)			1 (17)					1
A. vexans				(2)	(117)	99 (45)	38 (776)	82	3	38			260
A. zoosophus					(6)	51 (23)	62 (114)	61	1	4			179
A. dorsalis								1					1
Culex erraticus	4					255 (6)	390 (658)	472 (17)	160	37	(1)		1318
C. restuans						18							18
C. salinarius				(2)	(19)	2 (7)		2	1				5
C. tarsalis			3	7 (29)	4 (107)	18 (43)	7 (908)	(3)	9 (1)	12			60
C. territans	2				(4)	18 (10)	4 (36)	6					30
C. quinquefasciatus or C. pipiens						3		1					4
Totals	21		5	23	49	933	1050	837	222	182	15		3340

*Griffith (unpublished) light trap data in parentheses.

TABLE 6

INFESTATION RATE OF *ARRHENURUS* sp. (WATER MITES) ON

ADULTS OF *ANOPHELES QUADRIMACULATUS*

Number of parasites per host	Number of host examined	Percentage of parasitism
50-59	1	0.14
40-49	1	0.14
30-39	1	0.14
20-29	5	0.74
10-19	6	0.88
1- 9	39	5.77
0	622	92.1