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The Mosquitoes of Utah

BY

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PREFACE

In the preparation of this bulletin, an effort has been made to bring together what is known about the mosquito fauna of Utah. Prior to the initiation of the present investigation, very little work had been done in the state in connection with this important problem. The available information on the mosquitoes of Utah, before 1928, consisted of a few published collection records of some of the more common species, and a description of one new species taken in the vicinity of the Great Salt Lake and described by Dyar and Knab, 1918.

No extensive work on mosquito control was undertaken in Utah until the Salt Lake City Mosquito Abatement District began operations in 1926. The author became connected with this work in 1928. It had become apparent by this time, that without some knowledge of the systematics and biology of the mosquito species against which the work was directed, it would be impossible to secure satisfactory results. Consequently, this study was initiated as a basis for supplying a biological background necessary for effective control. This bulletin, however, is concerned entirely with the biological results which have been ascertained and any economic considerations are but incidental. The investigation in 1929 was extended by the author to include the mosquito fauna of the state. This work is still in progress.

The size of the state has made it difficult to collect mosquitoes in all localities at different times during the breeding season, but several collections have been made in all parts of the state and all principal types of localities. In addition, systematic collections have been made once a week, throughout the season, in the different types of mosquito habitats in the vicinity of Salt Lake City. From these data, certain important facts have been determined by the writer as to the species present in Utah and their biological characteristics.

Additional information will be obtained and, in all probability, other species added to the list of Utah mosquitoes as the investigation continues.

The author acknowledges the assistance of others that have made these studies possible. It is with regret that many of them must of necessity be referred to by groups.

I am particularly indebted to Dr. R. V. Chamberlin for assistance and guidance, and whose encouragement and interest has made it possible to continue this investigation. I sincerely appreciate the suggestions and help of Professor G. F. Ferris of Stanford University, in arranging the material.

Major J. A. LePrince, W. H. W. Komp, of the United States Public Health Service, and Dr. T. J. Headlee and co-workers in New Jersey, have been very helpful with advice and suggestions during the course of this study. Others to whom the author is obligated are: Dr. Alan Stone of the Federal Bureau of Entomology and Plant Quarantine, for checking certain identifications; the Salt Lake City Mosquito Abatement District for access to their records and permission to use the material; the University of Utah, Utah State Agricultural College, Brigham Young University and the Federal and State Pest Mosquito Control Projects, for access to their mosquito collections and records. Also the following individuals for collections made for the author in various parts of the state: A. C. Randle, Dr. G. F. Knowlton, Dr. J. S. Stanford, Dr. W. J. Gertsch, Dr. J. A. Rowe, Dr. B. E. Rees, Prof. S. D. Durrant, A. R. Gaufin and T. L. Nielsen. I am also indebted to Mr. Nielsen and other N.Y.A. student help for some of the drawings used in this publication and for the typing and final preparation of the manuscript. The author extends thanks and appreciation to the above mentioned and to all students and friends who have assisted in this work.

Finally acknowledgement is made to the University of Utah Research Committee for appropriating from the fund under its control the money required for the publication of this bulletin.

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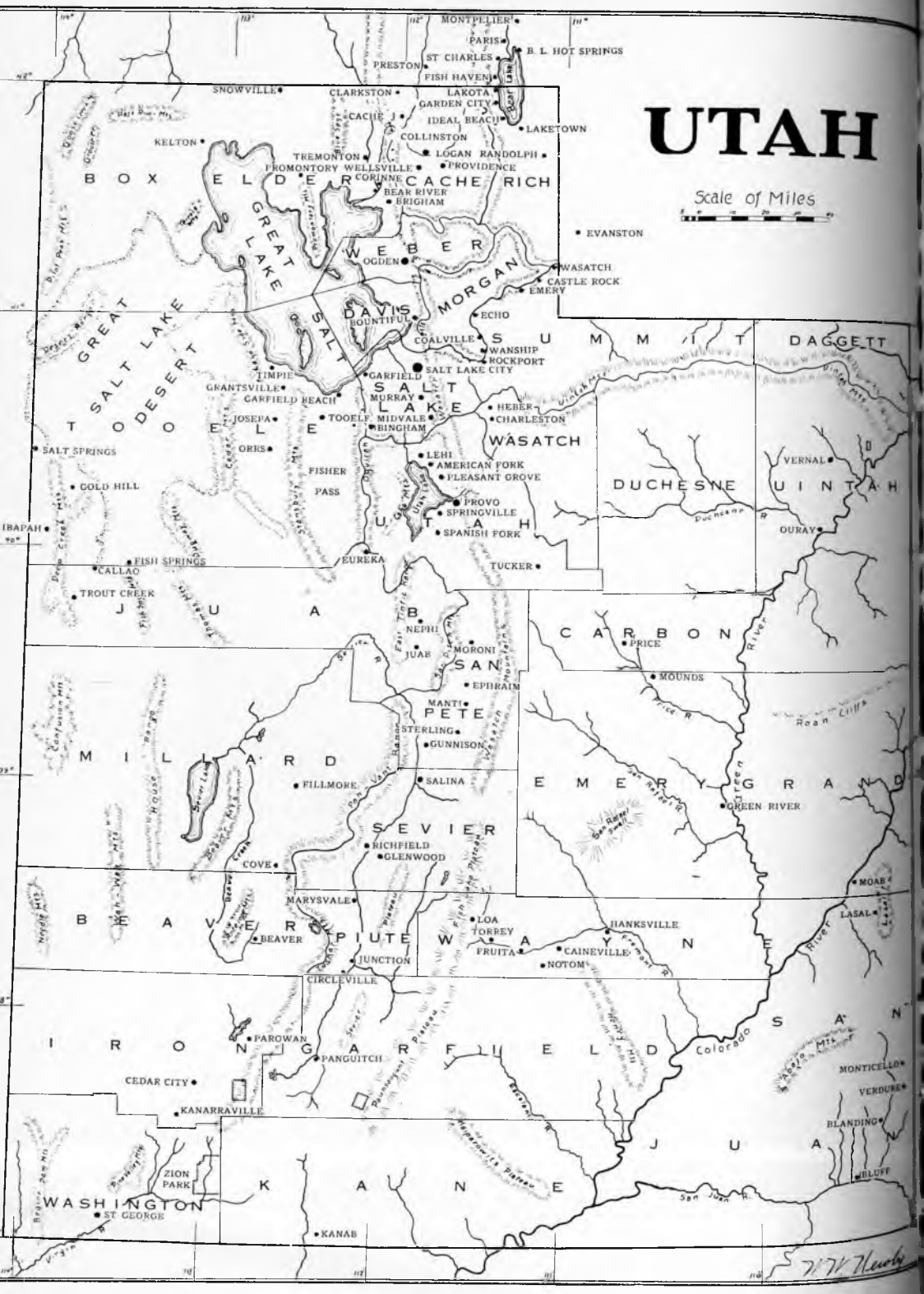
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KANAB
San Juan R.

The Mosquitoes of Utah

INTRODUCTION

The term "mosquito" used in its broad sense covers many species, each with a separate identity and distinctive biology. An organism is frequently referred to as "known" after it has been named and briefly described, when as a matter of fact, nothing is known about its biology.

In this bulletin, the treatment of each species includes: (1) a brief description of the adult females, male genitalia, and larvae; (2) a statement of the distribution throughout the state and association with other species; (3) the life history as far as determined; (4) the importance of the species in the state. Additional problems such as abundance, seasonal prevalence, feeding habits, time of activity, and flight range have been considered for each species and available information included.

This brief treatment of the biology of each species is of necessity only a summary of facts and represents conclusions drawn by the author from extensive collections, observations, and field notes accumulated during the past twelve years. It has not seemed necessary nor desirable to present a list of collection records, since such a list would amount to several hundred citations for most species and would unnecessarily lengthen the bulletin. These data are simply included in general statements, but extreme care has been taken to make this summary portray, as accurately as possible, the available information.

The descriptions and keys for indentifications have been arranged in part from the work of other investigators, particularly Howard, Dyar and Knab (1912-17); Dyar (1922); Freeborn (1926); Dyar (1928); Matheson (1929); Mail (1933); and Owen (1937). All specimens were identified by the author from adults, male genitalia, and larvae, when material was available. Doubtful identifications were verified by Dr. Alan Stone of the United States Bureau of Entomology and Plant Quarantine. The species considered are alphabetically arranged by genera and species without regard to phylogenetic order.

The present list consists of thirty-one species grouped in genera as follows:

Aedes Meigen	19
Anopheles Meigen	3
Culex Linnaeus	6
Theobaldia Neveu-Lemaire	3

The following species have been reported from the state but have not been collected by the author: *Anopheles quadrimaculatus* Say, Howard, Dyar and Knab (1912-1917, p. 1032); *Culex stigmatosoma* Dyar, (1928, p. 369).

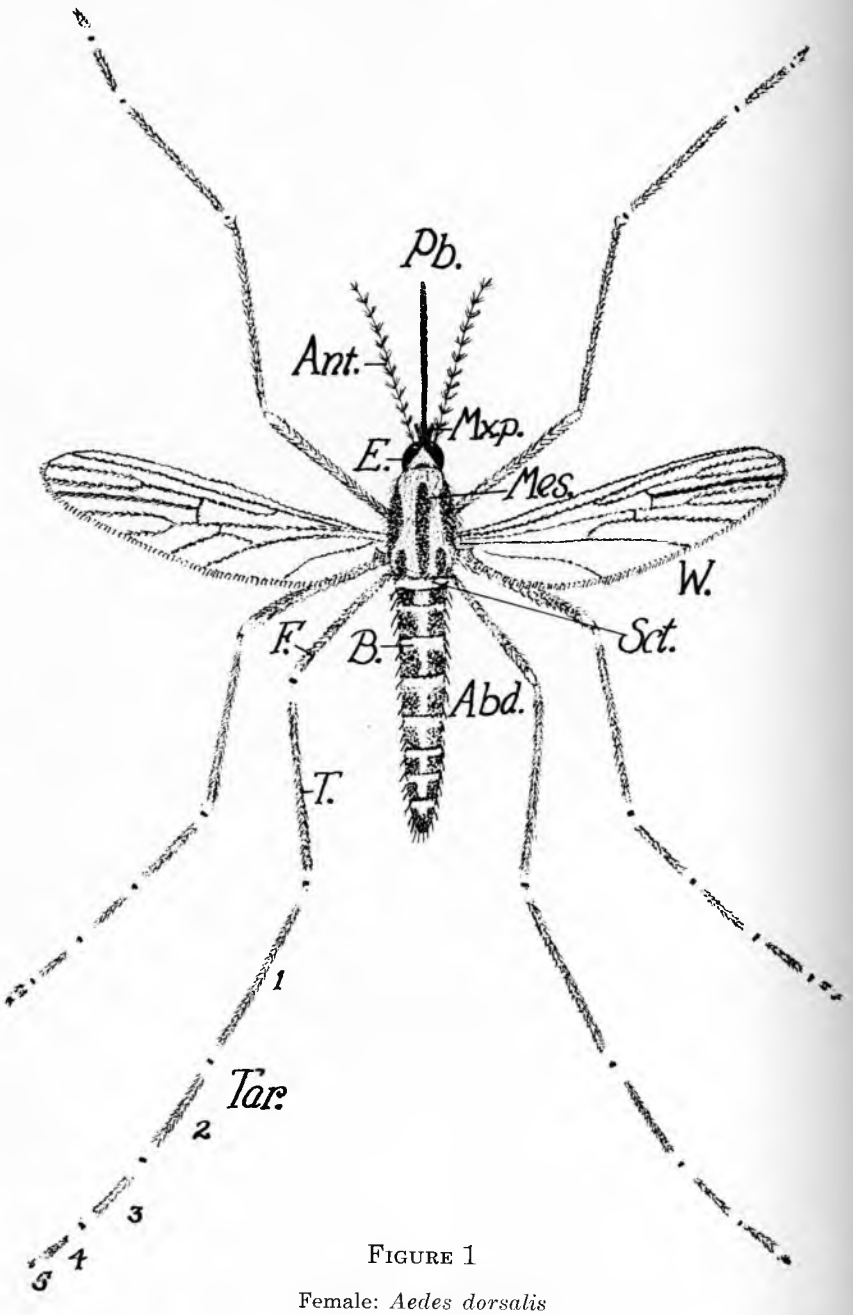


FIGURE 1

Female: *Aedes dorsalis*

Abd.	Abdomen	F.	Femur	Sct.	Scutellum
Ant.	Antenna	Mes.	Mesonotum	T.	Tibia
B.	Basal band	Mx.p.	Maxillary palpus	Tar.	Tarsus with five joints
E.	Eye	Pb.	Proboscis	W.	Wing

Collecting, Rearing and Preparation of Material

Larvae were collected in a round-bottomed pint ladle. An oval hole was punched in the side of the ladle just below the rim and covered with a brass screen held in place by solder. When larvae were dipped up in the ladle, the excess water was poured off through the screen and the larvae retained in the ladle where they were counted, examined and samples poured into pint bottles. Collection data written in pencil was placed in each bottle with the larvae. The bottles were never sealed with lids or stoppers but rag waste was sometimes used to prevent the water from splashing out of the bottles.

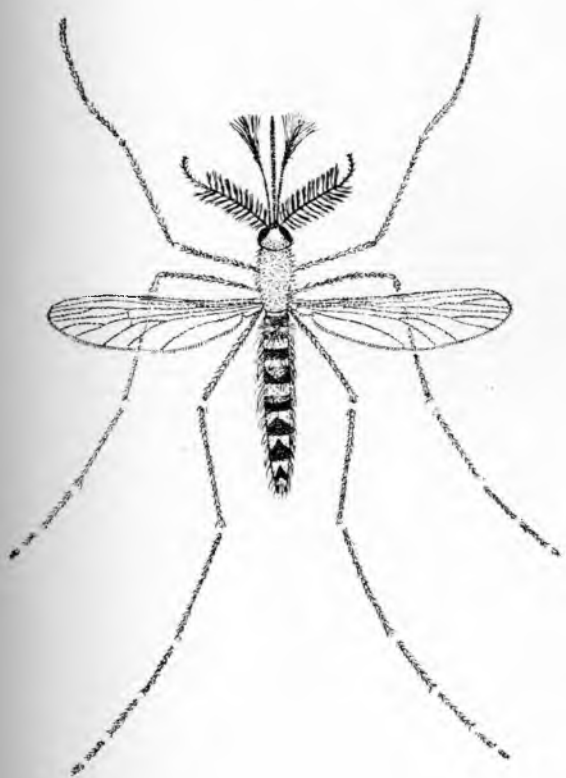


FIGURE 2

Male: *Aedes vexans*

In the laboratory, the larvae were reared in open mouthed jars ranging in size from vials to battery jars, depending upon the number of larvae or the instar. The larvae, when possible, were reared in water from the breeding pool from which they were taken. Additional food was sometimes supplied in the form of a few drops of pond scum. The top of each jar was covered with cardboard with a two-inch hole in the center. A lamp chimney with mosquito netting over the top was placed over the hole. As the adults emerged, they were collected in the lamp chimney, where they were permitted to live thirty-six to forty-eight hours before pinning. Isolated larvae were reared at times in vials to obtain the larval skins. Larvae, larval skins and pupae were preserved for study purposes in No. 2 vials in a solution of 80 percent alcohol. Some larval specimens were also preserved as balsam mounts.

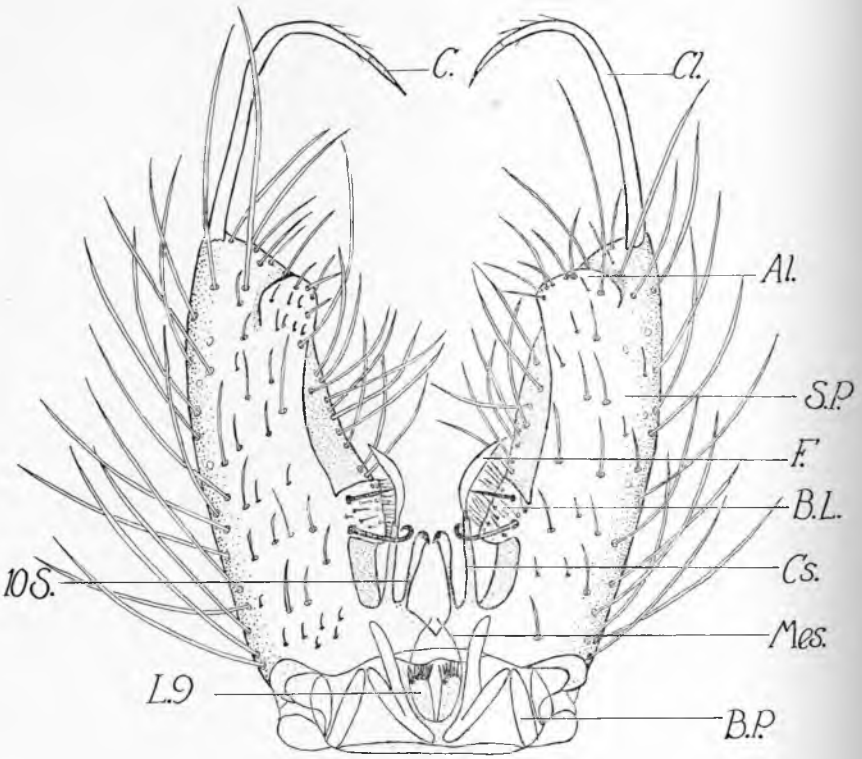


FIGURE 3

Male Hypopygium: *Aedes dorsalis*

A.L.	Apical lobe	Cl.	Clasper	L.9.	Lobes of ninth tergite
B.L.	Basal lobe	Cs.	Claspette stem	10 S.	Tenth sternite
B.P.	Basal plate	F.	Claspette filament	S.P.	Side-piece
C.	Claw	Mes.	Mesosome		

Adults were collected in aerial and sweeping nets, light traps, houses, outbuildings, and while feeding on man and animals. The adults were killed in chloroform jars, relaxed and mounted on minuten pins. The chloroform jars were made by cutting rubber bath sponges to fit the jar, moistening the sponges with chloroform and covering with blotting paper.

Male hypopygia were prepared as follows: The abdomens were clipped from the adults and gently boiled in ten percent KOH until clear. The length of time necessary was determined by examining the specimens at intervals as the boiling proceeded. The time varied from one to twenty minutes, depending upon the species. The specimens were then slowly boiled in water for one minute, then transferred to 95% alcohol for five minutes. The abdomens were then passed into carbol-xylene for two minutes. The hypopygium was cut from the

abdomen and mounted in thin balsam between two one-inch square cover glasses. The cover glasses containing the mount were inserted in an aluminum slide with a three quarter-inch round hole in the middle of the slide, so that the hypopygium could be examined from both sides by simply turning the slide over. The aluminum slides were turned under one sixteenth of an inch along the two edges, thus forming a slot for the cover glasses. The cover glass mount was held in place over the hole by cardboard plugs, the size of a slide label, inserted in the slot at each end.

Eggs were obtained by capturing feeding adults in jars provided with a metal cone. The adults were transferred to vials containing damp cellucotton on which they oviposited. A much higher percentage oviposited when the cellucotton was moistened with water from the breeding area where the adults were collected. Egg rafts of *Theobaldia* were frequently taken in the field. All eggs were preserved within vials in 2% formalin solution or 85% alcohol.

Ant. Antenna
E. Eye
H. Hypopharynx
Lb. Labium
Le. Labrum epipharynx
Md. Mandible
Mx. Maxilla
Mx.p. Maxillary palpus
Clp. Clypeus
V. Vertex

FIGURE 4

Head of Female Mosquito with Mouthparts Exposed

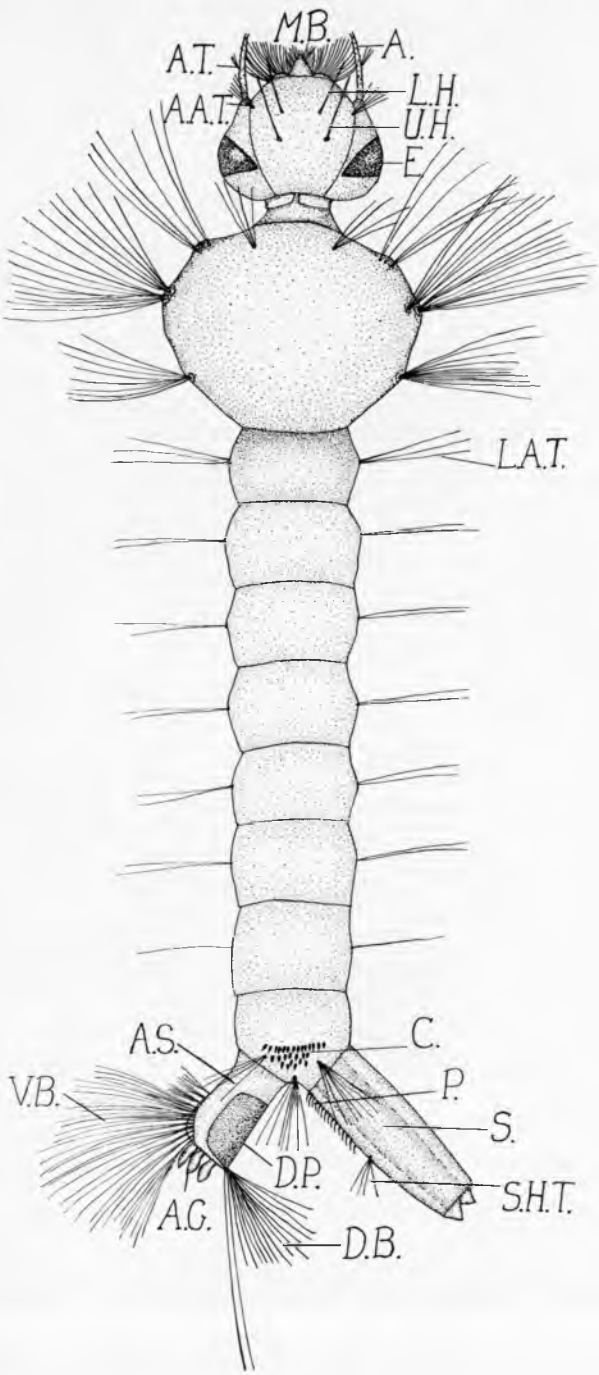


FIGURE 5

Larva: *Aedes dorsalis*

A.	Antenna
A.T.	Antennal tuft
A.A.T.	Anteantennal tuft
A.G.	Anal gills
A.S.	Anal segment
C.	Comb
D.B.	Dorsal brush
D.P.	Dorsal plate
E.	Eye
L.H.	Lower head hairs
M.B.	Mouth brushes
P.	Pecten
S.	Siphon or air-tube
S.H.T.	Hair tuft
U.H.	Upper head hairs
V.B.	Ventral brush

LIST OF UTAH MOSQUITOES, THEIR SYSTEMATIC POSITION AND RELATIVE ABUNDANCE

(Arranged according to Dyar)

Genus AEDES Meigen

Sub-genus **Ochlerotatus** Lynch Arribalzaga

Group Aurifer

Aedes pullatus (Coquillett)	Common
Aedes intrudens Dyar	Fairly rare

Group Punctor

Aedes hirsuteron (Theobald) (Syn. *Aedes sticticus* (Meigen))	Common
Aedes idahoensis (Theobald)	Fairly common
Aedes spencerii (Theobald)	Fairly common
Aedes punctor (Kirby)	Common

Group Communis

Aedes cataphylla Dyar	Common
Aedes niphadopsis Dyar and Knab	Common
Aedes communis (De Geer)	Common

Group Dorsalis

Aedes campestris Dyar and Knab	Common
Aedes dorsalis (Meigen)	Very abundant

Group Flavescens

Aedes excrucians (Walker)	Fairly rare
Aedes increpitus Dyar	Fairly rare
Aedes flavescens (Müller)	Rare
Aedes stimulans (Walker)	Fairly common
Aedes fitchii (Felt and Young)	Fairly common

Sub-genus **Taeniorhynchus** Lynch Arribalzaga

Aedes nigromaculis (Ludlow)	Common

Sub-genus **Aedimorphus** Theobald

Aedes vexans (Meigen)	Very abundant

Sub-genus **Aedes** Meigen

Aedes cinereus Meigen	Fairly rare

Genus CULICELLA Felt

(Syn. THEOBALDIA Neveu-Lemaire)

Sub-genus **Culiseta**

Theobaldia inornata (Williston)	Very abundant
Theobaldia impatiens (Walker)	Fairly common
Theobaldia incidens (Thomson)	Common

Genus CULEX Linnaeus

Sub-genus **Culex** Linnaeus

Culex stigmatosoma Dyar	Rare
Culex salinarius Coquillett	Rare
Culex erythrothorax Dyar	Fairly common
Culex territans Walker (Syn. *Culex restuans* Theobald)	Rare
Culex pipiens Linnaeus	Fairly rare
Culex tarsalis Coquillett	Very abundant

Genus ANOPHELES Meigen

Sub-genus **Anopheles** Meigen

Anopheles pseudopunctipennis Theobald	Common in Southern Utah
Anopheles maculipennis Meigen (Syn. *Anopheles freeborni* Aitken)	Abundant
Anopheles quadrimaculatus Say	Rare

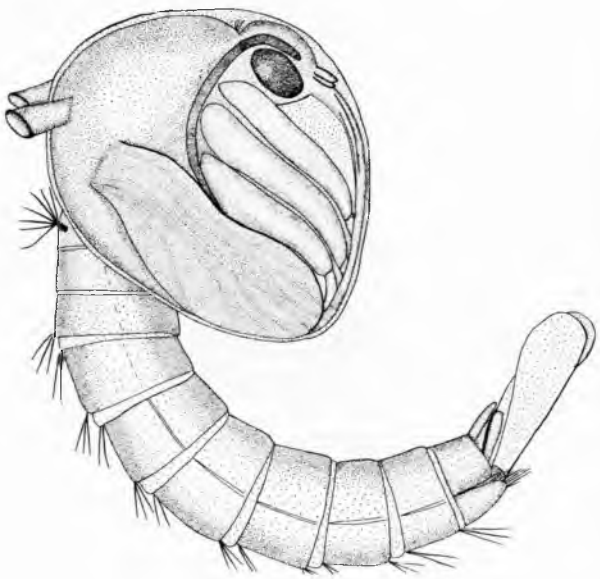


FIGURE 6

Pupa

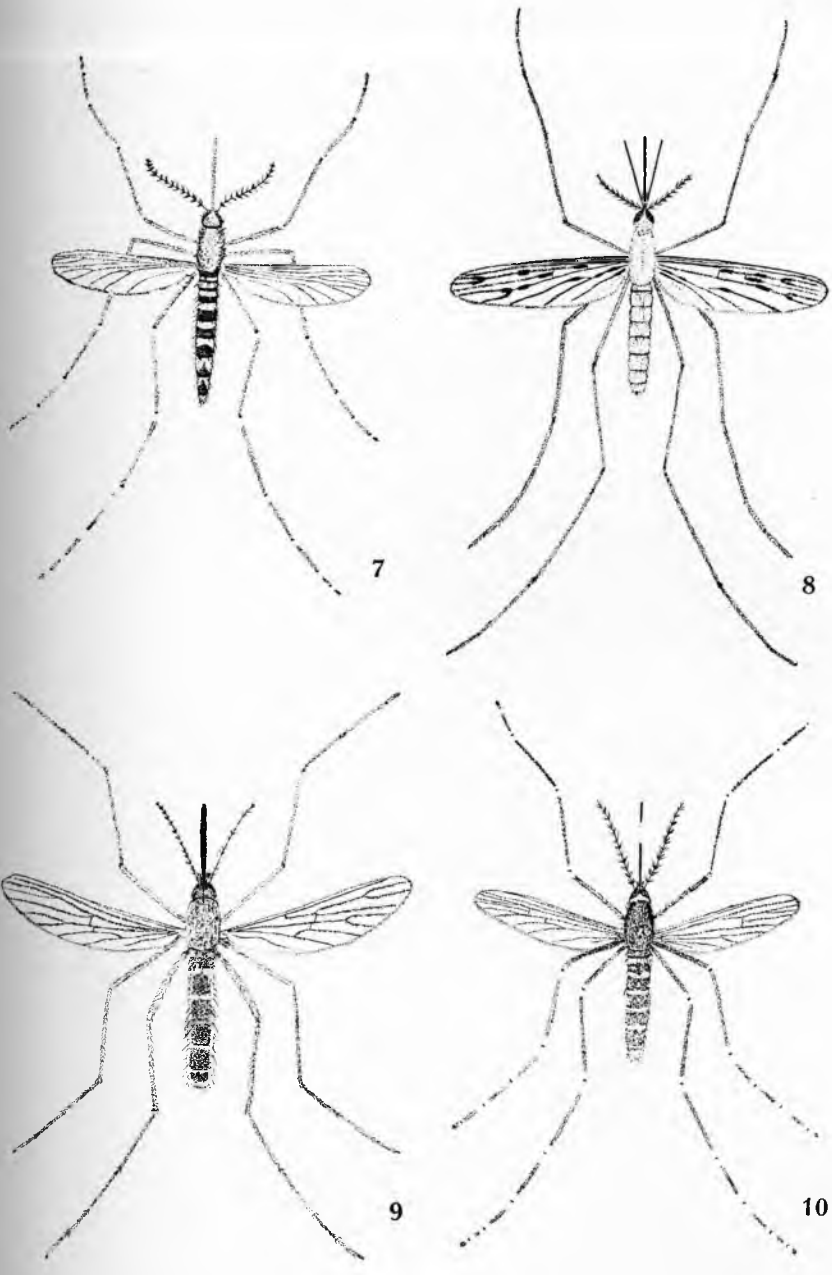


PLATE I

Females:

7. *Aedes vexans*
8. *Anopheles freeborni*
9. *Theobaldia inornata*
10. *Culex tarsalis*

Plate II

Lateral Aspect of the Thorax of:

11. *Aedes dorsalis* (Meigen)
12. *Anopheles freeborni* Aitken
13. *Culex tarsalis* Coquillett
14. *Theobaldia inornata* (Williston)

Mn.	Mesonotum	Sp.	Spiracle
Pa.B.	Prealar bristles	Sp.B.	Spiracular bristles
P.B.	Posterior pronotal bristles	Sc.	Scutellum
P.Sp.B.	Post-spiracular bristles	Stp.B.	Sternopleural bristles
Pn.	Postnotum	L.Me.	Lower mesepimeron

L.Me.B. Lower mesepimeral bristles

15. Wing of *Aedes dorsalis*

VEINS:		CELLS:	
C.	Costal	a.	Subcostal
Sc.	Subcostal	b.	1st marginal
R.	Radius	c.	2nd marginal
M.	Medius	d.	Submarginal
Cu.	Cubitus	e.	1st posterior
A.	Anal	f.	2nd posterior
Cv.	Cross vein	g.	3rd posterior
		h.	4th posterior
		j.	Anal

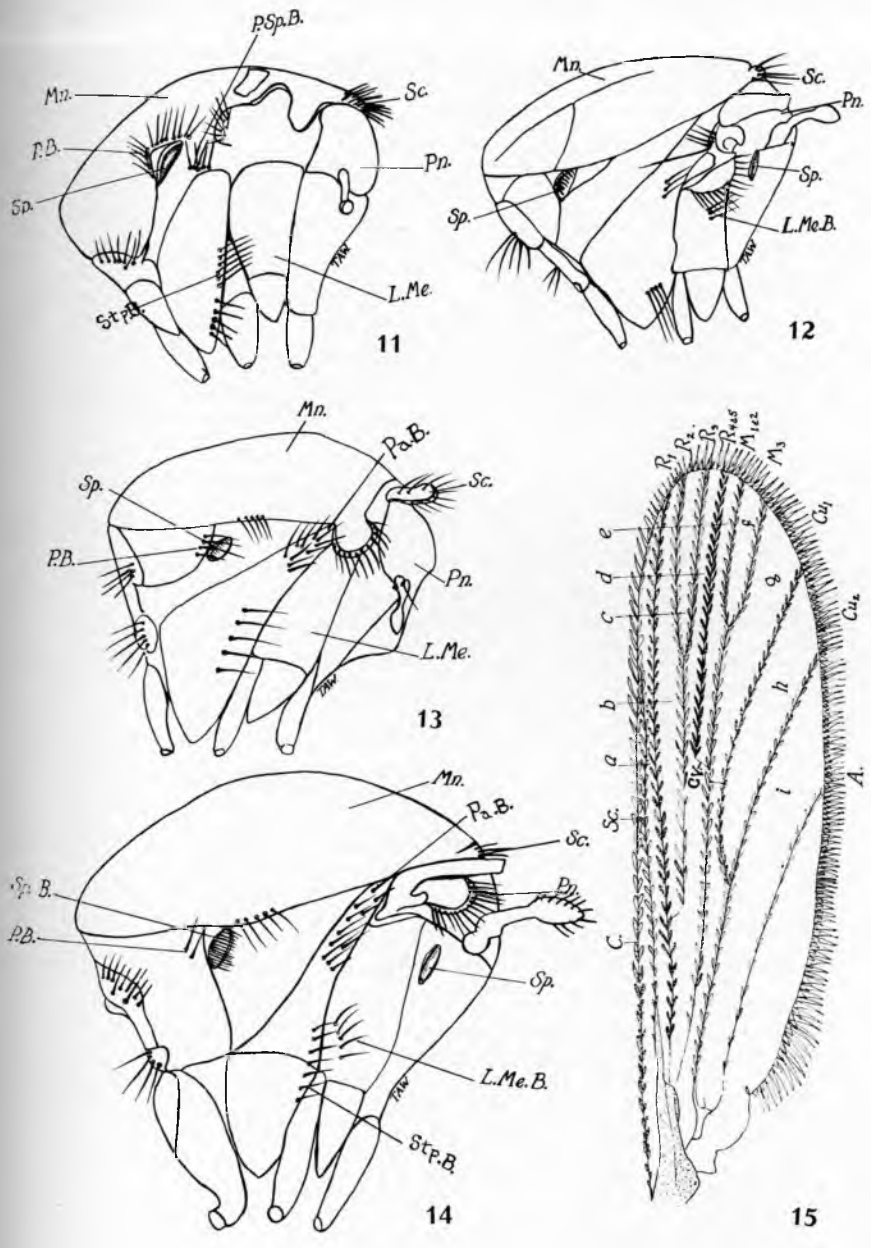

PSp.B.
Mn.
Sc.
P.B.
Pn.
Sp.
L.Me.
StP.B.
11
Mn.
Sc.
Pn.
Sp.
Sp.
L.Me.B.
12
Mn.
Pa.B.
Sp.
Sc.
P.B.
Pn.
L.Me.
13
Mn.
Pa.B.
Sc.
Sp. B.
P.B.
Sp.
L.Me.B.
StP.B.
14
R1
R2
R3
R4+5
M1+2
M3
Cu1
Cu2
A.
a
b
c
d
e
f
g
h
i
Sc.
C.
15

PLATE II

KEY FOR THE IDENTIFICATION OF UTAH MOSQUITOES

KEY TO THE GENERA

Adult Females

1. Scutellum rounded, never trilobed. Female palpi as long as proboscis ..... *Anopheles*
   Scutellum trilobed. Female palpi much shorter than proboscis 2
2. Tip of female abdomen pointed. Post-spiracular bristles present ..... *Aedes*
   Tip of female abdomen blunt. Post-spiracular bristles absent 3
3. Cross veins tending to be in line. Prespiracular bristles present ..... *Theobaldia*
   Cross veins not tending to be in line. Prespiracular bristles absent ..... *Culex*

Larvae

1. Air-tube absent ..... *Anopheles*
   Air-tube present, elongated 2
2. Air-tube with several pairs of ventral tufts ..... *Culex*
   Air-tube with single pair of ventral tufts 3
3. Pecten teeth followed by row of hairs ..... *Theobaldia*
   Pecten teeth not followed by row of hairs ..... *Aedes*

KEY TO THE UTAH SPECIES OF AEDES

Adult Females

1. Tarsal joints banded 2
   Tarsal joints not banded 10
2. Tarsi with white bands on both ends of the segments 3
   Tarsi with white bands at the bases of the segments only 4
3. Wing scales white and black, uniformly intermixed ..... *campestris*
   Wing scales white and black, vein R 4 + 5 entirely dark scaled ..... *dorsalis*
4. Proboscis of female banded with white ..... *nigromaculis*
   Proboscis of female not banded 5
5. Tarsal bands very narrow. Mesonotum vestiture uniformly brown ..... *vexans*
   Tarsal bands broad, especially on hind legs. Mesonotum vestiture usually not unicolored 6
6. Abdomen unbanded; covered with yellowish scales ..... *flavescens*
   Abdomen banded 7

7. Lower mesepimeral bristles absent ..... *excrucians*
Lower mesepimeral bristles present 8

8. Lower mesepimeral bristles two. Mesonotum with broad, light, reddish-brown median stripe ..... *fitchii*
Lower mesepimeral bristles, two to five. Mesonotum otherwise marked 9

9. Lower mesepimeral bristles three or five. Mesonotum of white and golden scales intermixed; sides sparsely scaled ..... *stimulans*
Lower mesepimeral bristles two. Mesonotum uniform; brown, interspersed with white scales or spots ..... *increpitus*

10. Abdomen with continuous, or nearly so, lateral white line. Mesonotum uniformly reddish-brown ..... *cinereus*
Abdomen without lateral line 11

11. Wing scales distinctly bicolored 12
Wing scales uniformly dark or nearly so 14

12. Wing scales predominantly black, intermixed with white, especially around basal cell and subcostally ..... *niphadopsis*
Wing veins alternating black and white 13

13. Abdomen with median dorsal pale stripe ..... *spencerii*
Abdomen without median dorsal pale stripe ..... *idahoensis*

14. Mesonotum with distinct, broad, golden-brown median stripe; sides white or yellowish-white ..... *sticticus*
Mesonotum not so marked 15

15. Lower mesepimeral bristles one or two; small. Mesonotum dark, bronzy; narrow median brown lines and a few white scales sometimes visible ..... *intrudens*
Lower mesepimeral bristles three or more, stout 16

16. Mesonotum without stripes or lines. A small species ..... *cataphylla*
Mesonotum with stripes or lines 17

17. Mesonotum vestiture pale yellow; paired, narrow, bare, median lines, separated by thin, yellow line ..... *pullatus*
Mesonotum yellow or gray; paired brown median lines separated by a narrow, yellow line or lines obsolete; variable ..... *communis*
Mesonotum vestiture golden or reddish-brown with dark brown median stripe; stripe sometimes divided or diffused ..... *punctor*

Males

(Based on Hypopygia)

1. Clasper attached at apex of side-piece 2
Clasper attached sub-apically on the side-piece, furcate at base ..... *cinereus*

2. Clasper elongate; furcate at tip. Claspette without filament, capitate, bearing dense setae ..... *vexans*
Clasper lobe like; not furcate at tip. Claspette with filament 3

3. Side-piece with basal and apical lobes 4
   Side-piece without distinct apical lobe; basal lobe only ..... *nigromaculis*

4. Basal lobe flat, rugose, setose; elongated towards apical lobe. Spines absent 5
   Basal lobe not as above 6

5. Basal lobe extending almost to apical lobe ..... *excrucians*
   Basal lobe not extending beyond the middle of the side-piece ..... *increpitus*

6. Stem of claspette stout at the base, distinctly angled outward near the middle; hirsute at the angle ..... *pullatus*
   Stem of claspette not as above 7

7. Side-piece with dense hair tuft beyond the apical lobe ..... *intrudens*
   Side-piece without dense hair tuft beyond the apical lobe 8

8. Apical lobe short, appressed setae 9
   Apical lobe with long hairs or nearly bare 11

9. Filament of claspette shorter than stem 10
   Filament of claspette as long or longer than stem ..... *sticticus*

10. Basal lobe detached posteriorly, expanded at apex; bearing short setae, a single spine associated with several hairs ..... *spencerii*
    Basal lobe not detached posteriorly, expanded at apex, bearing short setae, a single spine associated with several hairs ..... *idahoensis*
    Basal lobe quadrangular, extending almost to apical lobe; bearing a single marginal spine surrounded by a tuft of hairs ..... *punctor*

11. Basal lobe with a single stout spine on the margin 12
    Basal lobe with a long, heavy spine on the outer margin, surrounded by several shorter, weak spines ..... *campestris*

12. Apical lobe with numerous long hairs or short setae 14
    Apical lobe almost bare; long, finger-like 13

13. Filament gradually expanded in middle ..... *cataphylla*
    Filament not expanded in the middle ..... *niphadopsis*

14. Filament of claspette shorter than stem 15
    Filament of claspette as long or longer than the stem 16

15. Filament of claspette angular, with distinct notch at base ..... *fitchii*
    Filament of claspette angular, without notch at base ..... *communis*

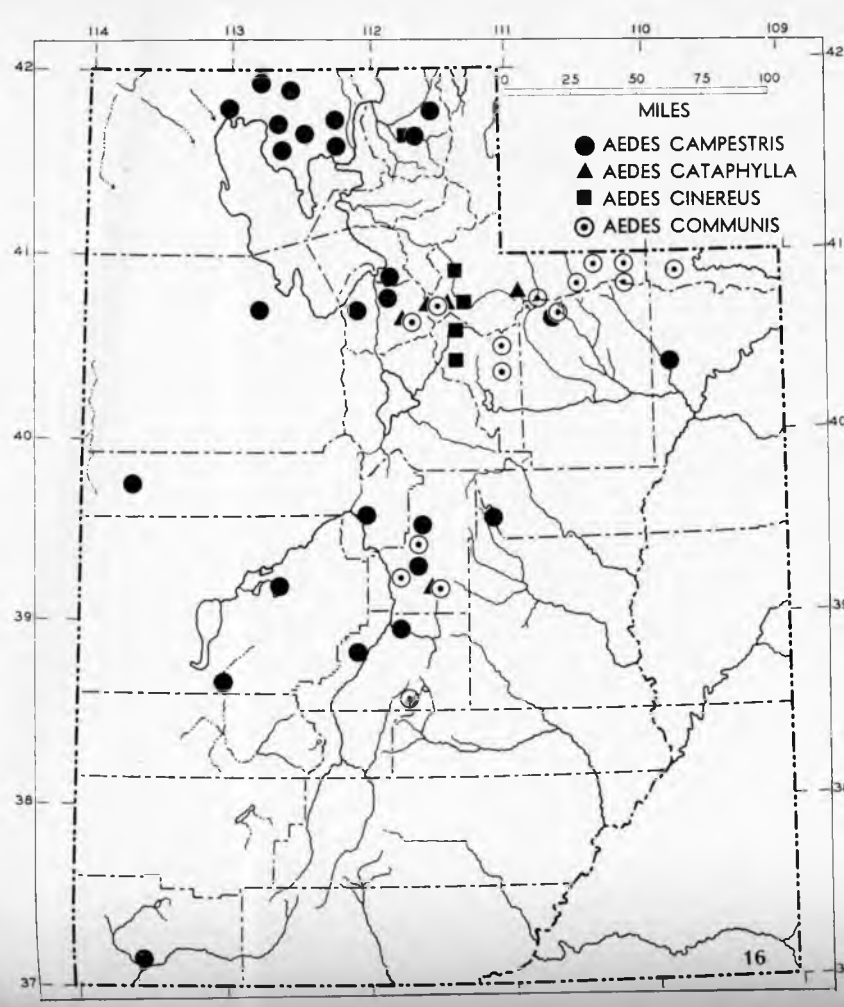
16. Basal lobe extending almost to apical lobe. Filament angular with spur at the middle ..... *flavescens*
    Basal lobe quadrangular. Filament not angular or spurred ..... *stimulans*

ERRATA

11. (continued)
    Basal lobe with two stout spines ..... *dorsalis*
    See Fig. 3

Larvae

1. Pecten teeth not extending beyond hair tuft 2
   Pecten teeth extending beyond hair tuft ..... *cataphylla*
2. Pecten teeth detached outwardly 3
   Pecten teeth not detached outwardly 10
3. Anal segment not ringed by dorsal plate 4
   Anal segment ringed by dorsal plate ..... *nigromaculis*
4. Air-tube three times as long as wide at the base, or more 5
   Air-tube less than three times as long as wide at the base 6
5. Dorsal head hairs multiple ..... *cinereus*
   Dorsal head hairs double ..... *excrucians*
6. Dorsal head hairs single 7
   Dorsal head hairs in tufts 8
7. Comb of about fourteen scales ..... *idahoensis*
   Comb of about nine scales ..... *spencerii*
   Comb of about twelve scales ..... *niphadopsis*
8. Dorsal head hairs, upper multiple, lower double 9
   Dorsal head hairs multiple ..... *intrudens*
9. Lateral abdominal hairs all double ..... *flavescens*
   Lateral abdominal hairs multiple on the first and second segment, double on third to fifth ..... *vexans*
10. Anal segment not ringed by dorsal plate 11
    Anal segment ringed by dorsal plate ..... *punctor*
11. Air-tube not four times as long as wide 12
    Air-tube four times as long as wide ..... *fitchii*
12. Dorsal head hairs single 13
    Dorsal head hairs in tufts 14
13. Anal gills as long or longer than segment ..... *communis*
    Anal gills short, bud-like ..... *dorsalis*
14. Dorsal head hairs not all multiple 15
    Dorsal head hairs multiple ..... *pullatus*
15. Lower head hairs typically single, rarely double 16
    Lower head hairs always double, upper multiple ..... *sticticus*
16. Upper head hairs multiple ..... *campestris*
    Upper head hairs double ..... *stimulans*



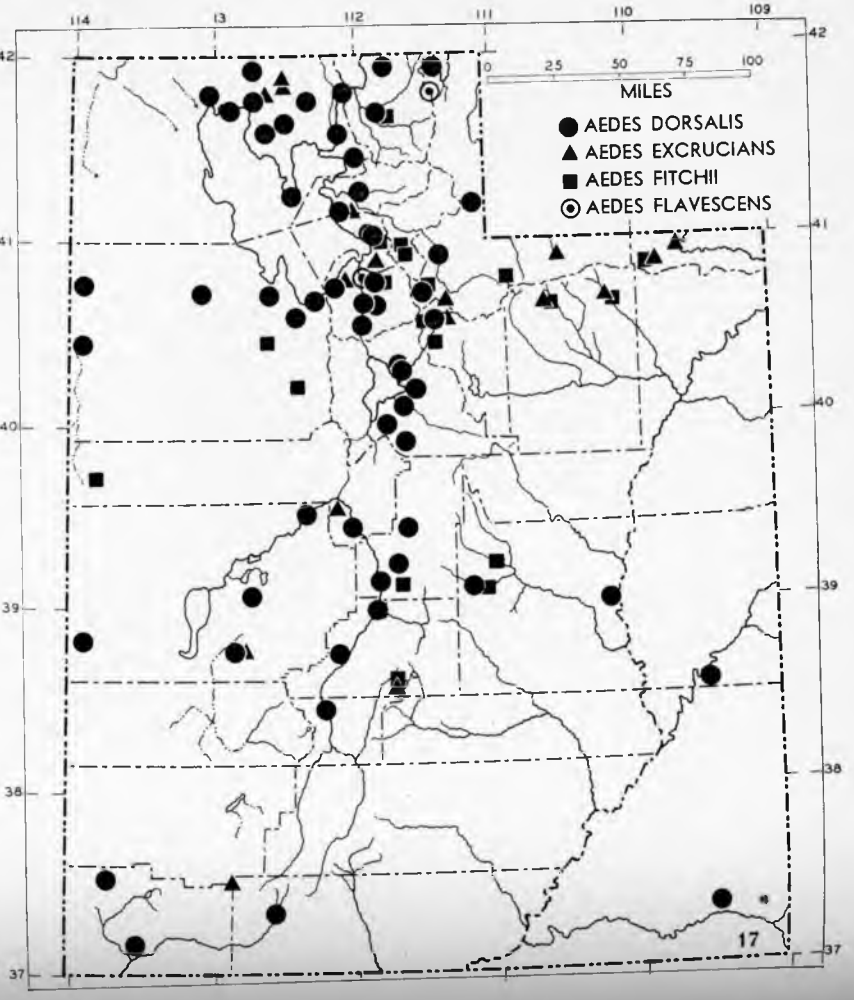


PLATE III

Known Distribution in Utah of:

Fig. 16. Aedes campestris. Aedes cinereus.

UTAH MOSQUITOES

Aedes campestris Dyar and Knab

1907 *Aedes campestris* Dyar and Knab, Jour. N. Y. Ent. Soc., 15:213.

Distinguishing Characters. — *Female*: A rather large mosquito; straw yellow to gray in color. Mesonotum vestiture yellowish gray with broad undivided brown medial stripe. Abdomen with basal segmental white bands, widening at the sides, or wholly suffused with white. Wing scales bicolored with white scales predominating. Tarsi ringed on both ends of joints.

Male Hypopygium: Side-piece at least twice as long as wide, rounded at tip; apical lobe small, rounded, covered with long setae; basal lobe low with a single large spine at the base on the outer margin surrounded by several smaller spines and covered with setae. Claspette filament expanded in the middle, stem short, stout, with subapical setae. Clasper large, slightly curved, narrow at tip, with long terminal spine.

Larva: Lower head hairs single or double, upper multiple. Air-tube more than twice as long as wide at the base; pecten extending three-fourths the length of tube, apical teeth heavier than basal, last one or two teeth often detached outwardly, tuft near the tip. Comb of many scales in triangular patch. Anal segment as long as wide, dorsal plate extending to lateral line. Anal gills small and bud-like.

Distribution. — *Aedes campestris* is a plains mosquito, and is generally associated with *Aedes dorsalis* throughout the semi-arid plains and prairie regions of Utah. It is widely distributed over the state but does not occur in the wooded sections or high mountain regions.

Life History. — The winter is passed in the egg stage. The eggs are deposited singly in considerable numbers during the spring and summer in the vicinity of depressions, which later become filled with water. The first over-wintering eggs generally hatch in May in the shallow pools filled from melting snow or early vernal rains. The larvae are frequently found in the same pools with *Aedes dorsalis*. Most of the eggs hatch in the late spring and early summer. Larvae may occur in certain pools from May to mid-July. It has not been definitely determined whether this species is produced in a single brood or not, but the author is of the opinion that the eggs pass the winter before hatching, and that these over-wintering eggs hatch under favorable conditions at different times during the spring and early summer. Some of the adults survive the summer, a few having been collected early in the fall of the year.

Importance. — *Aedes campestris* are abundant during the late spring and early summer in the regions where they occur, and constitute a pest in certain localities. The females bite freely at any time when opportunity affords, but are most active in the evening and early morning. This species has a determined flight range in Utah of ten miles from its breeding area.

Aedes cataphylla Dyar

1916 *Aedes cataphylla* Dyar, Ins. Insc. Mens., 4:86.

Distinguishing Characters.—*Female*: A small to medium sized grayish mosquito. Mesonotum vestiture of small crescent shaped scales, brown dorsally, gray at the sides and anti-scutellar space, colors frequently intermixed. Abdomen black with broad, even, white basal segmental bands. Wing scales black except for a few white scales at the base and extending along the costa. Tarsal joints without rings.

Male Hypopygium: Side-piece twice as long as the width at the base, narrow, rounded at the tip; apical lobe conical, prominent, with two short spines dorsally, a few setae at the apex, a group of stout spines at its base; basal lobe conical, small, with a single, stout, marginal spine and numerous long setae. Claspette long, sickle-shaped stem curving outward; filament pointed, broadly expanded in the middle. Clasper long, with long terminal spine.

Larva: Head hairs single. Air-tube nearly three times as long as wide; pecten followed by haired tuft near middle of tube; beyond tuft are three to five widely spaced teeth. Anal segment longer than wide; not completely ringed by dorsal plate. Comb scales in two irregular rows. Anal gills as long as segment, pointed.

Distribution. — *Aedes cataphylla* has been collected in the high mountain regions in various parts of the state. It is associated with *Aedes communis* and *Aedes punctor*.

Life History. — Like other mountain species of *Aedes* it passes the winter in the egg stage, and only one generation is produced during a season. The larvae develop in snow and flood water pools in the wooded sections of the mountains, at elevations usually above 7,500 feet. This species emerges from May until early July, depending upon the elevation and season. The broods are frequently large and the females attack readily. A few females have been taken as late as the middle of August.

Importance. — This mosquito is an important pest in high mountain areas of the state. It constitutes with *Aedes communis* the most annoying pest in the vicinity of several high mountain resorts in the Uintah and Wasatch mountains.

Aedes cinereus Meigen

1818 *Aedes cinereus* Meigen, Syst. Beschr. Eur. Zweifl. Ins., 1:13.

Distinguishing Characters. — *Female*: A small dark mosquito. Mesonotum vestiture of dark reddish-brown scales. Abdomen black with basal segmental white bands usually extending to form lateral white lines. Bands sometimes indistinct. Wing scales narrow, dark. Legs dark, a few white apical scales on femora.

Male Hypopygium: Side-piece about twice as long as wide, sharply tapering, densely haired at apex. Clasper distinctly forked, attached subapically on the side-piece. (This character is distinctive for the species).

Larva: Head hairs all multiple in tufts of five or more. Air-tube slender, nearly four times as long as wide; pecten extending past the middle; the last three teeth stout, followed by a small hair tuft. Anal segment longer than wide; dorsal plate extending to lateral line. Comb scales in irregular double row. Anal gills twice as long as segment, lanceolate.

Distribution. — *Aedes cinereus*, up to the present time, has been collected only in the northern part of the state. It is a woodland species and is found breeding in the lower mountain valleys along the margins of streams. This species is associated with *Aedes sticticus* and at times with *Aedes vexans*.

Life History. — The winter is passed in the egg stage; the first larvae hatch in snow and flood water pools along the margin of mountain streams in wooded sections. The larvae have been collected only in the late spring and early summer, indicating that there is but a single brood during the season. The adults are on the wing from the latter part of May to the end of July.

Importance. — *Aedes cinereus* is occasionally quite common in certain localized areas for a short time during the season. The females are rarely found in the open. They are rather vicious biters at times, but they will not always attack man. The flight range of this species seems to be limited, because they are usually found in the woods within the immediate vicinity of their breeding habitat.

Aedes communis (De Geer)

1776 *Culex communis* De Geer, Mem. des Ins., 6:316.

Distinguishing Characters. — *Female*: Medium sized, dark gray mosquito. Mesonotum vestiture dull yellow, two dark brownish lines extending back two-thirds, and posterior half lines. Lines may be fused in some specimens. Abdomen black, with basal segmental white bands. Wing scales narrow, dark. Legs dark, without bands.

Male Hypopygium: Side-piece stout, three times as long as wide; apical lobe large, bearing stout, short setae on the dorsal surface; basal lobe small, covered with hair and bristles and bearing one long, stout spine. Claspette stem long, thin; filament short, broad. Clasper short, expanded in the middle with long terminal spine.

Larva: Head hairs single. Air-tube three times as long as wide at the base; pecten not extending to the middle of the tube followed by a large tuft. Comb scales in three irregular rows forming triangular patch. Anal segment as long as wide, dorsal plate extending below lateral line. Anal gills slightly longer than segment, lanceolate.

Distribution. — *Aedes communis* is found in Utah in forested regions of high mountains. It has been collected repeatedly at elevations from 7,500 to 12,000 feet in the Uintah and Wasatch ranges, indicating a distribution in all the high mountain areas of the state. It is found associated with *Aedes punctor*, *Aedes cataphylla* and, in certain localities with *Aedes intrudens* and *Aedes pullatus*.

Life History. — *Aedes communis* over-winters in the egg stage, and there is one generation a year. The eggs hatch in the early snow water pools in ground depressions in the forests, mountain meadows, and around the margins of high mountain lakes. The larvae taken at later dates were at higher altitudes. The adults are found in the vicinity of their breeding areas from the latter part of May until the first part of August.

Importance. — This mosquito is very abundant in the high mountain regions where it matures during June and the first part of July. The females will feed in the timber any time during the day, but are generally more active towards evening. They are vicious biters when they attack, and at times are important pests in high mountain areas.

Aedes dorsalis (Meigen)

1830 *Culex dosalis* Meigen, Syst. Bcsch. Bek., Eur. Zweifl. Ins., 6:242.

Distinguishing Characters. — *Female*: Medium sized yellowish gray mosquito. Mesonotum vestiture extremely variable, consisting of whitish-gray to yellowish scales with a median yellowish to brown stripe of variable width; sometimes the stripe is divided into three lines or may be nearly obsolete. In certain specimens, the stripe is flanked posteriorly by spots of the same color. Abdomen black with white or yellowish scales basally, apically and dorsally on the segments, reducing the black to paired quadrate spots, which become smaller posteriorly until they frequently disappear on the last few segments. Wing scales bicolored but 4 + 5 are largely dark scaled; this characteristic is distinctive for the species but may be lacking in flown specimens. Tarsi ringed on both ends of joints.

Male Hypopygium: Side-piece more than twice as long as wide; apical lobe short, rounded, covered with long setae; basal lobe prominent, constricted at the base, expanded apically with two rather long, stout spines on the margin and numerous setae. Claspette with stout, setose, short stem; filament short, expanded in middle with recurved point. Clasper long and expanded medianly.

Larva: Head hairs single. Air-tube about three times as long as wide; pecten of about seventeen evenly spaced teeth, followed by tuft, does not reach the middle of tube. Comb scales in irregular double row. Anal segment slightly longer than wide; dorsal plate extending to lateral line. Anal gills small, bud-like.

Distribution. — *Aedes dorsalis* is the most abundant mosquito in Utah. This species is found on the plains and prairies throughout the state. It is also found in some of the wide river valleys in the mountains at lower altitudes. The larvae of *Aedes dorsalis* frequently occur in the same pools with *Aedes campestris* and, in some localities, with *Aedes vexans*.

Life History. — The winter is passed in the egg stage. The larvae of *Aedes dorsalis* are among the first to appear in the spring of the year, from eggs that were laid the previous season. The eggs are deposited singly on the ground in dry depressions or around the

margins of pools. The eggs, under favorable conditions, hatch within a few days after they are deposited, or they may pass through several winters without injury. The larvae require different periods of time to complete development. Under field conditions of high temperatures, the larvae complete development in five and one-half days, and the adults emerge from the pupae on the seventh day from the time the eggs hatched. The larval development may require twenty-two days, or longer, at low temperatures. The first larvae in the spring appear in surface pools filled with melting snow or early spring rains. Later broods are found developing in irrigation water, river flood water and, occasionally, in water from artesian wells. The eggs usually hatch immediately after each flooding over an area. At times, however, the eggs hatch intermittently, as larvae in all stages of development are occasionally found in the same pools. Seven successive broods have been taken from the same locality during a single season, these broods occurring after each successive flooding which is generally due to irrigation water. The adult females have a relatively long life; some females that hatch in the spring in desert localities where no subsequent breeding takes place, are known to live until early fall. Eggs may remain viable for two or three years before hatching, as some depressions that were dry for two seasons produced enormous spring broods of *dorsalis* after they were flooded in 1935.

Importance. — This mosquito is the most abundant and important pest species in the state. It breeds in the immediate vicinity of all larger communities and continues to reproduce in successive broods throughout the season. The females are vicious biters and will attack during the day or night, but they are particularly active in the evening and on calm, cloudy days. The females usually attack in the open and are seldom found in densely wooded regions. Dyar (1928) states: "they do not enter houses." The author has observed the blood thirsty females entering houses and outbuildings on numerous occasions. On the flats west of Salt Lake City it is necessary to tightly screen all houses and porches. To protect domestic animals from this pest, stables and outbuildings are frequently screened. The author has observed *Aedes dorsalis* crawling through the larger mesh on screen doors at night and entering residences in the central part of the city. At night, the females, and at times the males, show a strong positive phototropism, and are readily taken in great numbers by light traps. The females are strong fliers and occasionally migrate in large broods. They are commonly found ten miles from their breeding area, and a flight of twenty-two miles has been determined by the author in the vicinity of Salt Lake City.

Aedes excrucians (Walker)

1856 *Culex excrucians* Walker, Ins. Saund. Dipt., 429.

Distinguishing Characters. — *Female*: Large reddish-brown mosquito. Mesonotum vestiture brown, usually with broad medium reddish-brown stripe, the stripe sometimes indistinct. Abdomen with broad basal segmental yellowish-white bands, widening at the sides.

Wing scales bicolored, black predominating with yellowish-white intermixed, especially along costal margins. Tarsi with broad basal band of yellow or white scales; on the front and middle legs the rings are narrower.

Male Hypopygium: Side-piece large, more than twice as long as wide; apical lobe prominent, bearing numerous setae; basal lobe flattened, roughened, covered with setae and extending nearly to base of apical lobe. Claspette with long outwardly curved stem; filament with angular projection near the base. Clasper long enlarged near middle, constricted at apex.

Larva: Head hairs double. Air-tube slender and about four times as long as wide; pecten not extending to the middle, the last two teeth heavier, detached, followed by large tuft. Comb of many scales, triangular. Anal segment about twice as long as wide; dorsal plate extending below lateral line. Anal gills about as long as segment, slightly pointed.

Distribution. — *Aedes excrucians* has been collected from the timbered areas of northern and central Utah. The collections thus far have been from the mountain regions at lower elevations. This species is associated with *Aedes fitchii* and *Aedes sticticus*.

Life History. — The winter is passed in the egg stage, and there is but one generation a year. The larvae appear in the spring of the year in swampy ground surface pools in the vicinity of timber. The adults do not emerge until June or the first part of July. They appear first at the lower elevations.

Importance. — This mosquito is of local importance for a limited time in certain wooded sections of the state. The females bite readily, and may constitute a pest in timbered areas. They will feed in the woods at any time during the day but are most active in the evenings.

Aedes fitchii (Felt and Young)

1904 *Culex fitchii* Felt and Young, Science, N. S., 20:312.

Distinguishing Characters. — *Female*: A medium sized brown mosquito. Mesonotum vestiture brown with broad median line of yellowish-brown scales, or with no distinct pattern, the scales intermixed. Abdomen has broad basal segmental white bands, widening at the sides. Wing scales bicolored, predominately black, the white fairly evenly distributed. Tarsi basally banded with white, bands broader on hind legs.

Male Hypopygium: Side-piece about three times as long as wide; apical lobe large, covered with stout setae; basal lobe prominent, clothed with setae; at the margin, one long stout spine surrounded by several shorter spines. Claspette stem rather long, curved; filament short, sickle-shaped, notched at the base. Clasper slightly enlarged in the middle; long terminal spine.

Larva: Head hairs in multiple tufts. Air-tube about four times as long as wide at the base; pecten extending to middle, followed by large hair tuft. Comb triangular, numerous scales. Anal segment longer than wide, dorsal plate extending almost to mid-ventral line. Anal gills longer than segment, pointed.

Distribution. — *Aedes fitchii* is distributed throughout the wooded sections of the state. It has been collected in the valleys along wooded stream margins but in greater abundance in the mountainous areas at lower elevations. It is frequently associated with *Aedes excrucians*, *Aedes pullatus* and occasionally with *Aedes increpitus*.

Life History. — The winter is passed in the egg stage and but one generation is produced in a season. According to Freeborn (1926) "the eggs are laid singly in batches of four to ten on the mud at the edge of receding grassy pools or in the crevices of the sun cracked earth in the beds of previous pools." The larvae appear early in the spring in woodland pools filled with melting snow or along the margins of over-flowing lakes and swamps. The adults emerge from the latter part of April to July, the season and the altitude largely determining the time of emergence. The females occasionally live until the middle of August.

Importance. — *Aedes fitchii* is of no great importance in Utah, but the females readily attack man and animals and in timbered districts are of great annoyance during certain seasons of the year. In the woods they will feed at any time during the day.

Aedes flavescens (Müller)

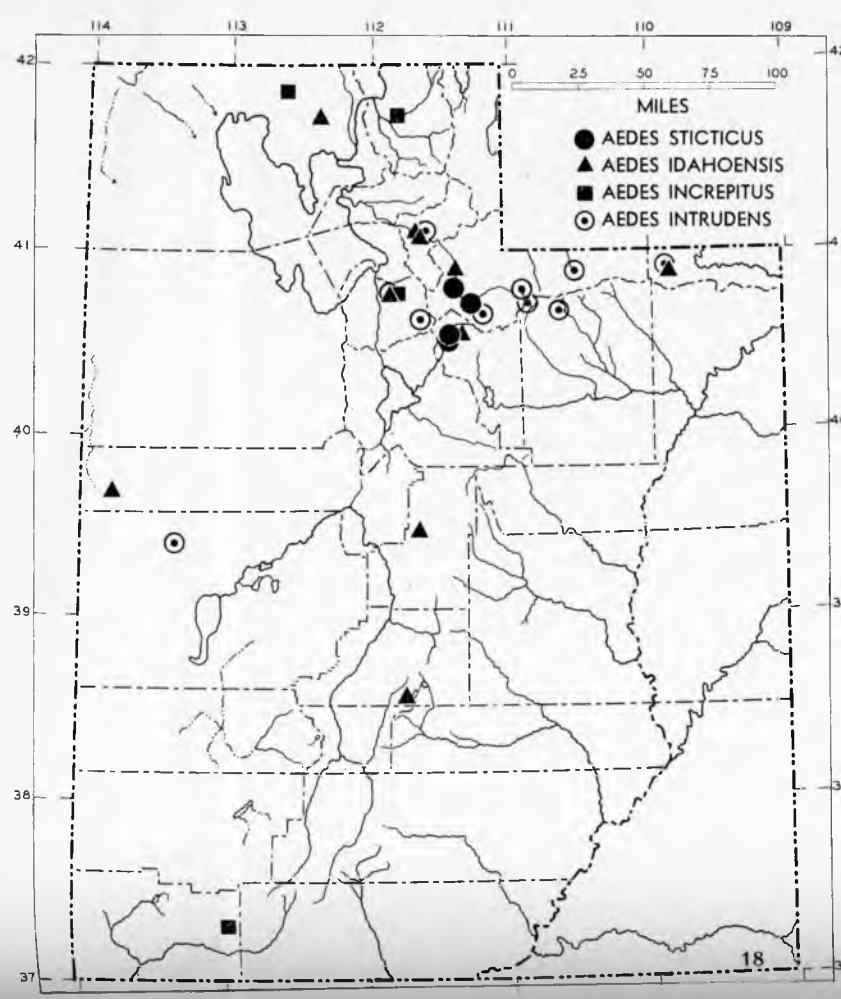
1764 *Culex flavescens* Müller, Fauna Ins. Fried., 87.

Distinguishing Characters. — *Female*: A large yellowish mosquito. Mesonotum vestiture yellowish-brown, usually a broad median stripe of darker scales is visible. Abdomen dull yellow, unbanded. (This character is quite distinctive for the species). Wing scales predominately black with yellowish-white intermixed. Tarsi banded basally with broad white rings on all joints.

Male Hypopygium: Side-piece large, more than twice as long as wide; apical lobe low, rounded, with stout, reversed setae; basal lobe low, roughened, extending to the middle of side-piece covered with setae, a stout spine at the proximal margin. Claspette stem short, stout, setose; filament is long, curved, expanded in the middle. Clasper large, swollen medianly, long terminal spine.

Larva: Head hairs multiple. Head bulging at the sides. Air-tube three times as long as wide; pecten extending to the middle, last two teeth stout, detached; followed by tuft. Comb triangular, numerous spine-like scales. Anal segment longer than wide; dorsal plate extending below lateral line. Anal gills as long as segment, pointed.

Distribution. — *Aedes flavescens* has been collected on a few occasions in the northern part of the state; it seems to be rather rare and found only around the flooded marshes of prairie regions. This species has never been taken in the wooded sections of Utah.



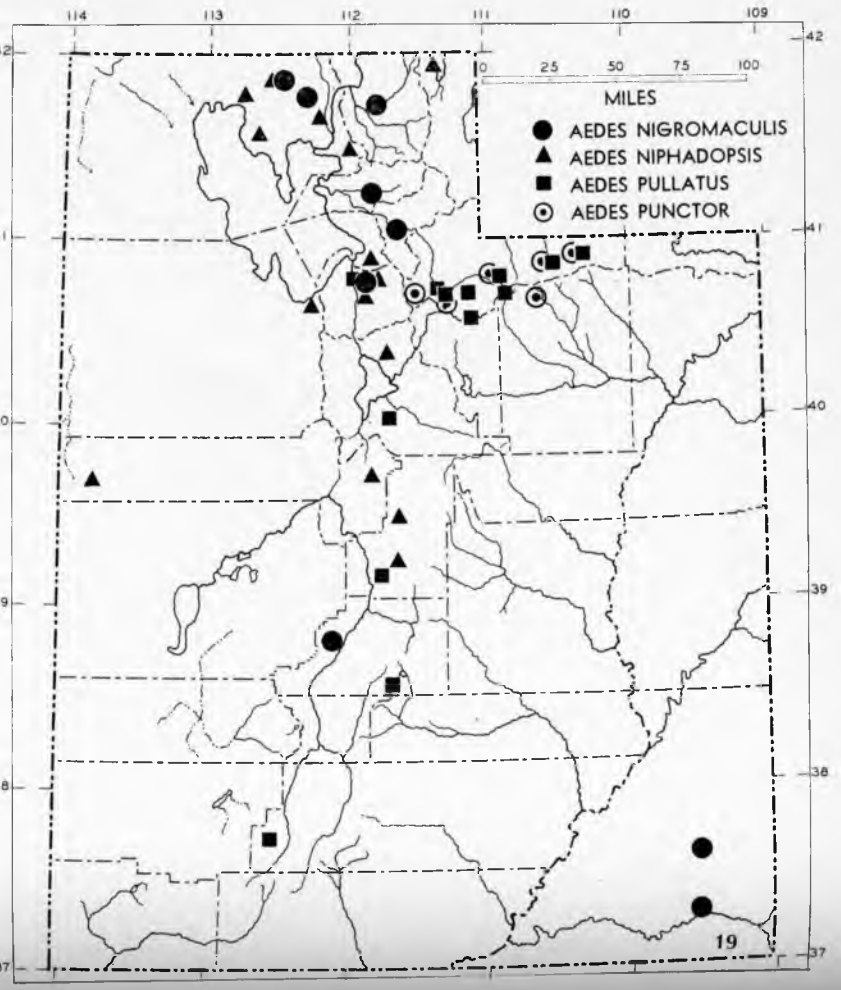


PLATE IV

Known Distribution in Utah of:

Life History. — The winter is passed in the egg stage. The eggs hatch in the spring of the year in the deeper pools in meadows and marshes. Larvae have been collected in the latter part of May in the vicinity of Bear Lake and also in alkaline pools near Salt Lake City. The larvae mature rather slowly and the adults do not emerge until June. According to Wesenburg-Lund (1921) "the mating habits of *flavescens* differ from those of most *Aedes* in that the males hover over low vegetation and mate with the females which rest on the leaves; the pairs fly together for half a minute." The adults are on the wing from May until the end of July; there is but one generation a year.

Importance. — This species is so rare that it is of no great importance in Utah. Where it occurs, however, the females attack livestock and man and are rather vicious biters. They will feed in the open any time during the day or early evening. The flight range has not been determined.

Aedes idahoensis (Theobald)

1903 *Grabhamia spencerii* var. *idahoensis* Theobald, Mon. Culic., 3:250.

Distinguishing Characters. — *Female*: A medium sized gray mosquito. Mesonotum vestiture gray with broad reddish-brown band extending back three-fourths, band sometimes narrowly divided by light line. Abdomen black with broad white basal bands. Wing scales bicolored, alternatingly black, then white, starting with costa. (This character is important in distinguishing *idahoensis* from *spencerii*).

Male Hypopygium: Side-piece more than twice as long as wide; apical lobe rounded, extending nearly to basal lobe; basal lobe prominent, covered with short setae; a stout spine arising at the base in dense tuft of setae. Claspette stem short, slightly tapering; filament sickle-shaped, pointed. Clasper stout, swollen in the middle; long terminal spine.

Larva: Head hairs single. Air-tube about two and one half times as long as wide at the base; pecten extending to the middle, last two teeth detached, terminated by hair tuft. Comb scales in irregular double row. Anal segment longer than wide, dorsal plate extending nearly to ventral line. Anal gills pointed and twice as long as segment.

Distribution. — *Aedes idahoensis* is found in the northern and central part of the state in the plains and low mountain regions. It is rather wide-spread over much of the same area in which *Aedes dorsalis* is found, but is much less abundant. It is an open plains species and has not been collected in wooded areas.

Life History. — The winter is passed in the egg stage and there is but one generation a year. The larvae appear early in the spring in snow water pools or pools filled by the early vernal rains. Larvae have been collected in the vicinity of Salt Lake City in rock pockets filled with water from melting snow. Larvae are frequently found in pools showing a high alkalinity. The adults emerge in April and May, and the females are found on the wing as late as July.

Importance. — *Aedes idahoensis* is of importance in certain localities for a few weeks during the spring of the year. The females will bite readily during the day but are more active in the evening. The flight range has not been determined, but there is some evidence that the females travel several miles from their place of emergence.

Aedes increpitus Dyar

1916 *Aedes increpitus* Dyar, Ins. Insc. Mens., 4:87.

Distinguishing Characters. — *Female*: A rather large, dark mosquito. Mesonotum vestiture brown, interspersed with white scales or spots, no distinct pattern. Abdomen black, broad basal segmental white bands widening at the sides. Wing scales dark, white scales frequently present on costal margin. Tarsal joints broadly banded with white, especially on hind legs.

Male Hypopygium: Side-piece rounded and about twice as long as wide; apical lobe prominent, conical, bearing a few small setae; basal lobe absent, represented by small roughened area, bearing sparse setae. Claspette stem medium, curved outwardly; filament slender, long. Clasper large, slightly swollen in the middle; long terminal spine.

Larva: Upper head hairs multiple, lower single or double. Air-tube about two and one half times as long as wide at the base; pecten not extending to the middle, terminated by small tuft. Comb triangular, numerous scales. Anal segment as long as wide; dorsal plate extending below mid-lateral line. Anal gills pointed, longer than segment.

Distribution. — *Aedes increpitus* is typically a western species. It is found throughout the northern and central part of the state in the plains region and in the mountains at lower altitudes. It is frequently found associated with *Aedes fitchii.*

Life History. — The winter is passed in the egg stage. This species probably produces but one generation a year, but there is some doubt about the number of generations. The larvae breed in flood water pools along the margins of streams. They are also occasionally found in depressions filled by irrigation water or spring rains. The eggs hatch in April or May, the first adults emerging during the latter part of April or May. The females have been taken on the wing as late as the latter part of July. The eggs are presumably laid singly on the ground around the margins of pools or in depressions that have been previously flooded by water.

Importance. — This mosquito is of importance in certain localities. It bites readily and will attack man or animals and is a source of considerable annoyance during the spring along the foot hills where it is most numerous.

Aedes intrudens Dyar

1919 *Aedes intrudens* Dyar, Ins. Insc. Mens., 7:23.

Distinguishing Characters. — *Female*: A medium sized dark brown mosquito. Mesonotum vestiture bronzy-brown, sometimes with two narrow, dark median lines. Abdomen dark with broad basal segmental white bands. Wing scales dark brown. Tarsi not banded.

Male Hypopygium: Side-piece about three times as long as wide, a large tuft of setae near the apex; apical lobe prominent, with small sclerotized cap bearing long, curved setae; basal lobe distinct, bearing two spines at apex and one stout spine at its base. Claspette stem, stout basally, sharply constricted in the middle to form a prominent angle, bearing a terminal spine; apex of stem slender, curved inward; filament large, widened in the middle. Clasper medium, swollen basally, long terminal spine.

Larva: Upper head hairs in tuft of four, lower in two or three. Air-tube about two and one half times as long as wide at the base; pecten extending to middle; last few teeth stout, detached, terminated by large tuft. Comb scales in double row. Anal segment longer than wide; dorsal plate extending to near mid-ventral line, ventral margin deeply incised. Anal gills bluntly pointed, as long as segment.

Distribution. — *Aedes intrudens* is found in the low mountain regions of Utah. This mosquito occurs only in the forest areas and is typically a woodland species. It has never been taken by the author in the plains sections of the state.

Life History. — *Aedes intrudens* over-winters in the egg stage, the eggs are laid on the ground in depressions in wooded regions. The larvae hatch in snow water pools in the spring and early summer. The pools in which the larvae are found developing are usually floored with dead leaves and vegetation. There is only one generation a year, and the adults emerge in May or June. The females are found on the wing until the middle of August. The time of emergence of the adults is variable depending upon the season and the elevation.

Importance. — This mosquito is fairly numerous in certain mountain sections in the vicinity of timber. However, it is not sufficiently numerous to be of any great importance in this state. Females bite in the day or night but are seldom found far from the woods. According to Dyar (1928) the adults are fond of entering houses in contradiction to the habits of other forest mosquitoes. This has not been particularly noticeable in Utah as houses are seldom found in the vicinity where these mosquitoes breed in greatest abundance. Nothing has been determined on their flight range, but apparently they are confined to the timbered sections, and therefore, have a limited flight range.

Aedes nigromaculis (Ludlow)

1907 *Grabhamia nigromaculis* Lundlow, Geo. Wash. Univ. Bull., 5:85.

Distinguishing Characters. — *Female*: A medium sized dark mosquito. Proboscis ringed with white. (This character is sufficient to distinguish this species from all other *Aedes* in Utah). Mesonotum vestiture of golden-yellow scales, with a broad median patch of brown scales extending posteriorly. Abdomen black with broad basal segmental bands and a median dorsal line of dull yellowish-white scales. Wing scales predominately dark, intermixed with yellowish-white, especially on costal margin. Tarsal joints ringed with broad, white, basal bands.

Male Hypopygium: Side-piece twice as long as wide; apical lobe absent; basal lobe flattened, bearing numerous short setae. Claspette stem short; a single stout setae near apex; filament as long as stem, slender, pointed. Clasper long, swollen in middle, tapering at tip; a medium terminal spine.

Larva: Head hairs single, antennal tuft small. Air-tube about twice as long as wide at the base; pecten extends three-fourths the length, terminated near the tip by small tuft; last three teeth detached and more stout. Comb irregularly triangular, few scales. Anal segment wider than long, ringed by dorsal plate. Anal gills longer than segment, pointed.

Distribution. — *Aedes nigromaculis* is a plains species and is distributed throughout the more arid plains of the middle west. It is found in Utah in the plains and prairies throughout the state in the same localities as *Aedes dorsalis*. It is also frequently associated with *Aedes campestris* and *Aedes vexans*. It occurs in irrigated sections and, like *Aedes dorsalis*, the larvae seem to favor alkaline conditions. This species does not occur in the timbered regions of the state.

Life History. — The winter is passed in the egg stage and there are several broods produced annually. It is evident that the eggs do not require the stimulus of low temperatures before hatching; thus, several batches of eggs are laid during the season and these eggs may hatch the same season in which they are laid. The first larvae that appear in the spring are later than *Aedes dorsalis* and *Aedes campestris*, and are usually found in depressions filled by rain or irrigation water. The larvae appear in May, successive broods occurring throughout the summer until the latter part of September. The first adults emerge in the latter part of May or the first of June and females have been taken on the wing as late as November.

Importance. — *Aedes nigromaculis* usually is not sufficiently abundant to constitute a pest, but because of its wide distribution over the plains area and its continuous breeding throughout the season, it is an important part of the mosquito fauna of the state. The females readily attack man and animals and inflict a rather painful bite. They feed during the day time but are more active in the evenings. This species is a strong flier and has been taken several miles from its breeding locality.

Aedes niphadopsis Dyar and Knab

1918 *Aedes niphadopsis* Dyar and Knab, Ins. Insc. Mens., 5:166.

Distinguishing Characters. — *Female*: A medium sized, dark gray mosquito. Mesonotum vestiture gray, white scaled around the margins, dark brown centrally; paired narrow dark lines and white spots distinguishable posteriorly on some specimens. Abdomen dark scaled above with broad irregular basal, segmental bands; a median dorsal stripe sometimes visible. Wing scales heavy, coarse, predominately black, intermixed with white, especially on costa, first vein, and veins bordering basal cell. Legs black and white scaled; tarsi not banded.

Male Hypopygium: Side-piece about three times as long as wide; apical lobe elongated, conical, with a few outwardly directed short setae; basal lobe small, low, bearing short setae; a single marginal long spine-like seta surrounded by one to three stout setae. Claspette stem moderate, slender; filament longer than stem, slender. Clasper large, slightly swollen on the basal half, with a long terminal spine.

Larva: Head hairs single, occasionally double. Air-tube nearly four times as long as wide at the base; pecten not extending to the middle, terminated by large tuft, last teeth stouter, with one or two detached. Comb in irregular double row of about ten to twelve scales. Anal segment nearly twice as long as wide; dorsal plate small, extending slightly beyond mid-lateral line. Anal gills small, bud-like.

Distribution. — *Aedes niphadopsis* was reported by Dyar (1928) from the eastern shores of the Great Salt Lake. It was named and described as a new species by Dyar and Knab (1918) and has never been reported from any other locality prior to this investigation. This species has been collected by the author throughout the plains region and low foothills in the northern and central part of the state. It has never been taken in the timbered areas. Matheson (1929) considers *niphadopsis* as probably a variety of *Aedes impiger*. The author, however, is of the opinion that *niphadopsis* is a distinct species, and its distribution extends into southern Idaho and into Nevada.

Life History. — The winter is passed in the egg stage. The eggs are deposited on the ground in the vicinity of depressions that are filled with water in the spring. There is only one brood annually. The larvae appear early in the spring in surface pools filled by melting snow. These pools are frequently alkaline and in some localities distinctly mineral in character. The larvae hatch from the over-wintering eggs in April or the first part of May, depending upon the season. The adults emerge usually in May, but not later than the middle of June. The author has found that while mating, the males swarm in a manner similar to the males of certain other species of *Aedes*. On May 12, 1930, at Wales, Utah, 125 miles south of the Great Salt Lake, males were observed at sun-down in large swarms hovering over low bushes of the genus *Artemisia*. The females were found in the vegetation near the swarming males. The swarms produced humming sounds that were audible several yards distant. The females upon entering the swarm immediately copulated with the males and the pairs would leave the swarm and generally alight on the vegetation in the immediate vicinity. Many males were captured from the swarm with an insect net but the swarming continued only temporarily disturbed by the sweeps of the net. The larvae of this species are sometimes found in the same pools with the larvae of *Aedes dorsalis* and *Aedes campestris*. However, they seem to prefer small, shallow scattered pools, and have never been taken in great numbers in larger bodies of water.

Importance. — *Aedes niphadopsis* is of considerable importance in the foot hills and plains region of Utah, for a short period of time, during the spring of the year. They reproduce in enormous numbers under favorable seasonal conditions, but the adults are seldom notice-

able in a region longer than about three weeks, generally during May. The females are vicious biters and will readily attack man or animals. Their bite is very painful. The females will feed any time during the day, but are more active towards evening. The flight range has not been established as it is difficult to determine flight because of the nature of the scattered snow water pools in which this species develop. They probably have a flight range of several miles as they are widely dispersed over the open plains region during their seasonal appearance.

Aedes pullatus (Coquillett)

1904 *Culex pullatus* Coquillett, Proc. Ent. Soc. Wash., 6:168.

Distinguishing Characters. — *Female*: A medium sized dark mosquito. Mesonotum vestiture yellowish-brown scaled, more yellowish around the margins. A narrow median bare line, paralleled on each side by narrow dark lines. Sometimes short posterior lateral lines sharply turned outward anteriorally. Abdomen dark with broad basal segmental bands. Wing scales narrow, dark. Tarsi dark, not banded.

Male Hypopygium: Side-piece about three times as long as wide; apical lobe prominent, numerous hairs on ventral surface; basal lobe small, with large spine and at the apex of a small projection two short curved spines. Claspette stem angled outward from the middle, basal portion stout, setose, distinctly smaller beyond the angle; filament expanded before the middle tapering to apex. Clasper enlarged in the middle.

Larva: Head hairs multiple, upper tufts more dense than lower. Air-tube more than three times as long as wide at the base; pecten extending over the basal third, hair tuft near middle. Comb triangular, large. Anal segment longer than wide, dorsal plate extending below lateral line. Anal gills pointed, nearly twice as long as segment.

Distribution. — *Aedes pullatus* is prevalent throughout the state in the wooded mountain regions at higher elevations. It has never been taken in plains regions or away from forests. It is frequently to be found associated with *Aedes communis, Aedes fitchii* and, at higher elevations, with *Aedes punctor*.

Life History. — The winter is passed in the egg stage and only one brood occurs annually. The larvae hatch in water in ground depressions in the forest and meadows of higher mountain regions. The pools are filled with water from melting snow or from the overflow of mountain streams. Larvae have been taken May 15, at an elevation of 8,000 ft. at Smith and Moorehouse, and Grandaddy Lakes on July 16, at 12,000 ft. elevation. The adults emerge from the latter part of May until the end of July, depending upon the season and elevation. The females have been taken on the wing from May until the twentieth of August, but are most numerous for a period of about three weeks after their emergence. Larvae have been taken in high mountain pools in great numbers in almost pure culture.

IMPORTANCE. — *Aedes pullatus* are restricted to the timbered regions of the higher mountains and in these localities during certain seasons constitute a serious pest. The females attack fiercely but their bite is not extremely severe. The females will feed at any time during the day in the timber where they occur.

Aedes Punctor (Kirby)

1837 *Culex punctor* Kirby, Rich. Fauna Bor. Amer., 4:309.

DISTINGUISHING CHARACTERS. — *Female*: A medium sized dark mosquito. Mesonotum vestiture yellowish-brown or grayish around the margins, broad median bronzy-brown stripe sometimes divided by a narrow line of pale scales. Coloration and pattern variable. Abdomen dark with variable basal segmental white bands. Wing scales dark. Tarsi dark, not banded.

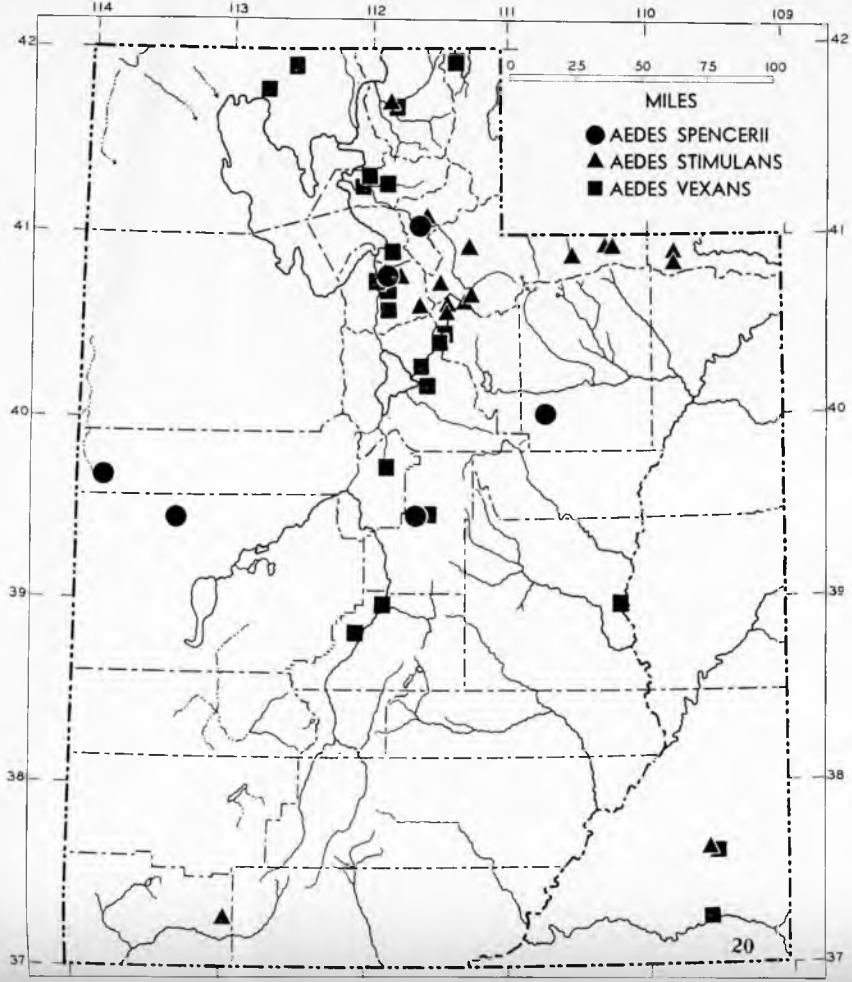
Male Hypopygium: Side-piece about three times as long as broad; apical lobe low, rounded, bearing several short spines or stout setae; basal lobe prominent, quadrangular, setose, a single long, hooked, spine at the margin surrounded by a tuft of stout setae. Claspette stem short, stout, curved outward; filament sickle-shaped, slightly swollen in the middle, point rather blunt. Clasper large, slightly tapering at the ends, long terminal spine.

Larva: Head hairs usually double, occasionally only one. Air-tube three times as long as wide at the base, stout; pecten not extending to the middle, teeth fine, even, terminated by tuft. Comb in irregular double row. Anal segment longer than wide, dorsal plate encircling segment. Anal gills longer than segment, tapering.

DISTRIBUTION. — *Aedes punctor* is found in the high mountains in the central and northeastern part of Utah. It is found only in timbered regions of the high mountains. It has never been taken on the plains or away from the timber. *Aedes punctor* is found in greatest abundance in the Uintah Range from 9,000 to 13,000 feet elevation. This species is associated with *Aedes communis*.

LIFE HISTORY. — The winter is passed in the egg stage and only one brood is produced annually. The larvae appear late in the spring or early summer, and are found in pools in the timber and mountain meadows, especially in pools that have mossy bottoms. These pools are usually filled with water from melting snow and the more permanent pools are slightly acidic. The adults emerge in June and the early part of July. Females have been taken on the wing as late as the first part of August.

IMPORTANCE. — This mosquito, during certain seasons, is considered a pest in the localities where it occurs. The females are persistent biters and will attack man and animals. The adults are confined to the timber and have never been taken feeding in the open. They will attack any time during the day when disturbed. Their flight is limited to the timber region; therefore, they probably do not travel any great distance from their breeding pools.



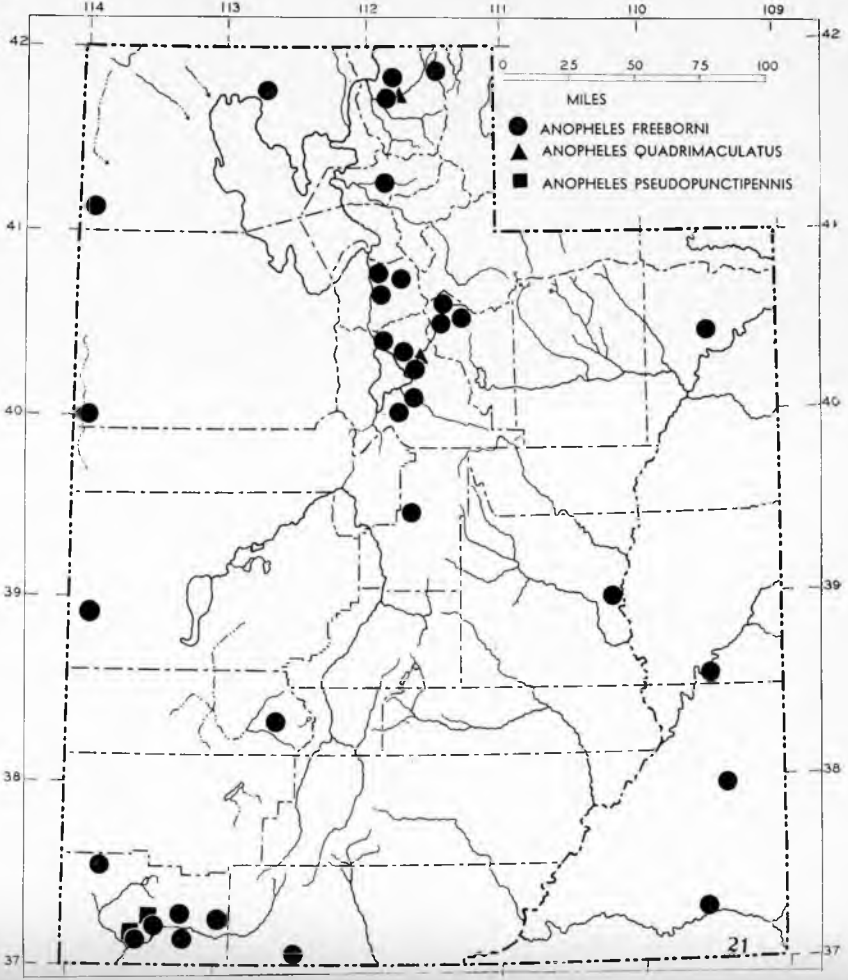


PLATE V

Known Distribution in Utah of:

Fig. 20. *Aedes spencerii*

Fig. 21. *Anopheles freeborni*

Aedes Spencerii (Theobald)

1901 *Culex spencerii* Theobald, Mon. Culic., 2:99.

Distinguishing Characters. — *Female*: A medium sized dark gray mosquito. Mesonotum vestiture yellowish-gray, with broad median brown stripe, stripe sometimes divided by pale line, pattern variable. Abdomen with pale scales forming irregular bands at both ends of the segments, a median dorsal pale stripe resulting. (This stripe aids in distinguishing *spencerii* from *idahoensis*.) Wing scales bicolored, visibly alternating white and black. Tarsi mostly black, not banded.

Male Hypopygium: Side-piece over twice as long as wide; apical lobe prominent, bearing numerous short reversed setae; basal lobe large, broadly expanded and separated from the side-piece posteriorly, bearing a large basal spine and numerous stout setae. Claspette stem medium, slightly tapering; filament, short, angular, pointed. Clasper long, swollen in the middle, long terminal spine.

Larva: Head hairs single. Air-tube about two and one-half times as long as wide at the base; pecten extending to the middle, last two teeth stout, detached, terminated by small tuft. Comb in irregular double row. Anal segment longer than wide, dorsal plate extending nearly to ventral line. Anal gills twice as long as segment, pointed.

Distribution. — *Aedes spencerii* has been taken in the northern part of the state. It is usually found in the plains and prairie regions, also along the foot hills of the principal mountain ranges. It is frequently found with *Aedes dorsalis*, *Aedes niphadopsis*, *Aedes campestris* and *Aedes idahoensis*.

Life History. — This mosquito winters in the egg stage and only one generation is produced each year. The larvae appear early in the spring in surface pools filled by melting snow or spring rains. The larvae generally appear in April or the first part of May. The adults emerge in May and are found on the wing as late as the latter part of July. The pools in which the larvae are found developing are frequently alkaline. The males swarm during mating.

Importance. — This mosquito is fairly common in certain localities in the spring and early summer. They are blood thirsty and attack man and animals. The females seem to be strictly diurnal, and will attack any time during the day. Their flight range has not been determined.

Aedes Sticticus (Meigen)

1838 *Culex sticticus* Meigen, Syst. Beschr. Eur. Zweifl. Ins., 7:1.

Distinguishing Characters. — *Female*: A medium sized dark mosquito. Mesonotum vestiture yellowish-gray, with broad median, brown band, sometimes divided; posterior sub-lateral stripes may be present. Abdomen with basal white bands widening at the sides. Wing scales dark. Legs dark, tarsi not banded.

Male Hypopygium: Side-piece about three times as long as broad; apical lobe long, rounded at apex, covered with short setae; basal lobe prominent, conical, clothed with setae, a long, stout marginal spine, surrounded by a tuft. Claspette stem stout, reduced near apex with a stout setae on the inner side at the place of constriction; filament short, expanded in middle. Clasper short, slightly swollen in the middle.

Larva: Upper head hairs multiple; lower one or two hairs. Air-tube nearly three times as long as wide at the base; pecten extending to the middle, terminated by tuft. Comb triangular, many scales. Anal segment as long as wide, dorsal plate extending almost to ventral line. Anal gills pointed, longer than segment.

Distribution. — *Aedes sticticus* is found breeding in the northern and central part of the state in the low mountain valleys along the margins of the larger streams. The adults are found in the wooded regions and also in the open a considerable distance from their breeding waters. This species has never been taken in the plains areas. It is associated with *Aedes cinereus* and at times with *Aedes vexans*.

Life History. — The winter is passed in the egg stage and only one brood occurs annually. The larvae are found developing in open or woodland pools on the flood plains of the principal streams where vernal flooding occurs. Larvae appear shortly after the first flooding of these pools during the season. This flooding generally takes place from the latter part of April to the middle of June. The larvae that appear in the early spring develop rather slowly due to the low temperature of the water. The adults emerge, according to conditions, from the first of May to the middle of June. The females are on the wing from the latter part of May to the middle of July, depending upon the time of their emergence. From observations during this investigation, it is apparent that eggs will remain viable for at least three seasons and perhaps much longer before hatching, when the water is not sufficiently high to flood the ground where the eggs are laid. This was determined on the Provo and Weber rivers during the drought of 1932, '33, and '34. This has also been observed in other parts of the country by such investigators as Twinn (N. J. Proc., 1931) and Dyar (1928).

Importance. — *Aedes sticticus* is of importance locally in the parts of the state where it occurs. Enormous broods mature under favorable conditions in these localities during the spring and early summer. The females are vicious biters and will attack animals or man when opportunity affords. They feed in the woods or in the open during the day but are generally more active in the evening. Twinn, (N. J. Proc., 1931) reports that in Ottawa the females will migrate four miles from their breeding pools. In this investigation, a flight range of at least two miles has been determined in the vicinity of Wanship, Utah.

Aedes Stimulans (Walker)

1848 *Culex stimulans* Walker, List. Dipt. Brit. Mus., 1:4.

Distinguishing Characters. — *Female*: A fairly large brownish mosquito. Mesonotum vestiture of yellowish-brown or white; markings variable. Usually white or yellowish around the margins and brown centrally. Abdomen dark with broad basal segmental white bands. Wing scales bicolored, black predominating, intermixed with white especially on costal margin. Tarsi dark with basal white bands on the joints, more distinct and broad on hind legs.

Male Hypopygium: Side-piece nearly three times as long as wide; apical lobe prominent, rounded, bearing numerous stout setae directed inward; basal lobe low, broad, slightly expanded, roughened, numerous setae, a single heavy marginal spine. Claspette stem long, slender, curved; filament long, sickle-shaped, expanded in the middle. Clasper long, swollen in the middle.

Larva: Upper head hairs double, lower single or double. Air-tube two or three times as long as wide; pecten extending about one-third, terminated by sparse tuft, teeth closely set. Comb triangular, many scales. Anal segment nearly twice as long as wide, dorsal plate extending below lateral line. Anal gills as long as segment, pointed.

Distribution. — *Aedes stimulans* occurs in limited numbers in certain sections in the northern and central part of the state. It is found in the wooded regions of the mountains at lower elevations. This species has never been taken on the plains. *Aedes stimulans* are sometimes associated with *Aedes sticticus*.

Life History. — The winter is passed in the egg stage and only one generation is produced each year. The larvae appear in May and June, and are found developing in pools formed by the over-flow of some of the principal streams. They have also been taken from surface pools filled from snow water and early spring rains. The adults emerge during the latter part of May and in June. A few females are on the wing as late as September.

Importance. —This mosquito is of importance in certain sections of Utah during the first part of the season. The adults are vicious biters and readily attack man or livestock. They are usually found in the woods along the stream courses. The females will feed any time during the day in these localities. Their flight range has not been determined in Utah. According to Matheson (1929) "this species rarely invades houses and it is not known how far it may travel though I have taken it at least two miles from any known breeding place."

Aedes Vexans (Meigen)

1820 *Culex vexans* Meigen, Syst. Beschr. Eur. Zweifl. Ins., 6:241.

Distinguishing Characters. — *Female*: A medium sized dark mosquito. Mesonotum vestiture bronzy-brown, paler at base of wings and antiscutellar regions. Abdomen black, with broad, segmental, basal, white bands, widening at the sides. Wing scales brown. Most

of the tarsal joints with narrow basal bands of white scales. (This character is quite distinctive for this species in Utah).

Male Hypopygium: Side-piece twice as long as wide; no apical or basal lobes. Claspette short, capitate, crowned with short, dense spines; no filament. Clasper stout, gradually widening at the apex, where it divides, one arm bearing a stout articulate spine, the other terminated by several small setae. (This character is sufficient to identify this species).

Larva: Upper head hairs multiple, lower double. Air-tube three times as long as wide at the base, tapering beyond the middle; pecten not extending to the middle, terminated by small tuft, last two teeth stouter, detached. Comb in irregular double row. Anal segment longer than wide, dorsal plate extending nearly to ventral line. Anal gills longer than segment, slender, tapering.

Distribution. — *Aedes vexans* is widely distributed throughout the state. It is found in the vicinities of streams both in the mountain and plains regions. However, in the mountains it has never been taken at the higher elevations, but is usually found along the margins of streams in the lower river valleys. It is found in all parts of the state where irrigation is practiced. This mosquito is generally associated with *Aedes dorsalis* and in wooded regions at lower elevations it occurs with *Aedes sticticus* and *Aedes cinereus*.

Life History. — The winter is passed in the egg stage and there is some disagreement as to the number of broods occurring in a season. Hearle (1926) in British Columbia, has proved experimentally that the eggs do not all hatch at the same time. Freeborn (1926) states that "unlike eggs of many *Aedes* those of *vexans* hatch if moisture is supplied during the same season." Mail (1934) states "the winter is passed in the egg state and there is but one generation a year." From observations made by the author in Utah, it seems apparent there is more than one brood produced in this locality. The eggs do not hatch all at once as larvae are frequently taken in the same pool that are in different stages of development. However, three to four different broods may occur in a single season, depending upon suitable environmental conditions. The over-wintering eggs usually hatch in the latter part of April or during May. The larvae are found developing in flood water pools in meadows and willow thickets along the margins of streams. Occasionally, the larvae are found in pools filled by early spring rains and, later in the season, in depressions filled by irrigation water.

The first broods appearing in the spring hatch from over-wintering eggs. In June or the first part of July, following rains or flooding from irrigation water, a second brood appears. The third brood may occur in July or during August. A partial fourth brood occasionally develops in September. During certain seasons, due to the absence of water, some of these broods may not occur; in seasons of extreme drought, as in 1934, very few *vexans* appeared and those were taken principally in the spring of the year. Under favorable conditions, the larvae are found developing in great numbers, and in receding water

or surface pools, the larvae are frequently concentrated so that 500 or more are found in each pint of water. This prolific breeding of *vexans* sometimes extends over considerable areas and enormous broods emerge under these conditions. The first adults appear ordinarily in May, subsequent broods hatching and emerging during the season as their breeding areas are created. The adults are found on the wing from May until late in September or early October.

IMPORTANCE. — *Aedes vexans* rank next in importance to *Aedes dorsalis* as a pest mosquito in Utah. It has a wide distribution and, considering the state at large, is perhaps second to *dorsalis* in numbers throughout the season. The adults attack readily during the day or night, but are more active in the wooded regions during the day than in the open; however, they show greater activity in the evening in all localities. They will enter houses when opportunity affords. *Aedes vexans* are attracted to light and both males and females are frequently taken in light trap collections. This species is migratory, moving out from their breeding areas in a general dispersal or migrating as a brood in a general direction. They have a determined flight range of from 5 to 8 miles in the vicinity of Salt Lake City.

KEY TO UTAH SPECIES OF ANOPHELES

Adult Females

Palpi banded with white rings ..... *pseudopunctipennis* Theo.
Palpi not banded ..... *freeborni* Aitken

Male Hypopygium

Mesosome leaflets, two pair ..... *pseudopunctipennis*
Mesosome leaflets, three pair ..... *freeborni*

Larvae

Leaves of palmate hairs in the tufts, long, drawn out, pointed ..... *pseudopunctipennis*
Leaves of palmate hairs in the tufts, short, rounded ..... *freeborni*

Anopheles Freeborni Aitken

1939 *Anopheles maculipennis freeborni* Aitken, Pan-Pac. Ent., (15) 4:192.

Distinguishing Characters. — *Female*: A medium sized dark mosquito. Palpi as long as proboscis. Mesonotum vestiture sparse, golden-scaled, with minute gray scales over the median area, appearing as a broad median stripe or divided into three lines. Abdomen brownish black scaled, with numerous short, pale hairs. Wing scales dark, forming distinct spots at base of second vein, at forks of second and fourth, and on the cross veins. (No light or coppery spot visible on the fringe at the apex of wing). Tarsi not banded.

Male Hypopygium: Side-piece about one and one-half times as long as the width at the base; apical lobe absent. A long spine, inwardly directed, just beyond the middle of the side-piece. Two stout basal spines present, maintained on small prominences, the outer spine the longer. Claspette lobes each bear three spines. Clasper longer than side-piece, constructed medially, with short inserted terminal spine.

Larva: Head hairs single, plumose in irregular line between the bases of antennae. Air-tube rudimentary. Anal segment longer than wide, dorsal plate small. Anal gills about as long as the segment, blunt.

Distribution. — *Anopheles freeborni* is widely distributed throughout the state in the plains and prairie regions. It is also found in low mountain valleys up to an elevation of about 7,000 feet. It is the most abundant anopheline in the state, and is frequently found associated with *Aedes vexans*, *Theobaldia inornata*, and *Culex tarsalis*.

Life History. — The adult females pass the winter in hibernation. These hibernating females are found during the winter months in sheltered places such as rock cellars, granaries, warm stables, and other out-buildings. The females seek the protected dark corners of these structures. They have been collected on numerous occasions

in the vicinity of Salt Lake City at different times during the winter. The hibernation is not complete as the females will take wing and fly short distances in the buildings while in hibernation, although they have never been induced to feed at this time. During the latter part of April or May the over-wintering females issue from their hiding places and become active in the vicinity of their breeding water. The date of their appearance depends on the weather conditions and is largely determined by the temperature. The females are fertilized by the males in the fall of the year before going into hibernation, and upon coming forth in the spring, they deposit their eggs singly on the surface of the water. It has not been determined whether a blood feeding is necessary in the spring before oviposition, but some females are known to feed before depositing eggs. The eggs are laid in shallow pools of clear water, preferably the more permanent pools containing mats of green algae or floating *Lemna*. The pools are usually created by streams, springs, flowing wells or irrigation water.

The first larvae usually hatch during the latter part of May or the first of June, and in certain seasons may appear as early as April. The larval development is rather slow during the spring. The first adults emerge the last of May or in June. This first scattered brood is responsible for the vast numbers that reach their seasonal peak during September. The number of generations occurring during the season have not been determined, but reproduction is continuous from May until October. After about the 20th of October, no further breeding occurs during the season and the adult males soon disappear, the females remaining in shelter from the middle of November or first of December until they come forth in the spring.

Importance. — *Anopheles freeborni* is the most important carrier of malaria in Utah. This is also true of the species wherever it is found in the western part of the United States, according to most authorities. It is also sufficiently numerous to constitute a pest in certain localities. The breeding areas are commonly located in the immediate vicinity of human dwellings. The adults are fond of entering man-made shelters such as houses and out-buildings. In a survey made by the author on the outskirts of Salt Lake City in 1929, 78 per cent of the outbuildings harbored adults of this species. The females resting during the day in these buildings seek the dark corners that are protected from wind and air currents. It is interesting to observe the adults in these sheltered corners resting with ease upon cobwebs and other kinds of spider webs without becoming ensnared in their meshes. They become active in the evening and during the night and will attack man and animals. They occasionally feed on dark cloudy days but the author has never observed them feeding in the open sunlight. Their flight range is limited to the vicinity of their breeding area. In Utah, adults have not been collected over three-fourths of a mile from their place of development, the distance of flight usually being much less.

Anopheles Pseudopunctipennis Theoblad

1901 *Anopheles pseudopunctipennis* Theobald, Mon. Culic., 2:305.

Distinguishing Characters. — *Female*: A medium sized dark mosquito. Palpi as long as proboscis, dark scaled with white rings at the joints. (The rings on the palpi distinguish this species from other anophelines in the state). Mesonotum vestiture of small golden and white hairs, the latter predominating on the anterior and central area. Abdomen with dark scales and numerous hairs. Wing scales bicolored, black, and pale yellow, the yellow forming long spots; four costal spots, the basal two on sub-costal vein only; third vein largely pale scaled; fifth pale scaled to forks except at base, lower fork with pale scales except at the tip; sixth medianly pale scaled; fringe at tips of veins pale, forming alternating dark and light spots. Tarsi uniformly dark.

Male Hypopygium: Side-piece almost twice as long as wide; a large inwardly directed spine just beyond the middle, and two very stout basal spines. Claspette bilobed, the ventral lobe larger with two stout apical setae, the dorsal lobe elongate, bearing three spines. Clasper long, reduced in the middle, with short, inserted terminal spine.

Larva: Similar to *Anopheles freeborni* except the leaves of palmate hairs in the tufts are long, drawn out, pointed.

Distribution. — This species to date has only been collected in Washington County in the southern part of the state. It is very abundant in this part of Utah and the author has taken *pseudopunctipennis* in all stages while collecting in this area. This species is found closely associated with *Anopheles freeborni*.

Life History. — The adult females pass the winter in hibernation and in other respects are similar in life history and habits to *freeborni* in that area. The adults are commonly found in out-buildings and human dwellings, contrary to the findings of certain investigators, Freeborn (1926).

Importance. — It is sufficiently abundant in certain localities to constitute a pest. It is also reported as a carrier of malaria at least under laboratory conditions.

Anopheles Quadrimaculatus Say

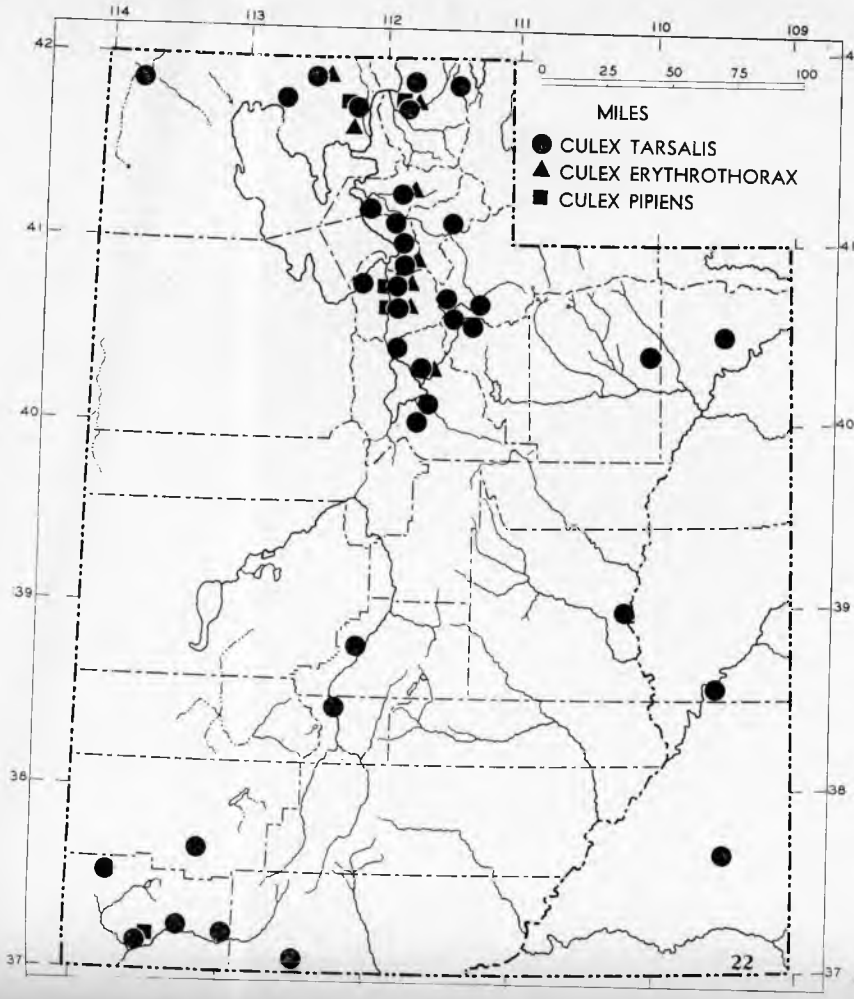
1824 *Anopheles quadrimaculatus* Say, Keat. Narr. Exp. St. Peters Riv., 2:356.

Distinguishing Characters. — *Female*: Black spotted wings. Mesonotum vestiture brown, paler on the sides. Abdomen dark scaled, with numerous pale yellow hairs. Wings with indistinct dark spots at the origin of second vein, on the cross veins, and at the bases of forks of second and fourth. Leg scales black, femora and tibia tipped with yellowish white.

Male Hypopygium: Side-piece as long as wide, conical; two large approximate spines near base; a slender internal spine beyond the middle. Clasper longer than side-piece; reduced in the middle. Claspette bilobed; dorsal lobe with two blunt, stout spines, fused at the apex; ventral lobe with two spines, the outer broader and longer. Mesosome long and narrow, with three pairs of narow leaflets, the outermost the longest.

Larva: No adequate key available.

Distribution. — Records of *Anopheles quadrimaculatus* from Utah County, Sept. 1910 and from Logan, Utah, Oct. 15, 1913, were reported by Howard, Dyar and Knab, (1912-17). The Dyar collection of mosquitoes in the National Museum have been examined by Dr. Alan Stone and the author and no *quadrimaculatus* from Utah were found in this collection. It is possible that *Anopheles freeborni* may have been identified on this occasion as *quadrimaculatus*. However, *quadrimaculatus* may have disappeared from this state, as Matheson suggests is occurring with this species in central New York. The author is inclined to accept the first probability.



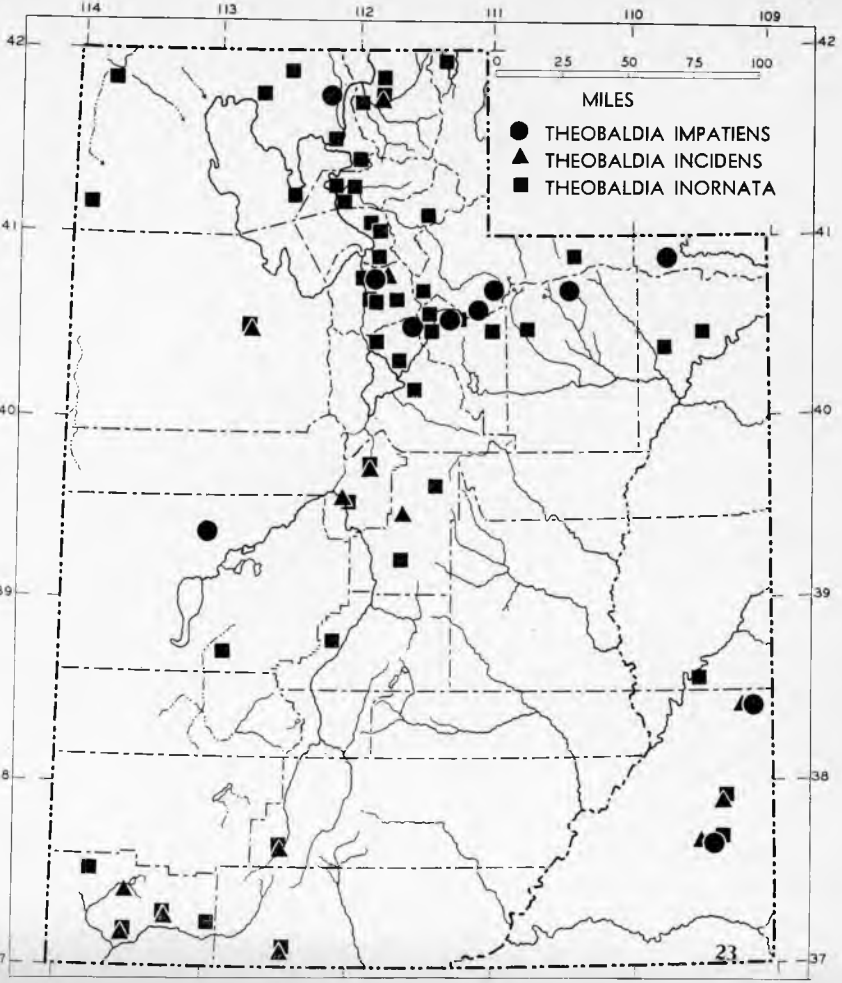


Plate VI

Known Distribution in Utah of:

Fig. 22: *Culex tarsalis*

Fig. 23: *Theobaldia impatiens*

KEY TO THE UTAH SPECIES OF CULEX

Adult Females

1. Proboscis ringed with white 2
   Proboscis not ringed with white 3
2. A dotted white line on the outside of femora and tibiae; V-shaped dark marking on venter of each abdominal segment ..... *tarsalis*
   Without white dotted line on the outside of femora and tibiae; black median spot on venter of each abdominal segment ..... *stigmatosoma*
3. Abdominal segments without basal white bands ..... *salinarius*
   Abdonimal segments with basal white bands 4
4. Mesonotum vestiture light red; scales hair-like ..... *erythrothorax*
   Mesonotum vestiture not light red; scales normal 5
5. Basal white bands of second abdominal segment usually not triangularly extended medianly ..... *restuans*
   Basal white bands of second abdominal segment usually triangularly extended medianly ..... *pipiens*

Male Hypopygium

1. Apical lobe with eight or more appendages ..... *pipiens*
   Apical lobe with six or less appendages 2
2. Apical lobe with five appendages ..... *tarsalis*
   Apical lobe with six appendages 3
3. Mesosome without median or lateral processes, consisting of two recurved plates ..... *restuans*
   Mesosome with median and lateral processes 4
4. Mesosome without long, recurved, basal arm ..... *stigmatosoma*
   Mesosome with long basal arm, recurved into approximately complete circle ..... *erythrothorax*
   Mesosome basal arm recurved into an approximate semi-circle ..... *salinarius*

Larvae

1. Air-tube with four or more pairs of tufts 2
   Air-tube with one pair of tufts and scattered single hairs ..... *restuans*
2. Tufts of air-tube not in line 3
   Tufts of air-tube five; all in line ..... *tarsalis*
3. Air-tube long and slender, 7x1 4
   Air-tube shorter and thicker, 5x1 5
4. Tufts on air-tube four pairs ..... *salinarius*
   Tufts on air-tube five pairs ..... *erythrothorax*
5. Sub-dorsal hairs of third and fourth abdominal segments double ..... *pipiens*
   Sub-dorsal hairs of third and fourth abdominal segments in threes ..... *stigmatosoma*

Culex Erythrothorax Dyar

1907 *Culex erythorthorax* Dyar, Proc. U. S. Nat. Mus., 32:124.

Distinguishing Characters. — *Female*: A medium sized reddish-brown mosquito. Mesonotum vestiture of fine hair-like golden-brown scales. Abdomen of brownish-black scales with irregular, basal segmental yellowish-white scales. Wing scales brown to black, narrow. Femora black above, yellowish beneath; tibia dark above, bronzy-brown beneath; tarsi unbanded.

Male Hypopygium: Side-piece more than twice as long as wide at the base; apical lobe with six appendages, three rods with flattened recurved tips, two setae and a leaf. Tenth sternite with long, basal arm, recurved into approximate circle; tuft of spines at the tip. Ninth tergite small, with few spines.

Larva: Head hairs multiple. Antennae thickened on basal two-thirds, spinose; outer third, tapering, unspined, terminated by two subapical setae, a long and short terminal seta and pedecilated digit. Air-tube about seven times as long as wide at the base; tapering; pecten on basal fifth; followed by five pairs of hair tufts, the subapical slightly out of line. Comb of numerous scales. Anal segment longer than wide; ringed by anal plate. Anal gills shorter than segment, obtusely pointed.

Distribution. — *Culex erythrothorax* is reported as being limited to California. The author has found this species fairly common in Salt Lake City and vicinity and also several other localities in the north central part of the Wasatch Mountains. Identifications were verified and checked with California specimens by Dr. T. H. G. Aitken.

Life History. — The females pass the winter in hibernation in sheltered places. The larvae appear sporadically throughout the season in shallow ponds containing an abundance of vegetation. Late in the season the larvae may become quite numerous in limited areas. The number of generations produced during the season has not been determined.

Importance. — Freeborn (1926) states that *erythrothorax* "seldom occurs in large numbers nor is it of any particular importance, as it confines its feeding activities to birds." In Utah, this species is of minor importance but on two occasions, in the late fall, *erythrothorax* has been encountered by the author in considerable numbers in limited areas. On these occasions they attacked viciously and their bites were very painful. They were able to bite through light clothing and were not easily disturbed while feeding.

Culex Pipiens Linnaeus

1758 *Culex pipiens* Linnaeus, Syst. Nat. Ed., 10:602.

Distinguishing Characters. — *Female*: A medium sized golden-brown mosquito. Mesonotum vestiture uniform, narrow, golden-brown scaled, two anterior narrow, bare, median lines. Abdomen pale scaled beneath with black scales above and basal segmental

white bands, wide in the middle, narrowing at the sides where they join triangular white patches. Wing scales dark brown. Leg scales black above.

Male Hypopygium: Side-piece about twice as long as wide; apical lobe prominent, bearing eight appendages from the base outward—three rods, two setae, a filament, a leaf, and a seta. Mesosome paired, each half with three processes, the median blade-like, long and curved outwardly.

Larva: Head hairs multiple. Air-tube over four times as long as wide at the base; pecten of about twelve teeth on basal fourth of tube, followed by four hair tufts, the third one out of line dorsally. Comb triangular, many scales, anal segment longer than wide; ringed by dorsal plate. Anal gills as long as segment, bluntly pointed.

Distribution. — *Culex pipiens* is rather rare in Utah and only a few specimens have been taken. The few *pipiens* collected in the vicinity of Salt Lake City were obtained in light traps. This species has also been taken at St. George in the larval and adult stages. No other collections have been made, but *pipiens* are undoubtedly present in limited numbers in other localities within the state.

Life History. — From all reports, the females pass the winter in hibernation. In the spring, the females deposit their eggs on the surface of the water. The number of generations during the season has not been determined.

Importance. — *Culex pipiens* are of no importance in Utah except in a few limited localities in the southern part of the state where they may at times become annoying.

Culex Restuans Theobald

1901 *Culex restuans* Theobald, Mon. Culic., ii:142.

Distinguishing Characters. — *Female*: A medium sized reddish-brown mosquito. Mesonotum vestiture reddish-brown; sometimes yellowish-white scales form indistinct spots on the disk and are sparsely scattered on the anterior margins and at the base of the wings. Abdomen dark scaled with broad basal segmental white bands, slightly widening laterally. Wing scales narrow, dark. Legs bronzy-black, femora and tibia tipped with white; tarsi unbanded or with narrow pale bands at both ends of the segment.

Male Hypopygium: Side-piece more than twice as long as wide; apical lobe prominent, bearing three rods, a leaf, and two long setae. Clasper short, tapering distally. Mesosome heavily sclerotized, sides sub-quadrate, each bearing a single median tooth.

Larva: Head hairs multiple. Air-tube four times as long as wide at the base; pecten confined to the basal third, followed by three tufts, the basal of two long hairs, the median slightly out of line with the other two consisting of four long hairs, and the apical, a rather dense tuft of short hair. Comb triangular, numerous scales. Anal segment slightly longer than broad, ringed by dorsal plate. Anal gills longer than segment, rounded at tip.

Distribution. — *Culex restuans* is found in the northern part of the state. It is undoubtedly present in other parts of the state but has not been taken thus far in the collection.

Life History. — The winter is probably passed in hibernation as occurs with other species of *Culex*. The larvae first appear during the last of April or the first part of May, successive broods continuing during the summer. Adult females are on the wing from May until about the first of November, depending upon the season. This mosquito breeds in marshes and swamps and has occasionally been collected in ornamental pools and rain barrels. According to Dyar (1928) "this species takes the place of *Culex pipiens* in the northern woods as the semi-domesticated house mosquito, breeding in rain-barrels."

Importance. — *Culex restuans* is very rare in Utah and cannot be considered of any great importance. Its feeding habits and flight range have not been determined.

Culex Salinarius Coquillett

1904 *Culex salinarius* Coquillett, Ent. News., 15:73.

Distinguishing Characters. — *Female*: A medium sized brown mosquito. Mesonotum vestiture of narrow hair-like golden brown scales, with two dorsal bare lines. Abdomen dark scaled without segmental white bands. (This character is distinctive for the species in Utah). Wing scales dark, narrow. Tarsi not banded.

Male Hypopygium: Side-piece more than twice as long as wide; apical lobe prominent, bearing three rods with hooked tips, a leaf-like appendage, and two apical setae. Clasper flattened towards the apex, with a sub-articulate spine. Mesosome with three processes, the upper or median possessing sharp distinct teeth on the under side, the lateral process with a tooth arising on the outer angle.

Larva: Head hairs multiple, long. Air-tube about seven times as long as wide at the base, gradually tapering. Pecten confined to the basal fifth, followed by four small tufts, the subapical smaller and out of line. (This character is distinctive for the species in Utah). Comb triangular, numerous scales. Anal segment as long as wide, ringed by dorsal plate. Anal gills as long as anal segment, pointed.

Distribution. — *Culex salinarius* has been collected by the author in the vicinity of Salt Lake City, but they probably occur in other parts of the state. The larvae have been taken in pools with *Aedes vexans*.

Life History. — The larvae first appear in the late spring or early summer, and are found developing in marshy areas; the pools containing considerable vegetation, such as grass, sedges, and *Lemna*. According to Dyar (1922) this species is "frequently very abundant near the seashore, and hence named; but also occurring inland, even

in water barrels on occasion." Little is known about the life habits of this species in Utah, because the females have never been taken while feeding. The adult females probably pass the winter in hibernation.

IMPORTANCE. — *Culex salinarius* is very rare in Utah and, therefore, of no great importance.

Culex Stigmatosoma Dyar

1907 *Culex stigmatosoma* Dyar, Proc. U. S. Nat. Mus., 32:123.

DISTINGUISHING CHARACTERS. — *Female*: A medium sized dark brown mosquito. Proboscis black with white band near the middle. Mesonotum vestiture bronzy-brown interspersed with white, without definite pattern. Abdomen black with yellowish-white basal segmental bands widening at the sides. Venter straw colored with oval median, black spots. Wing scales brown, sometimes a few white scales on costa. Legs black, tibia and femora white tipped; tarsi ringed at both ends of joints.

Male Hypopygium: Side-piece twice as long as wide; apical lobe usually with six appendages appearing from the base outward as three rods, a seta, leaf, and seta. Tenth sternite stout,crowned with fine spines, basal arm recurved to form semi-circle. Ninth tergite small with few short setae.

Larva: Head hairs multiple. Antenna spined, tuft at outer third. Air-tube five times as long as wide at the base; pecten on the basal third; five pairs of tufts, basal one within the pecten, subapical slightly out of line, the last one a single hair. Comb scales numerous in triangular patch. Anal segment as long as wide, ringed by dorsal plate. Anal gills as long as segment.

Dyar (1928) reports *Culex stigmatosoma* in Utah. To date, this species has not been collected by the author. The above description was made from numerous specimens obtained in California. In the opinion of the author, *stigmatosoma* is probably present in the state but is not abundant.

Culex Tarsalis Coquillett

1896 *Culex tarsalis* Coquillet, Can. Ent., 28:43.

DISTINGUISHING CHARACTERS. — *Female*: A medium sized dark mosquito. Proboscis dark with broad white ring near the middle. Mesonotum vestiture bronzy-brown with white scales forming two median subdorsal white spots and a white streak extending posteriorly from each spot. Abdomen dark with broad, dull white, basal, segmental bands. Wing scales dark, intermixed with a few white scales on the costal margin. Tarsal joints banded with white on each end.

Male Hypopygium: Side-piece more than twice as long as wide; apical lobe prominent, in the general shape of a fold, bearing three rods, a filament, leaf, and setae-like appendage. (This character is distinctive for the species). Clasper short, tapering from the base.

Larva: Head hairs multiple. Air-tube over four times as long as wide, uniformly tapering; pecten confined to basal third; followed by five tufts, each gradually decreasing in size towards the apex. Comb triangular, many scales. Anal segment slightly longer than wide, ringed by dorsal plate. Anal gills as long as segment, bluntly pointed.

Distribution. — *Culex tarsalis* is one of the most widespread and abundant mosquitoes of the state. It occurs throughout the prairie and plains regions and has been taken in the mountains up to elevation of 9,000 feet. It is associated with *Aedes dorsalis*, *Aedes vexans*, *Theobaldia inornata* and *Anopheles freeborni*.

Life History. — The adult females pass the winter in hibernation in the basement of houses, out-buildings, cellars, caves, etc. The males do not survive the winter. The females come forth in the spring in April or May depending upon the season. The eggs are laid in boat-shaped rafts that float on the surface of the water. The first larvae usually hatch during the latter part of May or the first part of June. Several generations are produced druing the season, production ordinarily reaching the maximum late in August or during September. Larvae are frequently taken until the first part of November. This species is found in all kinds of breeding water, such as rainwater barrels, roadside ditches, pools around artesian wells, hoofprints in pastures, irrigation waste water, and ornamental pools. The larvae are frequently found in water containing considerable vegetation, and in foul pools in corrals and around slaughter yards, the water in such pools being so contaminated that the larvae of other species are rarely present. Adults are on the wing from the time they emerge from hibernation until late October or November.

Importance. — This species is of major importance because of its wide distribution and abundance throughout the season. However, the females are never conspicious pests, they enter dwellings when opportunity affords and are occasionally taken feeding on man. They feed only after dark and constitute a pest in certain localities. Their bite is rather severe. Their flight range has not been determined but so far the author has not collected them any great distance from their breeding areas.

KEY TO THE UTAH SPECIES OF THEOBALDIA

Adult Females

1. Some tarsal segments with narrow, basal white rings; wings distinctly spotted ..... *incidens*
   Tarsal segments without white rings 2
2. Wings bi-colored especially along costal margin; wings not spotted; cross-veins scaled ..... *inornata*
   Wing scales entirely dark scaled; indistinct spots at forks of veins; cross-veins nude ..... *impatiens*

Male Hypopygium

1. Apical lobe absent ..... *inornata*
   Apical lobe present 2
2. Basal lobe large with a single small spine; eighth tergite with a row of short spines on the basal margin ..... *impatiens*
   Basal lobe small with two stout apical spines; eighth tergite with a small median group of spines ..... *incidens*

Larvae

1. Upper and lower tufts of head hairs multiple, alike ..... *impatiens*
   Upper and lower tufts of head hairs multiple, not alike 2
2. Basal pecten teeth slender with one or two appressed teeth ..... *incidens*
   Basal pecten teeth broader with three or four stout outstanding teeth ..... *inornata*

Theobaldia Impatiens (Walker)

1848 *Culex impatiens* Walker, List. Dipt. Brit. Mus., 1:5.

Distinguishing Characters. — *Female*: A large dark brown mosquito. Mesonotum vestiture rather sparse, scales reddish-brown, with yellowish scales forming patches along the anterior margin, two sub-lateral spots on the disk joining the antescutellar space by narrow lines. Abdomen black with broad, basal, segmental, white bands. Wing scales all brown, more dense at the base and forks of second and fourth veins, producing indistinct spots. Tarsi not banded.

Male Hypopygium: Side-piece almost twice as long as wide; apical lobe prominent, clothed with setae; basal lobe large, conical, setose, with a single stout spine at the apex. Claspette absent. Clasper stout, tapering, with small terminal spine.

Larva: Head hairs multiple, long. Air-tube about one and one-half times as long as wide; pecten with basal teeth changing into long hairs and extending nearly to apex. A large tuft near the base of pecten. Comb triangular, many scales. Anal segment wider than long, ringed by dorsal plate. Anal gills longer than segment, rounded at tip.

Distribution.—*Theoballdi impatiens* is distributed throughout the mountain regions of Utah. It is found in the mountains in the timbered areas up to an elevation of 8,500 feet. It occasionally occurs in the valleys at lower elevations. It has been collected in the vicinity of Salt Lake City and Bear River City, but always in the proximity of timber. It is associated in the mountains with *Aedes pullatus* and *Aedes fitchii*.

Life History. — The adult females pass the winter in hibernation in available shelters such as tree trunks, hollow logs, caves and beneath summer cabins. The eggs are laid in rafts on the surface of the water. The eggs hatch at different times during the season depending upon the locality. At lower elevations larvae have been taken as early as May 5. Biting adults that probably hibernated during the winter have been captured on May 16 at 8,000 feet elevation. The larvae occur in the mountains in deep snow water pools and springs. According to Dyar (1928) only one brood occurs during the season. Hearle (1926) states that there are a number of generations. The author has no information on this subject. Adult females have been taken on the wing from May until August.

Importance.—*Theobaldia impatiens* is of importance in certain mountain localities. The females ordinarily feed only in the evening about dusk and at times are very vicious in their attacks, but generally are rather timid and easily frightened away. The flight range has not been determined, but they are always found in the vicinity of timber and therefore their flight is probably limited.

Theobaldia Incidens (Thomson)

1868 *Culex incidens* Thomson, Kongl. Svens. Freg. Eug. Resa., pt. 6, Dipt., 443.

Distinguishing Characters. — *Female*: A large, dark, grayish-brown mosquito. Mesonotum vestiture of sparse dark brown scales intermixed with pale yellowish scales. Obscure longitudinal narrow stripes are sometimes visible. Abdomen black with broad, basal, segmental bands of yellowish-white scales. Wing scales dark, forming distinct spots at forks of second and fourth veins, upper branch of fifth at its base, and outer portion of sixth. Tarsi with small, pale, basal rings, more distinct on the first two tarsal segments.

Male Hypopygium: Side-piece more than twice as long as wide, conical; apical lobe small, bearing one long spine surrounded by setae. Basal lobe conical, with two stout spines at the apex. Claspette absent. Clasper stout, tapering, with small terminal spines. Lobe of ninth tergite, short, bearing a row of stout setae.

Larva: Head hairs multiple. Air-tube more than twice as long as wide at the base; slightly tapering at each end. Pecten with a large tuft near the base, a few basal teeth followed by long setae extending to apical third. Comb triangular, many scales. Anal segment wider than long, ringed by dorsal plate. Anal gills slightly shorter than segment, pointed.

Distribution. — *Theobaldia incidens* is distributed throughout the state at lower elevations. It is frequently found breeding in the vicinity of houses and can be considered a semi-domesticated species in certain localities. It is found associated with *Theobaldia inornata*, *Culex tarsalis* and at times with *Aedes vexans*.

Life History. — The females pass the winter in hibernation, coming forth in the spring during the latter part of April or in May. The eggs are laid in rafts that float on the surface of the water. The larvae appear in May, and successive broods occur throughout the season until October. The larvae are usually found developing in deep spring pools, rain-water barrels, ornamental ponds, and other receptacles in the vicinity of houses. They are also occasionally found in roadside pools and around artesian wells. The adults are on the wing from May until October.

Importance. — This mosquito is widely distributed and very abundant in the southern part of the state. The females are timid but occasionally attack man. It is reported that they frequently feed on domestic animals.

Theobaldia Inornata (Williston)

1893 *Culex inornatus* Williston, U. S. Dept. of Agric., Div. Ornith. and Mam., N. Amer. Fauna No. 7:253.

Distinguishing Characters. — *Female*: A large grayish-brown mosquito. Mesontum vestiture a mixture of golden-brown and grayish-yellow scales. Narrow lines of pale scales may be present on the disk. Two short, narrow, anterior, bare lines; and two lateral posterior bare stripes are usually visible. Abdomen dark scaled, with broad, basal, yellowish-white, segmental bands, widening laterally. Wing scales dark brown, a few white scales along the costal margin. Tarsi not banded.

Male Hypopygium: Side-piece about twice as long as broad, stout, conical; apical lobe absent, basal lobe prominent, conical, covered with setae and several stout spines at the apex. Claspette absent. Clasper stout, tapering, with short terminal spine. Lobe of ninth tergite prominent, rounded, crowned with numerous short, stout spines.

Larva: Head hairs multiple. Air-tube about three times as long as wide at the base, gradually tapering from the middle towards apex; pecten with basal one-fifth of stout teeth that gradually become long hairs, and extend to near apex. Large hair tufts arise near the pecten at the base of the tube. Comb triangular, many scales. Anal segment slightly longer than wide, ringed by dorsal plate. Anal gills longer than segment, broad, rounded at tip.

Distribution.—*Theobadlia inornata* is the most widely distributed mosquito in the state. It is found in all the plains areas and in the mountains up to an elevation of 9,000 feet. It prefers the timber regions but is often taken in the open. It is associated and found breeding with *Culex tarsalis*, *Anopheles freeborni*, *Theobaldia incidens* and, under certain conditions, with *Aedes vexans* and *Aedes dorsalis*.

Life History.—The females pass the winter in hibernation in secluded places. The hibernating females are much more difficult to find than those of *Anopheles freeborni*, but have been collected by the author in all winter months in places such as basements of homes, potato pits, and rock cellars. It is highly probable that some of the larvae of this species may successfully pass the winter, as the larvae are very resistant to low temperature. The larvae are frequently found developing in pools until they are permanently frozen over with ice in November, and on two occasions larvae have been taken in the fourth instar in early March just as the ice was breaking up in some of these pools. The hibernating females come forth in the spring on the first warm days; they sometimes appear in the winter during warm spells while the snow is still on the ground, and thus are given the name locally of "snow mosquitoes."

Importance.—*Theobaldia inornata* is one of the most important species in Utah because of its abundance, prevalence, and wide distribution throughout the season. The females do not readily attack man, they are rather timid in their approach, but bite occasionally, especially in the evening or in the shade of the wooded areas. They are easily frightened and do not constitute a pest of man. They attack domesticated animals more readily and, under certain conditions, they are of considerable annoyance to domesticated stock. The flight range of this species has not been determined with any certainty; they are usually found in the vicinity of their breeding areas, but specimens have been taken on certain occasions at least two miles distant from the nearest breeding water.

BIOLOGICAL DISCUSSION

Basis for Biological Work

IMPORTANCE.—An organism is frequently referred to as "known" after it has been named and briefly described, when, as a matter of fact, nothing is known about its biology. This has consistently occurred in referring to certain species of mosquitoes. Each species has a distinctive biology that is variable in different localities, a fact often overlooked by investigators. Many workers, finding that the life history and habits of a species have been determined by competent investigators in certain localities, refer to these findings as though they were unalterable in all localities where this species is found. A mosquito species widely distributed in different sections of the country frequently shows extreme changes in its biology, necessitated by modifications to its environment. It is important, therefore, to have some first-hand information on the biology of the species from the region in which it is collected. Overlooking this fact has often proved to be a serious mistake when economic workers have attempted the control of mosquitoes in different sections of the country.

TREATMENT.—Much of the information obtained by the author on the biology of Utah mosquitoes has already been given in the discussion of the individual species. The following presentation is an attempt to deal with some of the more salient principles of the biology of the mosquitoes of the state. The majority of the work on mosquitoes has been carried on in more humid sections than Utah, where rainfall, tides, and other factors are decidedly different from those in this semi-arid inland state. The author has, therefore, given special attention to these factors peculiar to the region and purposely omitted, or only briefly mentioned, the well known facts on the biology of mosquitoes that are the common property of all investigators of this subject. Some of the factors to be considered, and which have been given particular attention in this discussion, are: (1) Origin of mosquito producing water; this obviously is an important factor in a semi-arid region to the biology of an insect that reaches maturity in an aquatic habitat. (2) Mosquito flight is also important in a region of this type where breeding waters are frequently scattered over limited areas many miles apart. (3) Biological factors in mosquito control are of great importance, because much of the breeding waters are ephemeral in nature and aquatic enemies of mosquito larvae must be transitory or absent. These and other factors are considered in this bulletin with the aim of contributing some information to the biology of the mosquito fauna of a little known region.

This work is merely introductory and has by no means exhausted the possibilities for biological studies of the mosquitoes of this part of the country. In addition to contributing some information, it is the desire of the author that this bulletin serve as a stimulus for a continued and more extended study of this problem in the Great Basin Area.

PLATE VII

Alpine meadow flooded by melting snow; prolific breeding water of mountain species of Aedes.

PLATE VIII

Pools formed by melting snow and vernal rains; typical breeding water for spring broods of plains mosquitoes.

Seasonal Breeding of Common Species

The seasonal breeding of different species of mosquitoes is a determining factor in the prevalence of the mosquito fauna throughout the warmer seasons. Most of the mountain species of *Aedes* produce a single brood during the year; this occurs in the spring or early summer. The time of the appearance of this brood is largely determined by the altitude and seasonal temperatures. The prevalence of adults during the remainder of the season is governable by the date of their appearance, abundance, and longevity. A few of the adults of some of the mountain species survive until late summer or early fall. Some plains mosquitoes occur also in a single spring brood and soon disappear, while other common species of the plains reproduce by successive broods, or continuous breeding during the warmer months of the year. Were it not for the perpetuation of certain species by successive broods, the adult mosquito population in the plains region would become substantially decreased or entirely depleted during the summer, as is the case in mountainous areas. It is well known that the adult mosquito population almost completely disappears in the mountains during the late summer, while on the plains adults persist throughout the season and certain species are more numerous on the plains in the fall than at any other time during the year. This fact is principally due to the continued seasonal breeding of certain plains species, and to the single brood of most mountain species, rather than temperature differences or absence of water, which are frequently stated as the governing factors.

The following table indicates the seasonal breeding of the most common mosquito species in the vicinity of Salt Lake City. This table gives only the number of places wherein the larvae of these species were collected by the author. Only records of larvae allowed to complete development in the laboratory thus permitting accurate identification from adult male and female specimens, as well as from larval characteristics, were used in compiling these data. These collections were made at various times during the mosquito breeding seasons from 1929 to 1936. This is not an entirely satisfactory method for determining seasonal breeding, as the collections were not made regularly during each month; but since all larvae found in the vicinity were collected on each trip, and as these trips were made during several successive seasons, this material should give a fair index for comparing the prevalence of the breeding of these species during the respective months of the year. This table does not show the relative abundance of the larvae, as all places where larvae were found are given equal consideration regardless of the size of the area or the number of larvae contained in the area. Records of adults taken on the wing during these collecting trips were omitted as irrelevant in determining seasonal breeding because adults of certain species are more numerous, longer lived, and more widely dispersed than the adults of other species.

Number of Places where Larvae were Collected in the Vicinity of Salt Lake City from 1929 to 1936, and the Months in which the Collections were Made.

	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
A. dorsalis	1	25	48	40	20	23	40	12	5	1	2
A. campestris	0	8	28	9	5	2	2	0	2	0	0
A. niphadopsis	0	1	8	1	0	1	0	0	0	0	0
A. vexans	0	0	5	12	4	11	18	4	1	0	0
C. tarsalis	0	0	1	5	12	20	53	13	8	0	0
T. inornata	0	1	19	64	5	11	15	25	11	4	1
T. incidens	0	0	0	7	4	3	4	4	0	0	0
Anopheles freeborni	0	0	0	1	0	7	10	8	0	0	0

From the above table certain facts are obvious concerning the seasonal breeding habits of these species.

Conclusions

1. *Aedes dorsalis* reproduces almost continuously throughout the season. The larvae appear in many localities early in the spring of the year from over-wintering eggs, and successive generations occur until late in the fall, the numbers gradually diminishing with lowering temperatures. The uniformity in the number of collections during each month indicates that the species develops in waters of various sources that happens to be available. The slight reduction in numbers during June and August is accounted for by the reduction of all breeding waters during these months.

2. *Aedes campestris* reproduces principally in the spring of the year. The number of generations produced during the season is doubtful. It is believed by some investigators that the over-wintering eggs of this species do not hatch all at once, but that the eggs must be subjected to low winter temperatures before they become viable. This seems highly probable from the distribution of larval collections during the season. The principle brood is hatched in the spring and early summer. The few records of larvae appearing later in the season may be from over-wintering eggs that failed to hatch earlier in the season.

3. *Aedes niphadopsis* reproduces in a single brood during the spring or early summer.

4. *Aedes vexans* reproduces throughout the season. There is some uncertainty about the number of generations but there is evidence of three and a partial fourth brood, accounting in part for the uneven distribution of larval collections.

5. *Culex tarsalis* reproduces throughout the season. The larvae appear late in the spring of the year and gradually increase in number, reaching a maximum in August. This is explained by the fact that the adult females over-winter. The few females that emerge in the spring lay eggs that produces the first larvae, and generation after generation follow in rapid succession; the maximum number is attained in August.

6. *Theobaldia inornata* reproduces continuously throughout the mosquito season. The winter is passed in the adult stage. The occurrence of larvae is fairly uniform during the season as this species is very common, produces several generations, and utilizes all suitable breeding water throughout the season.

7. *Theobaldia incidens.* The larvae of this species occur with moderate uniformity during the summer months; they are found developing in ornamental pools and similar water that are available during the spring and summer.

8. *Anopheles freeborni* has a similar life cycle to *Culex tarsalis,* over-wintering as adult females and reaching maximum numbers in August. These larvae disappear rather abruptly with the sudden lowering of temperatures in the late fall.

Types of Breeding Habitats

It is difficult to satisfactorily classify the breeding habitats of mosquitoes in a region such as Utah. The development of the immature stages of mosquitoes is confined to water, and the origin of mosquito breeding waters in the state is given consideration later in this bulletin. Any attempt to classify habitats is largely arbitrary, but should be made for convenience and a more complete understanding of the mosquito biology of a region.

The term "breeding habitat" will be used in a broad sense to designate the general type of the region in which certain species are more or less limited, and will not be used to identify a particular kind of situation in certain localities. Numerous classifications of habitats have been used by different workers in other parts of the country. In general, these classifications are used to distinguish certain kinds of situations wherein the immature stages of mosquitoes are found developing, such as "woodland pools, rain water barrels, tide water pools, marshes", etc. Such a classification is inadequate for a semi-arid inland section like Utah, and these specific situations will be considered in the discussion of the origin of mosquito breeding water. In Utah, where the necessary water for larval development is generally restricted and frequently of seasonal occurrence, the biology of certain species is modified to meet these requirements.

Many species of *Aedes* produce but a single brood during the season usually under similar conditions, while other *Aedes* and species of other genera, especially those producing more than one brood during the season, may show preference for certain environmental conditions, but in the absence of these more desirable situations, the larvae will develop in other waters that are available. The latter species may

PLATE IX

Impounded water in shallow grassy depressions produces mosquitoes.

PLATE X

Flood water from overflow of Jordan River; typical breeding water for large broods of mosquitoes.

reproduce in several different kinds of limited habitats during the season. The broad types of breeding habitats in Utah will, therefore, be arbitrarily classified into two major divisions: (1) plains and (2) mountains. This seems to be the most natural division as many species are confined strictly to mountainous areas, while others are confined strictly to the plains; however, a few are transitional, but most of these transitional forms are primarily a plains or mountain species.

The typical plains species inhabit open country devoid of timber. They develop in all kinds of water available in such localities. The water in which the plains mosquitoes reproduce is generally neutral or alkaline in reaction. It is not uncommon to find larvae of these plains species developing in water with a pH of 9.6. Mosquito larvae have never been found developing in the water of the Great Salt Lake, which at present has a salt concentration by volume of about 22 percent. However, around the margin of the lake there are extensive bodies of salt water of a much lower salt concentration in which the larvae of certain species of plains mosquitoes develop. The salt concentration of these waters varies considerably, but larvae develop in these waters at higher salt concentrations than those of sea water or tide pools.

The adults of plains mosquitoes use as shelter the grass and low vegetation available in such areas. These species are distributed over the deserts, plains and often over the piedmont slopes at the base of the mountains and along the narrow valleys of the streams that extend into the mountains. The plains mosquitoes are never found in high mountain areas and are seldom found in Utah above an elevation of 7,500 feet. The plains mosquitoes, when found in the mountains, usually avoid timber and are found only in the more open country, in the valleys or on hillsides devoid of timber.

The typical mountain species inhabitat the mountainous area of the state and occur at all elevations. Certain species are limited to the higher elevations and rarely occur below 9,000 feet; others are found only at lower elevations and a few of the latter extend onto the plains. Many mountain species show a preference for timbered regions while others favor more open areas. The mountain species that continue onto the plains are generally found in the vicinity of streams that flow out of the mountains and these species are usually found near the trees and vegetation of stream courses. The mountain forms reproduce ordinarily in water created by melting snow, rain, or from the overflow of streams. The larvae of some species develop in open sun-light pools, while others prefer shady pools in the forest. The pools frequently contain considerable vegetation of various kinds. The water is commonly neutral in reaction, but in some of the more permanent pools it is slightly acid with a pH as low as 6.5.

Origin of Mosquito Producing Waters in Utah

An article has already been published on this subject by the author, Rees (1939) "Origin of Mosquito Producing Waters in the Vicinity of Salt Lake City, Utah." In this article, the complete data, procedure and conclusions pertaining to this study are presented.

The following graph and summary are taken from this published article.

The graph summarizes the data taken over an eight year period, 1930-37 inclusive, from the records of the Salt Lake City Mosquito Abatement District. The left hand column shows the source of the water treated with larvacide in all localities. The middle column indicates the source of the water in all treatments made with larvacides. Certain localities were treated several times during a season. The right hand column represents the number of gallons of larvacide used on water from various sources in all of the treatments made, thus indicating the size of the areas treated.

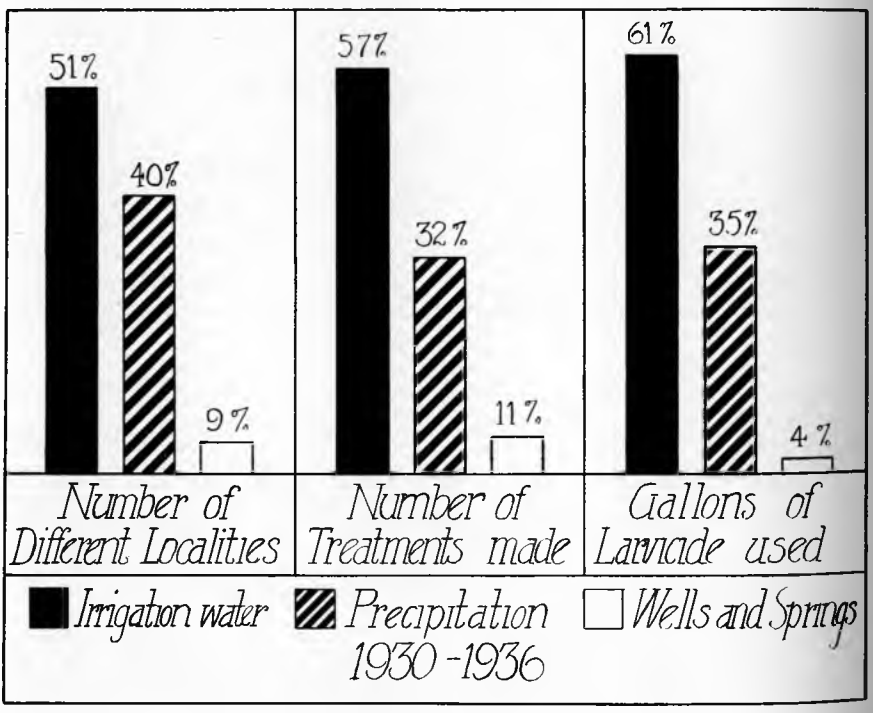


FIGURE 24

Origin of Mosquito Producing Waters in Utah.

Summary and Conclusions

1. Mosquito producing waters in Utah can arbitrarily be classified according to their origin as follows: (1) snow water, (2) rain water, (3) flood water from streams, (4) irrigation water, (5) impounded water, and (6) springs and artesian wells.

2. Irrigation water wherever present is the most important single source of mosquito production in Utah. This, undoubtedly, is equally true in all neighboring states where irrigation is carried on as it is in Utah.

PLATE XI

Typical Anopheline breeding water in Utah.

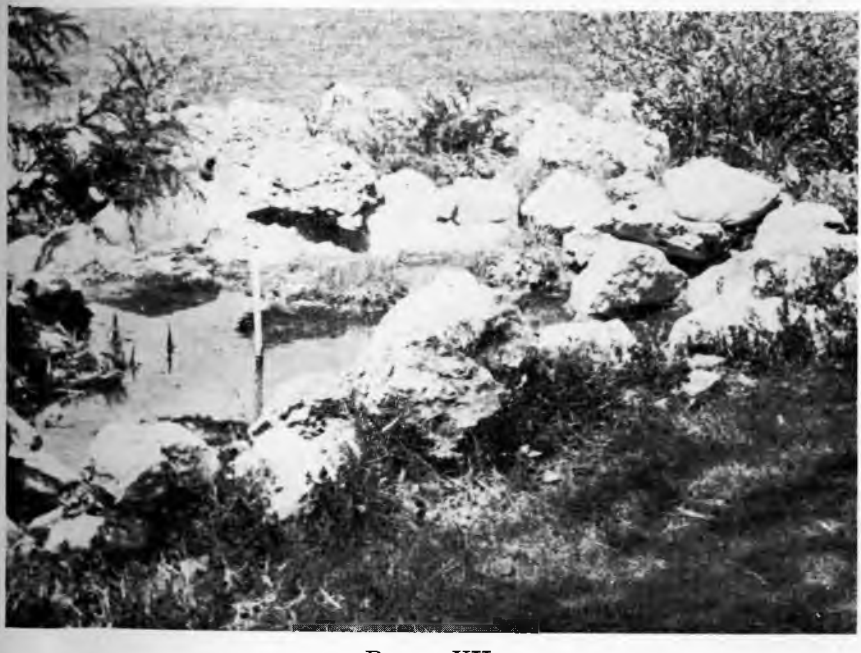


PLATE XII

Ornamental pool; an important source of mosquito production within city limits.

3. Water of a semi-permanent or temporary nature is the principal source of mosquitoes in this region. Permanent bodies of water maintaining a constant level, regardless of the source of the water, tend to support a sufficient number of natural enemies to greatly reduce or entirely prevent the development of mosquito larvae.

4. Temporary mosquito breeding waters occur in Utah principally in the spring of the year and are created largely by melting snow and vernal rains. From these temporary vernal waters issues the largest single brood of mosquitoes that occurs during the season.

5. Semi-permanent mosquito producing waters appear intermittently throughout the season in the same localities. These situations are usually maintained by irrigation water and certain types of impounded water, such as on gun clubs and in some ornamental pools. Mosquitoes that produce several generations during the season continue to reproduce in great abundance throughout the season in these semi-permanent waters, thus constituting the most continuous source of mosquito production.

The Effect of Atmospheric Conditions on Mosquitoes

Considerable work has been done to determine the effect of atmospheric conditions on certain species of mosquitoes. However, only a few extensive experiments of an exacting nature have been conducted. The writer, at this time, is not prepared to mention independently each species in Utah, nor to consider all the atmospheric factors involved. No detailed study has been made of the effects of atmospheric conditions on the mosquitoes of Utah, but a few general observations have been made on the influence of some of the more important atmospheric factors on a few of the common species.

The effect of atmospheric conditions on mosquitoes cannot be consistently treated as a whole, as each species constitutes an independent unit that shows varying reactions to these conditions. Certain species may be conveniently placed into small groups because of similar responses to atmospheric agencies, but even this method is obviously unsatisfactory for an exacting study. A consideration of all atmospheric conditions influencing mosquitoes would involve many factors about which little is known. These atmospheric conditions effect mosquitoes in all stages in their life cycle and play an important part in determining the development of immature stages, and in modifying the behavior of the adults. A few general observations will be given on the effect of some of the most important factors on the larvae and adults of common species.

Larvae

The influence of atmospheric temperature may consistently be considered as an indirect factor in controlling the rate of larval development. The propriety of including such a discussion under this major heading may be questioned, as the temperature of the water medium in which the larvae live, and not the atmospheric temperature, is the direct factor influencing the rate of larval development.

However, the temperature of the shallow surface water in which larvae develop is determined largely by the temperature of the atmosphere; the water temperatures, except in the mountains, are usually but a few degrees lower than the surrounding air temperatures. Therefore, atmospheric temperature indirectly influences the rate of larval development, and for this reason is included under this heading.

The rate of development of the larvae of all species is largely controlled by temperature. Under normal conditions the development of the larvae of *Aedes dorsalis*, *A. vexans*, *A. campestris* and *Theobaldia inornata* is accelerated in direct proportion to the increase in temperature. The increased speed of development of the larvae produced by a rise in temperature is not uniform for each of the above mentioned species. *Aedes dorsalis* larvae at low temperatures, with an average daily mean of 36 degrees F. may require 27 days under field conditions to complete development and pupate; with a daily mean of 77 degrees, larval development for this species may be completed in five and one half days. *Theobaldia inornata*, at low temperatures with a daily mean of 31 degrees F., may require over 30 days; and at high temperatures of 77 degrees, may require about 9 days to complete larval development. Larvae of different species also show varying degrees of resistance to low and high water temperatures. Larvae of *Theobaldia inornata* can withstand continued freezing temperatures usually fatal to other species. Larvae of this species have completed development after being exposed to freezing temperatures for five successive nights, being taken into the laboratory each morning and gradually thawed out of the soft ice completely enclosing them. Larvae of *Aedes dorsalis* is more resistant to low temperatures than larvae of *Aedes vexans* but not so resistant as *Theobaldia inornata*. The larvae of *Aedes dorsalis* can withstand waters of higher temperatures than the larvae of the other mentioned species; this is evidenced by their development, in the warm water of the hot springs north of Salt Lake City, where no other larvae are found developing. High water temperature in this instance seems to be the limiting factor, as larvae of the other species are found in this water when it cools to lower temperatures.

Adults

Adult mosquitoes are influenced in their behavior by a number of atmospheric factors, some of the most important are: temperature, wind velocity, relative humidity, precipitation, and light. These factors naturally operate collectively in influencing the activity of adult mosquitoes, and it is sometimes difficult from field observations to determine the particular factors responsible for their behavior. However, under favorable conditions the effect of certain factors can be ascertained with some degree of certainty.

All field observations, where data are used giving wind velocities or per cent of relative humidity, were made in the immediate vicinity of the Salt Lake City Airport and these data were obtained from the United States Weather Bureau Station established at this point.

The adults of different species show varying degrees of activity within definite temperature ranges. *Aedes dorsalis* and *Aedes campestris* females, under other suitable environmental conditions, are most active between 60 degrees F. and 74 degrees F. The activity increases with the increase in temperature, unless the temperature becomes too high. This is readily observed on the flats west of Salt Lake City. As the temperature reaches 90 degrees F. or higher during the day time, the activity of these females is noticeably diminished or ceases entirely. Likewise, temperatures below 60 degrees F. increasingly retards activity; at about 45 degrees F. noticeable activity practically ceases. The temperature ranges of other species is somewhat similar but is in general lower for certain mountain species of *Aedes*.

Temperature is probably the most important factor in determining the hibernation period of adults that pass the winter in this manner. This may be considered an enforced hibernation as a result of lowering temperatures. The adult females of *Anopheles freeborni*, *Theobaldia inornata* and *Culex tarsalis* that pass the winter in sheltered places in a state of inactivity, are forced into this type of hibernation by low temperatures. The date these females seek shelter in the fall and issue forth in the spring is variable in different years, depending on the temperature changes.

The influence of wind velocity on the activity of adult mosquitoes becomes apparent in mosquito infested regions. The true plains species such as *Aedes dorsalis*, *A. campestris* and *A. spencerii* are able to remain active on the wing at higher wind velocities than most other species. These plains mosquitoes remain active at wind velocities of 10 miles an hour but the number on the wing decreases as the wind velocity increases above this rate. Other species such as *Anopheles freeborni* are driven to shelter at much lower wind velocities. The plain species are in general strong fliers, and can travel against or with the winds of moderate velocities, while adults of *Theobaldia inornata*, *Theobaldia incidens* and *Culex tarsalis* do not ordinarily travel against winds exceeding a velocity of 8 miles an hour.

The relative atmospheric humidity is an important factor in influencing the activity of mosquitoes in a region such as Utah, which has normally low relative humidity. It has been observed that *Aedes dorsalis* and *A. campestris* are apparently confined to the immediate vicinity of their breeding waters during the hot, dry periods of low atmospheric humidity. During periods when the daily mean relative humidity of the region is 34% or lower, the activity of the adults seems to be confined to the vicinity of water. As the daily mean relative humidity of the atmosphere increases, the activity of the adults is correspondingly increased and their possible flight range extended. The greatest general activity of females of these species occurs when the daily mean of relative humidity ranges above 60%. Extremely high daily means above 80% relative atmospheric humidity does not occur in this area, so it need not be considered. This factor of the per cent of relative atmospheric humidity has a direct influence on controlling mosquito migrations and dispersals and will be considered later in this bulletin.

Previous precipitation seems to influence the activity of females of *Aedes dorsalis*, *A. campestris* and *A. vexans*. The females of these species apparently bite with more vigor and are more active in flight after light precipitation. Heavy rainfall or prolonged rains decrease the number of females on the wing.

The time of greatest activity of some species of adult mosquitoes is largely controlled by light intensity when other conditions are favorable. Adult mosquitoes are generally looked upon as being nocturnal, but this is true of only a few species. *Anopheles freeborni*, common in Utah, is nocturnal, feeding usually at night; however, this species, if not disturbed, will feed during dark, cloudy days and early evenings. *Culex tarsalis* is active during the late evening or at night. Some species such as *Theobaldia impatiens* and *T. inornata* are crepuscular, feeding at twilight and early morning, but the adults of these species are active in the shady woods during the day. Some plains and desert species are diurnal, while others such as *Aedes dorsalis* and *A. vexans* are more or less active and will feed at any time during the day or night.

Summary

1. Each species of mosquitoes reacts independently to atmospheric conditions and these reactions of the species may vary slightly in different sections of the country.

2. All stages in the life cycle of mosquitoes are influenced by atmospheric conditions.

3. Temperature is the most important atmospheric factor influencing the rate of development of mosquito larvae in Utah.

4. Some of the more important atmospheric conditions effecting the behavior of adult mosquitoes in Utah are: temperature, wind velocity, relative humidity, precipitation, and light intensity.

Mosquito Migration and Dispersal

The movement of adult mosquitoes from their breeding areas presents an interesting problem. At present, very little accurate information is available about mosquito flight. In the records of mosquito flights, frequently the species making the flight is unknown and other essential data are not available. It has been determined that different species of mosquitoes have varying flight ranges. *Culex pipiens*, the common house mosquito, is generally reported to have a short flight range, but Headlee (1921) has collected evidence showing a flight of this species of at least 2.5 miles. *Anopheles freeborni* observed by Herms (1923) and others, including the author, has been found to have a short flight range probably not exceeding a mile. Certain species of the genus *Aedes* are notably strong fliers and have been reported traveling 60 miles or more.

These mosquito flights have been mentioned by various observers with little or no data given, other than the distance of the adults from their nearest breeding area. The distances have been determined in some instances by swarms of mosquitoes arriving on vessels

at given distances out at sea. The nearest possible place of hatching of these adults were the marshes along the sea coast. By thus measuring from the vessels to the marshes, the approximate distance of the flight was established. Reported mosquito flights of various distances, some of these flights covering 60 miles, have been mentioned by Howard, Dyar and Knab (1912-17). In several instances the species was unknown.

Information on mosquito flights of coast species of *Aedes* that have been extensively studied, are summarized by Matheson (1929) as follows: "*A. sollicitans*, *A. cantator*, and *A. taeniorhynchus* are known to migrate considerable distances, at least forty miles in the case of the first species. *Aedes vexans* is another migrant, and in British Columbia Hearle finds that it migrates in the open a distance of at least 10 miles. In central New York migrations of from 3 to 5 miles have been observed. The time occupied in these migrations depends on the climatic factors, but it is usually a week or ten days." This statement essentially agrees with the writer's observations of the flights of *Aedes vexans* in Utah, except the movements observed have not taken place for such distances in the open. The maximum flights determined have been 8 miles and, when possible, in the direction of cover, such as willows, trees, or shrubbery. The other three species of *Aedes* have not been taken in collections in Utah.

During the course of this investigation in Utah, a number of mosquito flights have been observed in the vicinity of Salt Lake City. Considerable data have been obtained on the flights of *Aedes vexans*, *A. campestris*, and *A. dorsalis*. Of the two latter species no data on flight have been published prior to this investigation.

An explanation of the characteristics peculiar to the region surrounding Salt Lake City is necessary in order to understand the methods used in determining the flights of mosquitoes in this region. Salt Lake City is situated at the base of the Wasatch mountains at an elevation of about 4,400 feet. It is protected on the north and east by mountains rising abruptly to an elevation of 7 to 10,000 feet, the mountains forming a natural barrier in these directions. To the south is bench land traversed by numerous wide and swampy ravines, in which mountain streams meander, these streams eventually emptying into the Jordan River that flows along the west side of the city and north into the Great Salt Lake. The streams occasionally overflow their banks and produce large broods of mosquitoes, principally *Aedes vexans*. Extending west from Salt Lake City is a comparatively level expanse of country at an elevation of about 4,200 feet, the old bed of former Lake Bonneville. These flats continue to the shores of the Great Salt Lake, a distance of about 15 miles. The flats are principally waste land consisting of clay and silt, impregnated with alkali and salt. Some of the ground is under cultivation and irrigation, but extensive areas in the depressions are covered with salt grass. Large tracts are owned by gun clubs and are constantly under water. Other extensive areas are periodically flooded with water, and in these shallow, grassy pools enormous broods of *Aedes dorsalis* and, in the spring of the year, *A. campestris* are produced.

It is not difficult, knowing the definite breeding habitats of these different species, to follow their flight into Salt Lake City, as the city is protected from mosquito invasion from other directions by natural mountain barriers.

Observations on Flight of Aedes Vexans

During the early part of June, 1930, about 40 acres of meadow land were flooded along the banks of Mill Creek at 32nd South and Sixth West Street, approximately 3 miles southwest of Salt Lake City. A large brood of *A. vexans* hatched in this area from June 12 to June 15. A considerable number of these mosquitoes arrived in the southeast part of the city on the evening of June 16, a distance of about 2 miles from their place of hatching. On the evening of June 17, they were found throughout the city, a maximum flight of 5 miles. On June 19, fewer mosquitoes were collected in the southeast part of the city, the place of entry of brood. On June 20, it was raining and no adults were taken; between June 21 and June 22 a gradual decrease in numbers was observed throughout the city and, by June 26, conditions were normal. The brood had apparently passed through the city or dispersed. The general movement of the brood was in a northeasternly direction. Collections in other directions from the breeding area showed no increase in the mosquito population of this species. Their flight was traced for about 5 miles, and was completed in 10 days from their first appearance in the city until the time when they could no longer be detected.

A number of essentially similar flights of this species have been observed. These mosquitoes appear in large broods when conditions are favorable, and occasionally a brood will travel in one general direction. Their flights have been definitely traced from 3 to 8 miles. Undoubtedly some of the adults taken have flown greater distances than the maximum flight determined. These movements generally follow the vegetation that provides shelter, such as willows, trees, and shrubbery along streams, etc. However, one flight was observed on June 24, 1931, north of Salt Lake City, where the adults traveled 3 miles over a grassy prairie.

In each instance, when the flights of *A. vexans* have been observed in this region, the general direction has been toward Salt Lake City. However, the main brood has not always passed through the city, but on at least two occasions has passed along the outskirts of the city, in the vicinity of the stream course of the Jordan River. Depending upon the area where the brood hatched, the flights have been in different directions, at times up stream, down stream, or across the meadows and fields. Undoubtedly, flights have occurred other than toward the city, but facilities for determining these flights that did not menace the city were not available.

The length of time required for the passage of the broods has been on each occasion about 10 days from the time of their arrival until the time that they were no longer noticeable.

Observations on Flight of Aedes Campestris and Aedes Dorsalis

A. campestris are usually found breeding in the same pools or in the immediate vicinity of *A. dorsalis*. They occur only in the spring and early summer and at this season accompany *A. dorsalis* in their flight. *A. campestris* have been collected 10 miles from their nearest breeding area and fly perhaps much further under certain conditions, but this is the maximum flight that could be determined. A movement consisting entirely of adults of *A. campestris* has not been observed by the author.

On numerous occasions, broods of *A. dorsalis*, the most common pest mosquito in the vicinity of Salt Lake City, have been observed moving in a general direction, and it has been possible to definitely trace their flight.

The approximate distance traveled in 24 hours and the length of time taken by the brood to pass through a given locality has been established on several occasions. Some of the smaller broods have been followed only a short distance from their breeding area, then lost in a general dispersal. Other broods have been followed for several miles, some passing through the city, others bordering the city with only a few of the migrants entering the outskirts. The flights observed have been in different directions, but the majority of movements of this species have been from the west in a general eastwardly direction toward Salt Lake City, although two minor flights have been observed from the north toward the south not entering the city. It has not been possible to determine the maximum distances of all of these flights, but records were occasionally obtained of 10 miles or more, the maximum being 22 miles. The rate of movement of these flights show considerable variation. On August 13, 1931, after a slight rain and with a gentle breeze blowing from the west towards the east, *A. dorsalis* passed through the city from the flats west of the city to the foothills east of the city, a distance of 8 miles, in about two hours. Observations of other rapid flights have been observed under similar conditions, but generally the movements are much slower, the broods advancing from 1 to 4 miles in 24 hours.

The duration of the migrants in a given region is much more uniform. The time of their first appearance, until the migrants can no longer be detected in a region, extends over a period of 14 days; the average is about 10 days. The size of the broods, as well as the rate of movement, determines the length of time migrating swarms can be detected in a given area. The smaller broods are lost more easily than the larger populations.

During the past eleven years, a number of mosquito flights of *A. dorsalis* have been observed and considerable information has been obtained about the movements of this species. It has not been possible, however, to obtain complete data on some of these flights; but during September, 1932, it was possible to observe a flight under such ideal conditions that the facts could be ascertained with far greater certainty than usual. Rees (1935).

From observations and data obtained it has been found that *Aedes dorsalis*, *A. vexans*, and *A. campestris* fly considerable distances from their place of hatching. These movements are of two types:

(1) a general dispersal and (2) a direct migration. It has been found that generally these species of mosquitoes move out from their breeding areas in all directions when conditions are favorable. This can be considered as a general dispersal, as this is the method usually employed, and it may be ascribed as representing the normal method of distribution. This general dispersal is characteristic of many kinds of motile organisms. The direction of movement, when other factors are equal, radiates out in all directions from the centers of population. The distance traveled from these centers varies with the species. Under favorable conditions, the species of mosquitoes mentioned, as well as other species of the same genus, are produced in enormous broods in limited water breeding areas and generally move out in all directions from these centers of production. The second type of movement of these species seems to be a migration in a general direction. In flights of this kind, part of, or at times practically the entire population starts moving in a general direction. These migrations occur only on rare occasions. In the vicinity of Salt Lake City during certain years, the entire mosquito breeding season has passed without migrations taking place among the above named species. During other seasons as many as four migrations of varying magnitude have been observed for *Aedes dorsalis* and *vexans*.

Causes of Mosquito Migrations

From observations of mosquito migrations by various investigators, no satisfactory explanation has been found to account for these movements. Previous investigations of flight have been made principally on the coast species of *Aedes*, such as *A. sollicitans*, *A. taeniorhynchus*, and *A. cantator*. Howard, Dyar and Knab (1912-1917) state "only the females are concerned in these migrations and there is little reason to doubt that their object is to obtain food. It is probable that these females which obtain blood and survive accidents return to the salt marshes to deposit their eggs. It is doubtful, however, that in these migrations the wind is an important influence."

Dr. Headlee and his co-workers (1921) state "that most of the migrants exhibit undeveloped ovaries but this fact does not necessarily mean that breeding cannot take place when the new breeding ground is reached."

Frequent reference is made in the literature to mosquitoes being carried in flight by the wind. On the other hand, Dr. John B. Smith (1912-1917) has watched *Aedes sollicitans* on many occasions and found that it flew quite readily against a brisk wind and made good progress. Knab (1912-1917) observed in Sakatchewan, *A. spencerii* flying against a strong wind.

Dr. Headlee and his co-workers (1921) consider the factors that influence flight as follows:

"Without doubt, low temperature reduces, may suspend, or even destroy, the activity of the adult mosquito. Excessively high temperature always retards mosquito activity. A warm temperature, 80 degrees F., is extremely favorable."

"Light is avoided by most species and some have such an abhorence of it that they will not become active while it is strong."

"Atmospheric moisture has a very powerful effect upon the adult. High percentages are favorable and low percentages deadly. Rain itself is decidedly injurious and prevents adult mosquito activity."

"Air movements greatly influence mosquito activity. A stiff breeze is usually quite sufficient to stop their movements and to compel them to cling to shelter. Winds of low velocity (10 miles an hour or less of high temperatures (about 80 degrees F.) and high humidity appear to be the ones that favor long flights."

Hamlyn-Harris (1933), in Queensland, has made a report on the flights of *Aedes vigilans* of 60 miles and recorded some factors influencing the movement of this coast breeding *Aedes* in Australia. He concludes that migrations of this species inland occur with the wind; that suitable humidity and temperatures are also essential for these flights.

Different species have different habits, and it is impossible to draw conclusions for all species of *Aedes* from the meager data obtained from a few coast forms. Some information has been obtained during this study of flights of *A. vexans*, *A. campestris* and *A. dorsalis* from inland breeding areas. The flights of the last named species have been given particular consideration as this is the dominant species in Utah.

It is conceded that the principal reason for movement away from the breeding area is the search for food, as breeding requirements are unlimited. However, many factors are undoubtedly involved that determine the type of the movement, the time, rapidity, and distance of the flight. No attempt will be made here to account for all of the factors influencing the flights of these species, but certain facts will be given as they were observed in connection with the flights of the species under consideration.

These species are frequently hatched in large broods after extensive flooding in certain areas. However, broods of *A. campestris* appear only in the spring. The broods complete emergence within 2 to 5 days and generally within 24 hours begin to move out from the breeding place in all directions. At times a brood under apparently very similar climatic conditions, for some unknown reason, will migrate as already explained.

A. dorsalis is produced west of the city throughout the season, and a new brood begins after each flooding of water; the flooding usually comes from irrigation waste water, but occasionally from precipitation. This is not true of *A. vexans* which breeds in swampy ground along stream channels, and not on the flats west of the city. In pools where *A. dorsalis* are developing, successive broods are frequently found in various stages of development in the same pool. As these broods hatch they usually disperse. However, during the hot, dry summer months of the recent seasons, the adults of these successive broods of *dorsalis*, upon hatching, remained in the vicinity of the water, accumulating in enormous numbers. This was evident by the absence of mosquitoes on the hot, dry flats within a hundred yards or less of these pools, while at the edges of the water adults were present in unbearable numbers. At such times adults were also found along the streams and ditches entering these pools. It was noticed that the adults remained in the vicinity of the water under

these climatic conditions until cloudy weather occurred. Then they moved out from the pools, usually dispersing in all directions, and were found on the flats miles away from their breeding pools. These movements were more obvious and rapid after a slight rain. While the flights under these conditions were usually dispersals, on a few occasions migrations occurred. After slight rains with continued cloudy weather, the adults at times moved in a general direction with only a few of the original population remaining near the water.

This seems to indicate that in this region, atmospheric humidity is a controlling factor on the flight of this species of mosquito. However, so far as could be determined, atmospheric humidity does not determine the kind of flight that takes place at least in the instances observed.

Temperature may have some effect on the flight of *A. dorsalis*, but no conclusion can be drawn from these data. The flights have occurred in May, June, July, August, and September, at various temperatures. However, cloudy weather and rain is usually followed by a drop in temperature. It has also been observed that while adults are found in the immediate vicinity of the water under these climatic conditions, they are found biting at a much greater distance from the water at night than they are during the day. This may be due to the influence of the cooler night temperatures. It may also be affected at night by an increase in humidity. This mosquito is normally most active in the evening but will feed at any time when opportunity affords. No extensive flights have taken place during extreme high or low temperatures.

From studies of weather reports and field notes on wind direction during the progress of these observed migrations of *A. vexans*, *A. campestris* and *A. dorsalis*, it may be concluded that no definite influence upon migration can be accredited to wind. During the time of these flights, some of which were observed for several days, the wind with an average hourly velocity of from 6.5 to 8.4 for 24 hours, shifted its directions frequently during the day. These flights apparently continued in the same general direction, regardless of wind direction. The adults were not constantly on the move but in the flight of *A. dorsalis*, cited in September, 1932, approximately the same distance was traveled each day. This is true also of wind data obtained from observations of other migrations, the adults moving with or against the wind without changing their course or altering the distance traveled. Abnormally high, steady winds seem to check the flights temporarily. The adults seek shelter during high winds. On two occasions, *A. dorsalis* traveled into the city in one night, a distance of about 7 miles, when winds were blowing with high velocity. On August 25, 1930, Salt Lake City was comparatively free from *A. dorsalis*, but this species was very numerous around the pools about 3 miles west of the city. On the evening of August 25, a strong wind was blowing from the west toward the east. About midnight the wind reversed its direction and increased in velocity, continuing until about 4:00 A.M., when it subsided. At 7:00 A.M., considerable numbers of *A. dorsalis* were found in all parts of the city. It could not be determined whether these mosquitoes came in against or with the wind, or after it ceased, but the wind seemed to have influenced the movement. Since then, several flights under similar conditions have been observed.

Another environmental factor that seems to show an influence on migrations of *A. dorsalis* and *A. vexans* is the moon. This phenomenon has not been previously considered. In examining data of migrations of these species in Salt Lake City, it was found that the major flights have occurred during the periods of full moon. It may be a coincidence that the moon has been full when these flights have occurred but it is not at all improbable that this factor has stimulated migrations when other conditions have been favorable.

The full moon is not necessary for the flight and activity of *A. vexans* and *A. dorsalis*, as these species may be active on dark nights, but are ordinarily considered crepuscular in habit. General dispersals have been observed taking place at all times of the month. A few minor movements that seemed to have been in a general direction have occurred when the moon has not been full. The evidence is not sufficient to attribute this as a controlling factor of migrations, but the full moon is known to influence the dispersal and migrations of diurnal birds and mammals and may be a contributing factor in the migration of these species of mosquitoes. This factor will be given consideration in future investigations of mosquito migrations.

Summary

1. Females of *A. vexans* and *A. dorsalis* travel long distances from their breeding areas under favorable environmental conditions. A few males have been found accompanying the females in migrations of *A. dorsalis* and *vexans*.

2. This distribution is of two kinds: (1) a general dispersal, and (2) a migration in a general direction.

3. No data of a return flight to the breeding area have been obtained.

4. Factors influencing flight are: (1) production of large numbers in a limited area, and (2) suitable environmental conditions.

5. Flight may be with or against winds of moderate velocity.

6. Increased humidity is necessary for long flights of *A. dorsalis* during the dry summer months, flights always occurring during cloudy weather or after slight rains.

7. Suitable temperatures are also essential. Extremely high temperatures or excessively low temperatures inhibit extensive flights.

8. The moon may be a contributing factor in mosquito migrations under favorable climatic conditions.

9. The reasons for migrations on certain occasions rather than a general dispersal have not been satisfactorily ascertained.

The Distribution of Mosquitoes by Human Agencies

The dispersal of adult mosquitoes in Utah by human agencies is of minor importance when compared to the distribution by natural flight, nevertheless, this means of dispersal is important in certain localities under favorable conditions.

Numerous references are made in the literature by various investigators, to different species of mosquitoes being transported considerable distances by ships, trains, and more recently by airplanes. The automobile may also be considered an important agent for carrying mosquitoes short distances. Various authors cite numerous records of mosquitoes being introduced into new regions or transported considerable distances in areas where they were already found, by carriages, railroads, trains, river boats, ocean vessels and airplanes. Since 1931 some important work has been carried on by the United States Public Health Service on the carrying of mosquitoes by airplanes, and other means of transportation. Dr. T. H. D. Griffiths and co-workers of the Public Health Service have carried on a number of experiments demonstrating the importance of airplanes in the transportation of mosquitoes from one terminus to another, particularly from Central and South America to the United States.

The importance of human agencies in the distribution of mosquitoes has three possible roles. First, the introduction of species into favorable habitats previously free from these species; second, the increase of the population of certain species by carrying in additional numbers; and third, a factor in establishing misleading collection records and data. The importance of this first role has been amply demonstrated throughout the world on numerous occasions when pest or disease carrying species have been introduced permanently or temporarily into a region by human agencies. The second role is not important when great distances are involved, but can be a significant factor in increasing the number of mosquitoes in large cities. The number of mosquitoes introduced in this manner may be relatively few, but each adult liberated in a city has access to a human victim. The third role, that of establishing misleading collection records and biological data, is the result of the first two roles, but may, under certain conditions, assume considerable importance. This factor probably accounts for some apparently contradictory records and data found in the literature on mosquitoes.

The industrial centers of Utah may have had species introduced by human agencies. This may have occurred in the past, and such species may have become temporarily established, but there is no reason to believe that any species have been permanently established in Utah in this manner. It is possible, however, that such an introduction may occur in the future. The transportation of indigenous species from their breeding areas to cities is a common occurrence and under certain conditions may assume local importance in the state.

In the vicinity of Salt Lake City, railroad trains and automobiles have been found to assist in the distribution of mosquitoes of several species. The following species have been collected from trains and automobiles upon their arrival in Salt Lake City, Utah, from local points outside the city limits: *Aedes dorsalis*, *A. campestris*, *A. vexans*, *A. fitchii*, *Theobaldia inornata*, *Culex tarsalis*; and from automobiles only, *Anopheles freeborni*.

Undoubtedly other species are occasionally brought into the city, especially mountain species of *Aedes*. Some of the species collected have been taken from such vehicles only in a few instances and in very

limited numbers, while *Aedes dorsalis*, and at times, *Aedes campestris*, have been taken from trains and automobiles regularly in considerable numbers.

From actual counts, 1 to over 100 *A. dorsalis* have been collected during certain periods of the season from cars returning from the flats west of the city. During the peak of the breeding season of this species, the cars of the Salt Lake City Mosquito Abatement employees returning from the breeding area always carry a number of adults. This is also true of all automobiles remaining on the flats for a time, then returning to the city. *A. dorsalis* has been transported from Ogden to Salt Lake City, a distance of 40 miles, by the author in an automobile with the windows open, several short stops being made enroute. Carrying mosquitoes of this species by automobile long distances in any great numbers is highly improbable.

Trains coming in from the west when *dorsalis* are numerous on the flats, frequently bring in large numbers of these adults. Collections in the vicinity of the railroad yards generally show a much higher average of *dorsalis* taken than similar collections in other parts of the city. From collections, it was found that passenger trains making no stops on the west flats rarely carried any adult mosquitoes. A few, however, were occasionally found in the under carriage beneath the cars of these trains. Empty freight cars sidetracked on the flats, carried great numbers of *dorsalis* during the breeding season. These adults were found to leave the cars shortly after their arrival in the railroad yards. The cars while standing on the flats offered shelter for these mosquitoes, and great numbers accumulated and were transported into the city.

It was also found that the passenger trains running to the Saltair Resort were important carriers of *Aedes dorsalis*. The number brought in by these trains were few early in the season or during seasons when few adults were found on the flats, but at times, innumerable *dorsalis* were brought in daily by these trains. It was observed that the greater number of these adults left the trains while they remained at the city terminus.

These conveyances, considered singly, have little effect upon the mosquito population; but considered in the aggregate, it can readily be seen that the mosquito numbers are increased in a given locality by automobiles, and especially by trains that discharge their load regularly at the same place.

Summary of Conclusions

1. Different species of mosquitoes are carried at times by human conveyances; ships, boats, trains, airplanes, automobiles, etc.

2. The carriage of mosquitoes by human agencies plays two important roles in the distribution of mosquitoes; first, and most important, the introduction of species into new regions; and second, to increase the number of mosquitoes in certain localities.

3. The number of *Aedes dorsalis* is substantially increased in Salt Lake City under favorable conditions by their transportation into the city by trains and automobiles.

Biological Factors Effecting Mosquito Reduction

The literature is very extensive on the biological factors that result in a reduction in the mosquito population of a region. Howard, Dyar and Knab (1912-1917), give a general treatment of this subject. Since their publication, numerous investigators have made contributions to this information. The voluminous literature need not be cited for the purpose of this discussion; it has no direct bearing on the problem in Utah, as the observations have been made in other sections of the country or parts of the world.

The writer is not prepared to present data on exacting quantitative studies of the numerous biological factors effecting the production or the reduction of the number of the various species of mosquitoes in Utah. Such quantitative studies are difficult to make under field conditions, where a number of different biological factors are operating in the same body of water. Some studies of this nature, checked by laboratory experiments, are now in progress but the data at present are incomplete. In this preliminary investigation of the biological factors influencing the reduction of mosquitoes in this region, it has been necessary to determine the important factors present; and, in a general way, to evaluate the relative importance of these factors. In the following discussion, these preliminary facts are presented and certain significant conclusions drawn from this information acquired by the author.

Mosquitoes have many natural enemies in all stages of their life cycle. However, little is known of the biological factors destructive to the eggs of mosquitoes, and as the pupal stage occupies such a short period of time the reduction in numbers is limited during this stage; therefore, only the biological factors effecting the reduction of adults and larvae will be considered in this discussion.

Natural Field Conditions

Field conditions which constitute the natural breeding habitat of different species of mosquitoes are diverse. Some species are found breeding in several different kinds of situations, while others are limited to more uniform conditions. The natural enemies of mosquitoes are generally not found in a region merely because of the presence of a mosquito fauna, but their presence is largely determined by suitable environmental conditions. Therefore, the environmental conditions in the field determine the kinds and numbers of natural enemies of mosquitoes present in a locality. As adult mosquitoes are more widely distributed and aerial in their mode of living, their natural enemies are more diversified, and as the larvae of mosquitoes are confined to the water their enemies are aquatic or semi-aquatic in habits.

Adults

Adult mosquitoes have many natural enemies, both plant and animal predators and parasites. Accounts of plants destructive to adult mosquitoes have been mentioned by some investigators in other parts of the country, but no observations of this phenomenon have as yet been made in Utah.

Adults are frequently attacked by many different kinds of animal parasites. Adult females of several different species, but particularly females of *Theobaldia inornata*, are commonly infested with small red mites attached to the body near the base of the wings. However, there is no evidence that this parasitism is fatal to the host.

Animal predators of adults are numerous in Utah. The relative importance of these various predators is difficult to ascertain; but it is well known that certain species of mammals, birds, reptiles, amphibians, fish and arthropods, under various conditions, will feed on adult mosquitoes. Among the mammals, the insectivorous bats perhaps consume the greatest number of adult mosquitoes. The bats are only destructive among the adults of crepuscular and night flying species. Other mammals of several species occasionally feed on mosquitoes in limited numbers. Certain species of insectivorous birds feed on adult mosquitoes when available, and are particularly destructive to diurnal and crepuscular species. Frogs and toads readily gorge themselves with mosquitoes whenever these insects are available. Certain game fish, common in Utah, principally trout and white fish, feed extensively on adult mosquitoes floating on, or flying over, the surface of the water. The author, in an examination of the stomach contents of the native trout *Salmo utahensis* has, on certain occasions, recovered over 100 adult mosquitoes.

Predatory arthropods, principally species of arachnids and insects, are very destructive to adult mosquitoes. Among the insect predators observed in Utah, several species of dragon flies and two species of wasps are among the most active in destroying mosquitoes in the adult stage.

Larvae

The larvae of mosquitoes, confined to a water habitat, are restricted to limited areas. The mosquitoes at this stage in their life cycle are frequently concentrated in enormous numbers. The larvae are defenseless, slow moving organisms, and are easily attacked by all parasitic and predatory enemies present in the water, in which they develop, and also by certain terrestrial forms inhabiting the surface or shores of these waters.

A number of different kinds of lower animals have been reported parasitizing mosquito larvae, but only one instance of this has been observed by the writer in this region. It was found that many larvae of *Anopheles freeborni*, developing in Utah, are infected with a disease caused by a small microsporidian of the genus *Thelophania*. (Identification by W. H. W. Komp). This disease causes a whitening and enlargement of the ventral surface of the larvae. The disease is not usually fatal but seems to retard development.

Some lower animals are predatory on larvae. In Utah, the common fresh water hydra will destroy larvae that come within reach of their tentacles, especially if the larvae are in the first or second instar of their development. This has been observed by the writer both in the field and in the laboratory.

The most conspicuous and, therefore, the best known biological factor effecting the reduction of mosquito larvae, are the predatory enemies of mosquitoes found among the higher animals. The most

important enemies of this type in Utah are certain amphibians, birds, arthropods and fishes. For convenience, these organisms will be referred to collectively as "natural enemies" and the most important forms of these major groups will be discussed separately. As fish are the principal enemies of mosquito larvae in the state, they will be considered later under a separate heading. All other natural enemies of mosquito larvae constitute, by their combined efforts, a check on the production of mosquitoes, but are so sporadic in their occurrence and numbers that they are only locally, under certain conditions, of biological importance in reducing the prolific multiplication of mosquitoes.

The importance of natural enemies in reducing or completely prohibiting mosquito larvae from developing under certain conditions has been noted by the writer in the vicinity of Salt Lake City on numerous occasions. It was observed that shallow permanent ponds on the gun club properties northwest of the city were practically free from developing larvae during the major part of the summer months, while other semi-permanent ponds in the vicinity produced enormous broods of larvae intermittently during the same season.

The ponds were similar in size, depth, amount of vegetation, and other characteristics. However, the ponds free from developing larvae were maintained at a constant water level, as they were connected by a number of channels through which water was slowly moving out to the Great Salt Lake; the ponds in which larvae were found developing intermittently were semi-permanent and the water level fluctuating, receding at times until these ponds were dry. In the waters of the permanent ponds, the natural enemies of mosquito larvae were abundant; while in the semi-permanent ponds, these enemies were scarce and limited to a few species able to adjust themselves to this semi-permanent water. The presence of a sufficient number of natural enemies seemed to be the controlling factor in preventing the development of larvae, but to test the validity of such a conclusion the following field experiment was made:

In 1934, one of these semi-permanent ponds that had been a prolific breeder of mosquito larvae during the 1932 and 1933 seasons was selected for experimentation. This pond, early in the spring of 1934, was connected by channels to a constant water supply and a weir installed at the outlet of the pond so that the water could be maintained at a constant level throughout the season. Larvae appeared in this pond early in the season before the natural enemies were established, but these early larvae were destroyed by a concentration of enemies, principally fish, that entered the pond through the connecting water channels before the larvae completed development. No other larvae developed during the season, nor during subsequent seasons while the experiment was continued. As further evidence that natural enemies in this area is the factor responsible for controlling production of mosquito larvae in these ponds, it has been repeatedly observed by the writer that in the same ponds in which larvae are absent, while the water level remains constant for considerable periods, larvae will develop in great numbers when excessive flooding occurs due to abnormal precipitation and the boundaries of the ponds materially extended, so that the natural enemies are insufficient in numbers to destroy the larvae over the increased area.

Under these conditions native minnows were the most important natural enemies involved, but in small areas under different situations other organisms are at times the primary factor. These organisms, constituting the principal natural enemies of mosquito larvae, will be considered separately as follows.

Amphibians. — Salamanders of the genus *Amblystoma*, under certain conditions, are active in the destruction of mosquito larvae. In pools and ponds around Salt Lake City where salamanders are numerous, no mosquito larvae were found developing. In October, 1929, a number of salamanders were taken from these pools and placed in an aquarium. Mosquito larvae and pupae were liberated in the acquarium at different intervals, and the salamanders devoured them immediately. Salamanders are not relatively numerous in the vicinity but undoubtedly aid in the reduction of mosquito larvae in a few localities.

"Tadpoles". — The immature stages of common frogs and toads may be a factor in limiting larval development. It is claimed by some authorities that tadpoles will not destroy mosquito larvae. The writer has never observed tadpoles feeding on mosquito larvae but has never found larvae developing in any great numbers in water where tadpoles were numerous. Early in the spring mosquito larvae appear in pools, but later as these pools become infested with tadpoles, the mosquito larvae disappear. Still later in the season, after the tadpoles have completed development, these same pools again become prolific producers of mosquitoes. This phenomenon has been noted each year by the author, but no satisfactory explanation has as yet been obtained. There is evidently a biological correlation existing in these situations between the presence of tadpoles and the absence of larvae.

Birds. — Shore birds probably feed on mosquito larvae when available, as part of their insect diet. However, their effectiveness in reducing the number of mosquito larvae seems to be negligible, as the author has frequently noted larvae developing in great numbers in waters where shore birds were numerous.

Arthropods. — Some species of spiders, crustaceans and insects play an important role in destroying large numbers of mosquito larvae. Certain spiders of the genus *Pardosa* have been observed running over the surface of the water capturing mosquito larvae as they came to the surface to breathe. A crustacean belonging to the genus *Apus* has been observed in certain localities devouring mosquito larvae.

Many insects that are aquatic in their immature stages, or as adults, are factors affecting a reduction in the number of mosquito larvae. In the larval, nymphal or adult stages certain species of Odonata, Hemiptera, and Coleoptera are particularly destructive. In Utah, the writer on numerous occasions has observed the larvae of several species of Odonata feeding upon mosquito larvae and pupae, particularly on those species of mosquitoes whose larvae feed on the bottom of the pool. The author has noted several species of Hemiptera belonging to forms living beneath the water, *Nepa*, *Ranatra*, *Notonecta*

and *Corixa*, destroying considerable numbers of mosquito larvae. However, *Nepa*, *Notonecta* and *Ranatra* occur chiefly in permanent waters and influence the reduction of mosquito larvae restricted to water of this type. Among the Coleoptera are several species that are active destroyers of mosquito larvae. Gyrinidae or "whirligig beetles" which live near the surface of the water attack mosquito larvae whenever present. From observations of the author, the larvae of Dytiscidae are perhaps the most efficacious enemies of mosquito larvae found among the insects. It was observed in the field that Dytiscid larvae were voracious feeders on mosquito larvae. In April, 1931, a large Dytiscid larva was taken into the laboratory and placed in a small aquarium. For a period of 19 days from 10 to 12 large mosquito larvae were liberated in the acquarium. Immediately the Dytiscid would commence destroying them. Frequently 6 mosquito larvae would be seized in rapid succession and in 1 to 2 hours all the larvae would be destroyed.

Collectively, all the natural enemies mentioned contribute materially in the reduction of the mosquito population of the region. However, we have yet to consider fish, which are undoubtedly the greatest single factor in reducing the number of mosquito larvae in localities where mosquito feeding fish are present.

Native and Introduced Fishes

There are several different species of native fish that feed on mosquito larvae when available, but the habitat of the fish must correspond to the habitat of developing mosquito larvae before fish can be considered an important factor in limiting mosquito production. This minimizes the importance of most game fish found in the state, as these fish normally inhabit running streams or cold mountain lakes where mosquito larvae rarely occur.

There are at least two native minnows that inhabit stagnant water in which mosquito larvae naturally develop in abundance, and these minnows play an important part in the reduction of larvae in these regions. The most important is *Leuciscus timpanogenesis* (Cope). The juveniles of this minnow feed on mosquito larvae at all seasons when the larvae are available, but larvae seem to be their choice of food during the early spring months. These minnows are abundant in all of the permanent mosquito breeding waters west of Salt Lake City. They have frequently been observed by the writer feeding on mosquito larvae that were carried into these pools and ponds by water in drains. Nine of these minnows were taken into the laboratory in April, 1931, and were fed from 50 to 60 mosquito larvae every other day for a period of 27 days. All of the larvae, before they pupated, were devoured by these fish. In certain permanent bodies of water in the state there are literally millions of these minnows and mosquito larvae rarely complete development in such waters.

Two species of fish that have been introduced into Utah are important biologically in reducing the number of mosquito larvae. Other introduced species, principally species of trout, may be of minor importance, but will not be considered in this discussion. Gold fish introduced into small, ornamental pools are of some importance in destroying mosquito larvae. It has been noted that in ornamental pools

where gold fish are kept in sufficient numbers, mosquito larvae do not develop; in the immediate vicinity, howover, mosquito larve occur regularly in pools not stocked with gold fish. Gold fish are omnivorous in their feeding habits, and devour mosquito larvae as part of their diet, but larvae do not seem to be the primary food of these fish, and occasionally larvae occur in ornamental pools where gold fish are found in limited numbers.

Several attempts have been made to establish the "mosquito fish" *Gambusia affinis* (Baird & Girard) in Utah. These attempts to introduce *Gambusia* were for the purpose of economic mosquito control, but the introduction of these fish has a bearing on the biological factors effecting mosquito reduction in Utah and will therefore be considered in this discussion.

In 1931, 12 specimens of *Gambusia affinis* were introduced into Utah from Selby County, Tennessee, through arrangements made by the writer. These fish, through careful attention, have multiplied very rapidly and at present number several hundred thousand. *Gambusia* multiply in Utah in all kinds of mosquito breeding water during the summer season, but are unable to withstand the low temperatures in certain pools during the rigorous winters of this region. However, *Gambusia* are able to overwinter in many of the pools around artesian wells and springs where the surface is not completely frozen over with ice during the winter months. These fish overwinter in great numbers in pools created by the warm springs north of Salt Lake City. From these warm water rearing ponds, and a few other pools where they are able to successfully pass the winter, several hundred pools in the vicinity of Salt Lake City are stocked each spring with *Gambusia*. It is interesting to observe that all of these pools, many of them prolific breeding places of mosquito larvae before being stocked with *Gambusia*, remain entirely free from mosquito larvae throughout the season after the introduction of these fish. This biological factor is one of the most important means of reducing the number of mosquito larvae developing in small bodies of water in the vicinity of Salt Lake City, and may attain even greater importance if the *Gambusia* are successfully introduced into other parts of the state. An attempt is being made at the present time to introduce *Gambusia* into all suitable localities in Utah. Rees (1934).

Summary

1. Biological factors effecting mosquito reduction in Utah seem to be primarily animals that are predatory on mosquito adults and larvae.

2. Adult mosquitoes in this region are reduced in number principally by bats, certain species of birds, game fish, spiders, and insects.

3. Larvae are readily destroyed by many kinds of aquatic or semi-aquatic enemies, among the most important being arthropods, certain fishes, amphibians, and shore birds.

4. Certain species of fish, wherever they occur in the state, are the most important single biological factor affecting the reduction of mosquito larvae.

Correlation of Preceding Data

The significance of the preceding data contained in this bulletin has been referred to occasionally during the presentation, but these references have, in the most part, been made to particular factors or conditions as independent units and not as integral parts of a complex system constituting or determining the biology of the mosquitoes of the region. The Systematic Section lists the mosquitoes of the region, and the known facts obtained by the author are recorded for each species. The Biological Section is an attempt to determine some of the important environmental agencies effecting the biology of mosquitoes. These environmental factors have been classified into major groups according to their character, and each group treated independently. The various agents within the group, and their relative importance on the biology of the mosquitoes of Utah have been determined whenever possible. However, in the author's opinion, the correlation between these major environmental factors are jointly very important in determining the biology of the mosquitoes of the region.

Accepting the mosquito fauna of Utah as long established, and the biology of the various species primarily adjusted to the natural environment of the region, it is obvious that certain seasonal factors control or modify this biology. For instance, it is well known that all mosquitoes in Utah are only active during certain seasons of the year. However, this annual period of activity, determined largely by temperature, is fairly constant from year to year, varying but slightly with minor seasonal temperature changes. Other factors such as annual precipitation, relative humidity of the atmosphere, wind velocity, etc., are all part of what may be considered as a relatively stable seasonal environment. Slight fluctuations of these factors during a single season may greatly modify the production and behavior of certain species of mosquitoes, as already pointed out previously in this paper, but taken over a period of a year, these minor changes may be considered as normal. They will therefore be dismissed without further discussion.

It is apparent from all the preceding data that a few primary factors are responsible for the prevalence and abundance of certain species of mosquitoes in Utah, which are present in excess of the natural norm during the mosquito breeding season. It is also evident that these principal factors, necessary for continued mosquito production throughout the season, are only present in agricultural sections, and these sections contain the majority of the people of the state. It is further apparent that most of the factors responsible for mosquito production in Utah are different, or at least greatly modified, in their relative importance, when compared with other parts of the country where mosquito biology has been studied more extensively.

The information obtained from this region and presented in this bulletin, though not reduced in all instances to quantitative amounts, indicates a high correlation between: the origin of mosquito breeding water, presence of natural enemies of mosquito larvae, and the seasonal prevalence and abundance of dominant species of mosquitoes. Minor fluctuations in other atmospheric, physical, chemical, and biological factors, though they may be of considerable importance in

certain sections of the world, are of secondary importance in determining continued production of mosquitoes during the natural mosquito breeding season of Utah.

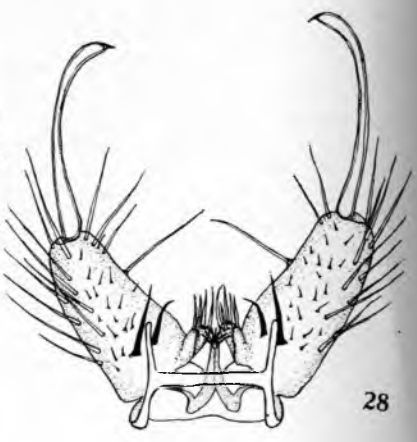
The correlations of these primary factors responsible for the prevalence and abundance of the dominant species of mosquitoes in the region are as follows:

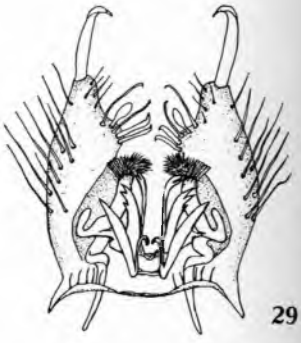
1. *Permanent* bodies of water that maintain a constant water level, which may be supplied by water from various sources, contain a sufficient number of natural enemies, principally fish, to greatly reduce or entirely prevent the development of mosquito larvae. These waters, as previously explained in the discussion, are only productive of mosquitoes when the normal water level is raised. Under these conditions, when the water is extended into the vegetation around the margins where natural enemies of mosquito larvae cannot penetrate, or occasionally when the water surface is rapidly extended over vast areas by high precipitation or vernal flood waters and the natural enemies are insufficient in number to cope with the rapid development of mosquito larvae in these greatly enlarged breeding areas, enormous broods of mosquitoes may be produced. This extended breeding area is not permanent, and, therefore, water of this type can more consistently be considered as semi-permanent. Thus, permanent large bodies of water regardless of their origin are in a relative state of biological balance and are of little or no importance in the production of mosquitoes in Utah.

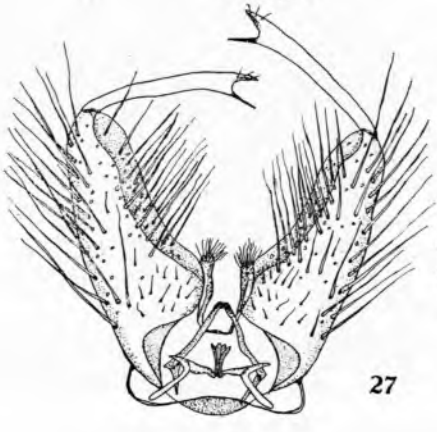
2. *Temporary* breeding waters are created in the spring of the year by melting snow and early vernal rains. These temporary waters are comparatively free from natural enemies of mosquito larvae, and the largest single brood of mosquitoes during the season completes development in these extensive breeding areas. Most species of mosquitoes developing in such waters produce but a single brood during the year because these temporary waters are primarily vernal and rarely appear later in the season in this semi-arid country. The eggs of most of these species that produce but a single brood, as mentioned in the previous discussion of their life histories, are not viable until a certain period of dormancy has expired and the eggs subjected to freezing temperatures. This is the important factor preventing these eggs from hatching in occasional temporary pools created by summer showers that probably would not endure a sufficient length of time to permit the larvae to complete development. The adults of these species occurring in a single generation are usually very abundant at the time of their emergence, but their numbers rapidly diminish as the season progresses. Thus temporary breeding waters are of major importance in the production of mosquitoes in Utah during the first part of the mosquito breeding season.

3. *Semi-permanent* mosquito breeding waters in the same localities, appear and disappear intermittently throughout the season. These semi-permanent waters are created principally by irrigation water, a factor peculiar to the region and not present in other sections of the country where practically all studies of mosquito biology have been made. Mosquito breeding waters of this type are practically free from

natural enemies of mosquito larvae, containing only a few forms that can quickly establish themselves when water is present. Naturally, fish shown to be the most destructive enemy of mosquito larvae in Utah cannot survice in these semi-permanent waters. In these waters, successive broods of mosquito larvae complete development throughout the season and the mosquitoes maturing in these semi-permanent pools are species that produce several generations a year. All of these above mentioned agencies contributing to the prolific reproduction of mosquitoes in semi-permanent waters of Utah have been previously evaluated independently under major headings in this paper and their primary importance established. It is significant that irrigation water is the most important breeding water throughout the season, when compared to breedng waters from other sources. This has been conclusively shown in a typical section in the vicinity of Salt Lake City. It has been consistently demonstrated in this area that fish constitute the most important natural enemies of mosquito larvae, and where fish are well established in bodies of water that retain a constant level, mosquito larvae rarely complete development. It is further significant that *Aedes dorsalis*, the most abundant and dominant species of mosquito in Utah throughout the season, is a plains type; it reproduces most abundantly throughout the year in agricultural sections where irrigation is common, and produces many generations during a season. Thus, *Aede dorsalis* is admirably suited to this semi-arid region where irrigation is present, reproducing in great numbers in these semi-permanent waters free from natural enemies. This combination of factors in Utah insures, under present conditions, the continued prevalence and excessive abundance of adult mosquitoes in the agricultural sections throughout the entire mosquito breeding season.







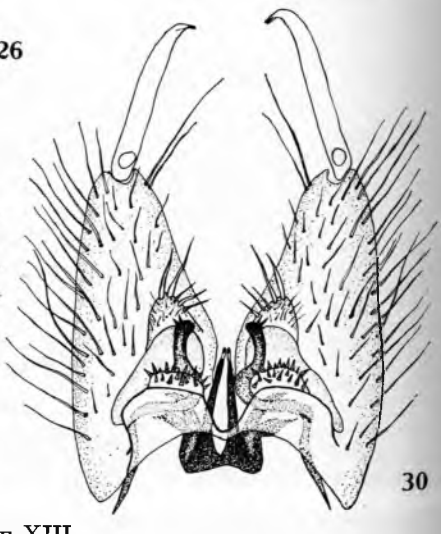
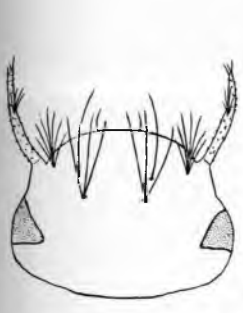


PLATE XIII

Male Hypopygia:

25. *Aedes campestris*
26. *Aedes niphadopsis*
27. *Aedes vexans*
28. *Anopheles freeborni*
29. *Culex tarsalis*
30. *Theobaldia inornata*



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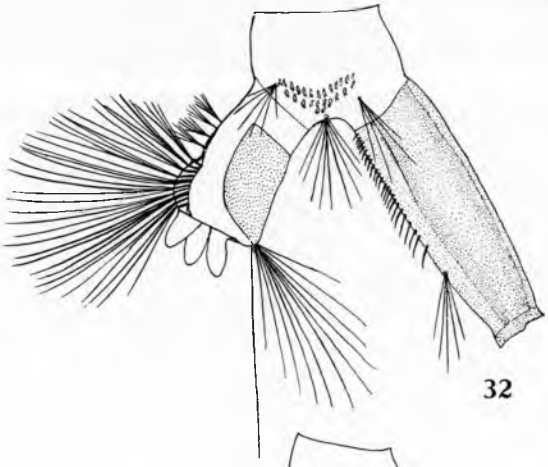

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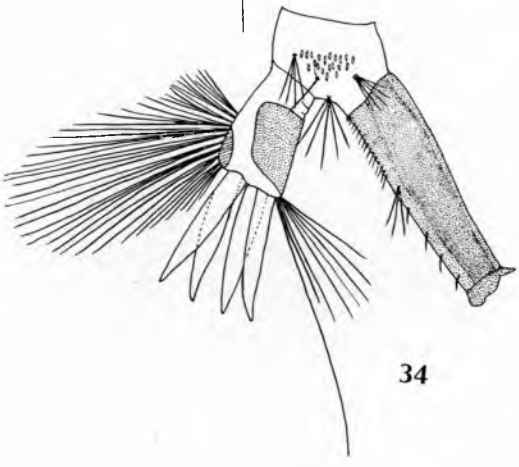

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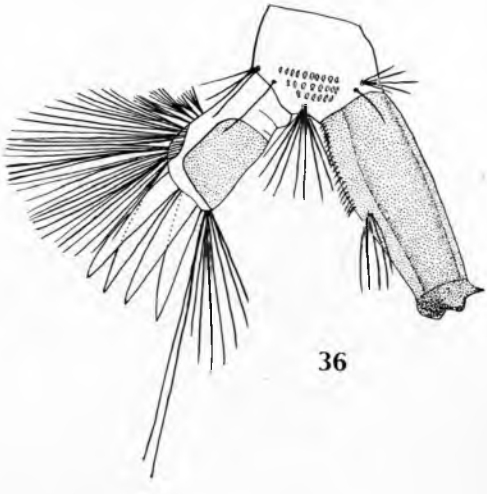


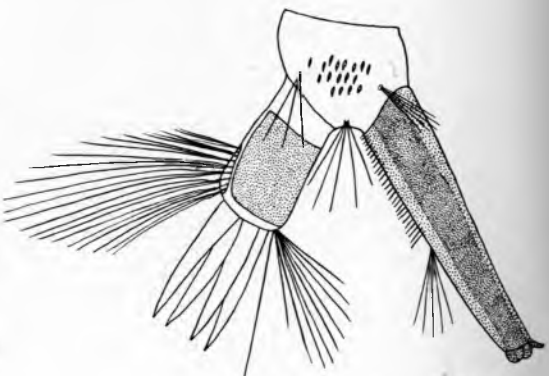
36

PLATE XIV

Mosquito Larvae: Head and Posterior Segments

31, 32. *Aedes campestris* 33, 34. *Aedes cataphylla* 35, 36. *Aedes communis*

37



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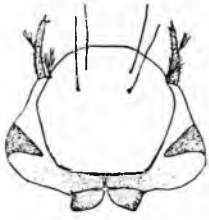

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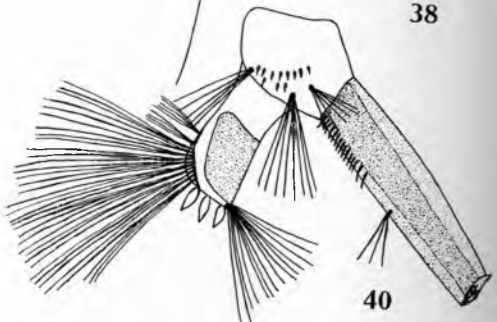

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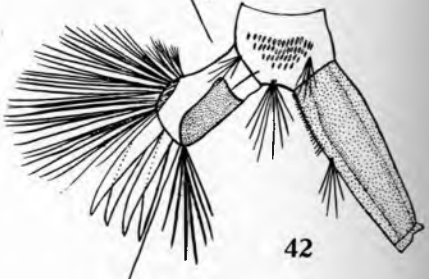

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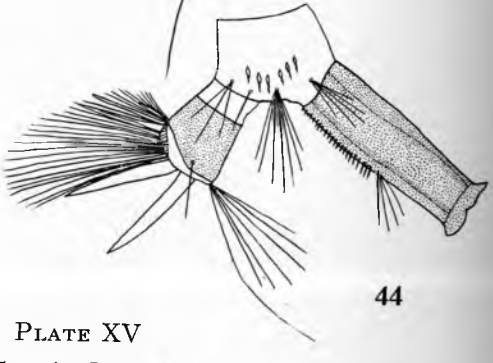
43



44

Plate XV

Mosquito Larvae:

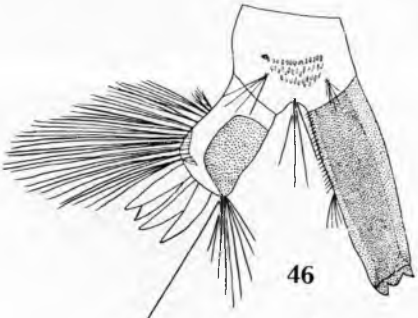
37, 38. *Aedes fitchii*

39, 40. *Aedes niphadopsis*

41, 42. *Aedes pullatus*

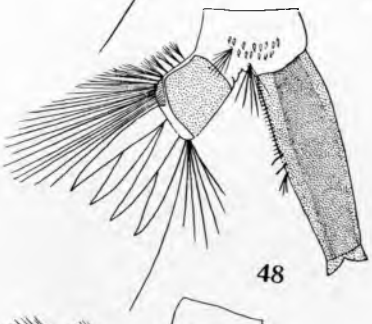
43, 44. *Aedes punctor*

45



46

47



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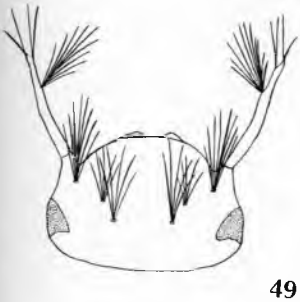

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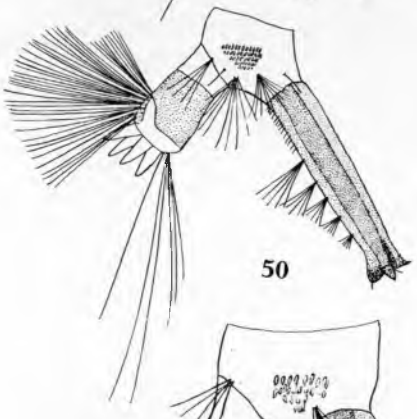

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51

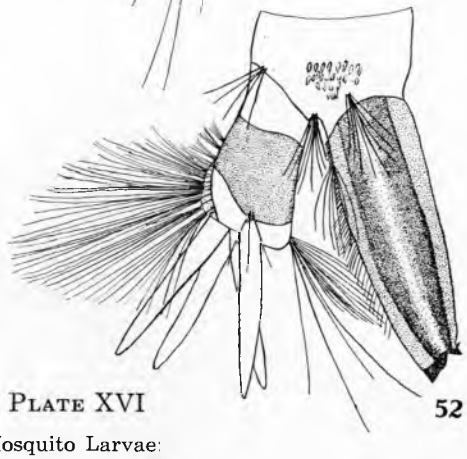

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PLATE XVI

Mosquito Larvae:

45, 46. *Aedes stimulans*
47, 48. *Aedes vexans*
49, 50. *Culex tarsalis*
51, 52. *Theobaldia inornata*

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