and developmental defects in *Anopheles stephensi*. At safe dosages it was not effective against nosema disease in this mosquito.

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CURRENT INVESTIGATIONS IN UTAH OF THE BITING GNAT *LEPTOCONOPS KERTESZI*

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The current investigations in Utah of the biting gnat *Leptoconops kerteszi* Kieffer are supported by funds from a research grant awarded to the University of Utah by the U.S. Army Research and Development Command.[2] The study is being conducted with the cooperation of the three mosquito abatement districts in Salt Lake County and the personnel of Tooele Ordnance Depot in Tooele County. Other agencies and individuals in the state are interested and participating in parts of this study.

The objectives of this study are: (1) to determine the distribution and unknown phases of the life history and behavior of *Leptoconops* in Utah; (2) to improve methods of sampling larvae and adult populations; and (3) to improve on existing, or develop new, methods for the control of this gnat.

In current studies the distribution of *L. kerteszi* in Utah is being determined by collecting and from existing records. The field studies on the abundance, life history and behavior are being conducted on the sandy southeastern shores of the Great Salt Lake. This site is readily accessible and the gnats are extremely abundant. The field investigations are supplemented by studies conducted in environmentally controlled chambers in the laboratories at the University of Utah.

Some of the first work conducted in Utah on the biology and control of these gnats was started in 1948 by Rees and Smith (1950, 1952) on the property of the Salt Lake Refining Company located near the north boundary of Salt Lake City.

In 1964 the Marquardt Company requested assistance in controlling *Leptoconops* gnats on their experimental grounds at Little Mountain on the eastern shore of the Great Salt Lake in Weber County. The gnats were so annoying at this site for about 6 to 8 weeks each spring that the working efficiency, for day-time employees working outside of buildings, was reduced by about 20 per-

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cent. A survey was made and control measures similar to those used by Rees and Smith (1950, 1952) were applied (unpublished reports, Rees, 1964 to 1968).

COLONIZING STUDIES

LARVAL REARING. The larval medium first used consisted of 200 gm. sand, 2 gm. vermiculite and 2 gm. alfalfa leaf meal as described by Sjogren and Foulk (1967). This medium was thoroughly mixed and then saturated with distilled water and placed in a rearing chamber. In about one week this medium putrefied and emitted a very unpleasant odor. As a result mortality of larvae was very high.

To combat these problems a study was begun to develop a better larval medium with optimum nutrients and moisture content. The following media were used: (1) oolitic sand and alfalfa leaf meal in a ratio of 100:1; (2) oolitic sand, alfalfa leaf meal and ground commercial dog biscuit, 100:1:1; and (3) unmixed oolitic sand as a control. Each medium was placed in a separate larval rearing container and in each of these containers, 200 larvae of approximately the same instar were placed. Moisture content of each medium was maintained at approximately 15 percent and the temperature at 80° F. The number of adults that emerged from each medium after 4 weeks is contained in Table 1.

FEEDING, MATING AND OVIPOSITION. Sjogren and Foulk (1967) reported that attempts to feed adult *L. kerteszi* on restrained rabbits, mice, rats, baby chicks or human hands placed in clear plastic cages were unsuccessful. Small restraining chambers taped to a suitable host were tried with 85 percent of the adult females feeding to engorgement. Most gnats took 10 minutes or less to completely engorge. Sjogren (1969) stated that this reluctance to feed in an open cage made blood-feeding of these gnats very laborious.

In current colonization attempts, adult female *L. kerteszi* have readily engorged on a human arm placed into a screened cage 2′ x 2′ x 4′ high. The top of the cage was shrouded with a black cloth with a hole cut in the center through which a light was directed onto the exposed arm. Larval rearing pans were placed in the bottom of the cage. A horizontal shelf of peg board masonite with numerous small holes was placed 2 feet from the bottom of the cage, dividing it into two parts. Light coming through these holes attracted the newly emerged adults which flew up through the holes to the top of the cage. This masonite shelf prevented most of the gnats from returning to the larval medium. The gnats concentrated in a small area at the top of the cage where the light came through the hole in the shroud. Numerous swarms were observed in the cage directly below the light source. Swarming was induced by lightly tapping the cage.

Small trays of dry and wet sand were placed on the masonite shelf to provide oviposition sites. Numerous eggs were laid on the moist sand but it has not yet

TABLE 1.—Adult emergence in relation to larval media.

Medium	Sand and Alfalfa Leaf Meal		Sand, Alfalfa Leaf Meal and Ground Dog Biscuit		Control Oolitic Sand	
Gnats	#	%	#	%	#	%
Emerged	143	71.5	175	87.5	22	11

It appears that the medium with the extra protein source of ground dog biscuits allows a higher percentage of gnat larvae to develop to the adult stage. Putrefication was reduced by maintaining the moisture content at 15 percent and thus preventing surface moisture from forming on the top of the media.

been determined if they are viable. Hatching attempts are now in progress.

FIELD STUDIES

DISTRIBUTION. Adult biting gnats have been collected in certain areas from the northern to the southern boundaries and from the Wasatch Mountain range to the western boundary of Utah. The eastern part of the state has not been collected to date, but reports of the presence of these gnats have been obtained from residents of eastern Utah.

SAMPLING LARVAE. Rees and Smith (1950) reported that they obtained larvae of *L. kerteszi* from soil samples by washing the soil through a series of fine mesh screens, the finest containing 76 squares per square inch. The fraction in the finest screen was examined under a wide field stereoscopic microscope and the number of larvae counted. This method proved to be efficient but time consuming.

Lauret (1958) obtained larvae from the soil by: (1) screening material through 40 and 80 mesh screens; (2) mixing the soil in a thin slurry, stirring and analyzing the top fraction for larvae; and (3) mechanically breaking soil into tiny fractions and visually observing each fraction for larvae. All three methods were found to be very time consuming.

Davies and Linley (1966) reported on a standardized flotation method for separating larvae and pupae of *Leptoconops becquaerti* (Kieff.) using a solution of magnesium sulfate with a specific gravity of 1.13.

Foulk (1966) washed soil samples through .71 and .35 mm. sieves; flooded the portion collected in the .35 mm. sieve with a 40 percent sucrose solution (sp. gr. 1.13) and removed the larvae and pupae from the surface.

Magnesium sulfate and sucrose flotation techniques both work well and are fairly rapid. The cost of these materials and their availability are limiting factors in their use. As a result of experimentation during this study a sodium chloride solution with specific gravity of 1.13 was found to be equally effective for obtaining eggs, larvae and pupae from soil samples. Salt is readily available and inexpensive. It was found that larvae and pupae are able to survive longer in a sodium chloride than in a magnesium sulfate solution. In order to increase the percent of recovery of larvae and pupae the concentration was increased to saturation (sp. gr. 1.19). At saturation a recovery of 85 to 90 percent was obtained from test samples with a known number of larvae.

Rees and Smith (1952) observed that when larvicide was applied to the surface of the ground the larvae exposed themselves and squirmed around for several minutes before dying. They used this method in their surveys, applying a 5 percent DDT solution to about a foot square surface and about 5 minutes later carefully examined this surface for larvae. This method proved to be successful when larvae were in late instars or in the top quarter inch of soil.

HABITAT OF LARVAE. The greatest problem in rapid sampling for larvae is to locate and delineate the sites where larvae are present.

In this study an attempt is being made to determine some of the important ecological characteristics of larval sites including: (1) soil types, chemistry and composition; (2) soil moisture, quality and amount required; and (3) vegetation types and other visible indicators that may be associated with the presence of larvae. The following results have been obtained to date.

Soil: Larvae are found mainly in sandy soil with some in sand mixed with clay and silt. Most of the soil has been alkaline wih a chlorine content varying from 100 to 50,000 ppm. The amount of sulfate has ranged from 0 to 600 ppm. while nitrates and iron have been absent. Traces of phosphorous, .5 to 2.5 ppm. have been found.

Moisture: Larvae have been found in soils with a moisture content ranging from 5 percent to saturation. Optimum

moisture content is in a range of about 12 to 16 percent. The water is generally high in salt content. Ground water level in larval sites varies from the surface of the ground to 2 or 3 feet beneath.

Vegetation: Generally associated with larval habitats are a few salt tolerant forms of vegetation such as greasewood, *Sarcobatus vermiculatus* (Hook) Torr.; glasswort, *Salicornia rubra* A. Nels.; and saltgrass *Distichlis stricta* (Torr.) Rybd. The percent cover of the vegetation ranges from 0 to 75 percent.

SAMPLING EMERGING ADULTS. Rees and Smith (1950) used rectangle box traps, 18 x 24 x 8 inches high. The traps were covered with heavy black cloth, the bottoms open to the soil. In one end of the traps small holes were made in which the neck of a pint bottle, partially filled with water, was securely fastened. As the gnats emerged from the ground they attempted to escape through the hole and were captured in the bottle. One of these traps in a 5-week period collected 5,710 adults.

Kettle (1962) reported that box traps can be extremely effective in catching newly emerged adult gnats.

Foulk (1966) described a flower pot trap for catching emerging *L. kerteszi*. He concluded that flower pot traps are valuable for survey and population studies due to their small size, ease of handling and construction, and their relatively low cost.

In current studies little success has been obtained with flower pot emergence traps. The rectangle box traps, described above, have been used successfully, collecting 1,073 adults in one trap during a 3-month period starting June 14, 1969, after the seasonal peak of adult emergence.

SAMPLING BITING FEMALES. Whitsel and Schoeppner (1965) reported that an adhesive cylinder trap using solid carbon dioxide readily attracted females of *L. torrens* and *L. kerteszi*. When adults were scarce, the baited trap gave some indication of the presence of the insects whereas the soil emergence traps did not.

Rogers, Schoeppner and Whitsel (1967) described a wind-oriented carbon dioxide attractant trap for collecting adult *L. torrens*. They reported that stationary traps collected as many or more gnats than the wind-oriented traps. More gnats were collected on the lee side of the trap than on the windward side.

In this study four-sided box "Stickem Special" traps, 4 inches square per side, were used to take collections that could be used to estimate adult population levels of female *L. kerteszi*. "Stickem Special," a slow drying adhesive was applied to the surfaces of the traps and carbon dioxide, escaping from a pressurized cylinder, was used as an attractant. This trap was much smaller but similar to the trap used to collect deer flies as described by Knudsen and Rees (1969). The box stickem traps, baited with carbon dioxide, proved to be a very effective device for sampling adult female gnats. It was discovered that adult gnats preferred the north and east surfaces over the south and west by a ratio of 6:4. Both north and east surfaces were in the shade during most of the time during peak adult activity, substantiating the report of Foulk (1968) that adult *L. kerteszi* prefer resting on shaded surfaces. The prevailing wind was from the north where the traps were used. This factor was minimized by placing the traps in protected depressions between sand dunes whenever possible.

To test whether the color of the trap was a significant factor, red and white stickem traps were placed side by side during the sampling period and carbon dioxide was used as an attractant for both traps. The red trap collected seven times the number of gnats collected on the white trap, demonstrating a strong color preference for red.

In this study several other methods have been tried with little success. Davies (1964) reported that the mechanism by which the gnats are attracted to a host is very complex. This could explain why some methods are not consistent and vary according to the worker and the location.

FEEDING, MATING AND OVIPOSITION. Rees and Smith (1950) reported that *L. kerteszi* prefer to bite where the clothing fits close to the skin, such as around hat bands, shirt collars and cuffs, stating that the victim does not feel the bite for the first 30 or 60 seconds, then a slight irritation becomes noticeable. In about 10 to 15 minutes a hard white swelling forms which becomes red and inflamed. Itching and irritation may continue for 72 hours or more.

Foulk (1969) reported that human hosts are readily attacked by adult females of *L. kerteszi* which prefer the head and hairy portions of the body and few bites go unnoticed by a human host. Engorging gnats frequently elicit no response from cats, rabbits, horses and burros.

Sjogren and Foulk (1967) reported that *L. kerteszi* is not believed to be naturally ornithophilic. Accordingly nucleated erythrocytes have never been observed in squash preparations of engorged females collected in the field, and in a serological analysis of more than 20 field-engorged specimens, no bird feedings were demonstrated. Of 25 field-collected, unengorged females examined for spermatozoa, 18 (72 percent) of the gnats contained spermatozoa, suggesting that mating occurs in the field prior to the females taking a blood meal.

Kettle (1962) also reported that most *Leptoconops* caught when attempting to feed were fertilized.

During current investigations, gnats in the field have been observed readily attacking horses which showed little response to the bites. Human hosts are readily attacked on the hairy areas of the body as reported by Rees and Smith (1950), and also on bare skin areas such as between the fingers, on the forehead, cheeks and the underneath surface of the arms. If a gnat is disturbed while feeding it will fly to a new site or host where it will complete engorgement. This is one important requirement for a potential vector.

In the spring of 1969, numerous swarms of adult *L. kerteszi* were observed from midmorning hours until about noon. There were literally thousands of gnats in some of these swarms, the majority being males. They swarmed over rocks, vegetation of several types, above the head of the observer and over small mounds in the sand. Matings were not observed but female gnats occasionally entered the swarm. Biting females were present with their numbers increasing from the early hours to a peak about noon.

Linley (1968) reported that there are two distinct sizes of *L. becquaerti* females, one being much smaller with a shorter wing length. In a given population the smaller females are autogenous and the large females are anautogenous with comparable number of eggs in females of both groups.

In current collections two distinct sizes of *L. kerteszi* have been distinguished in the natural population. In the field, females of both sizes have been observed biting and obtaining blood meals. To date it has not been determined if there are autogenous females in this population.

LARVAL CONTROL. Kettle (1952) stated that larval *Culicoides impunctatus* can be destroyed by surface application of DDT or BHC, but the main problem is discovering where to apply the insecticide. Each species of Ceratopogonidae shows marked breeding habitat preferences.

Lauret (1958), reporting on control of *L. torrens,* stated that the problems in chemical control were: (1) getting the insecticide into the soil where the gnats were; and (2) to use the formulation which will be most effective.

Rees (1964) reported that *L. kerteszi* can be prevented from developing and emerging by adequate drainage or covering the soil with surface water. In areas where this is not practical, the soil can be treated with a residual insecticide that may possibly destroy some adults before oviposition or more probably the larvae before they complete development. Preventive measures and source reduction methods are more effective and less ex-

pensive than any measures yet devised for control of the adults. These methods are similar to those reported earlier by Rees and Smith (1950, 1952).

Rees (1965) stated that effective larval control could be accomplished by spraying breeding areas with DDT at the rate of 1 lb/acre for immediate control or 2 lbs/acre for prehatch residual control. He recommended applying this prehatch insecticide in 28 gallons of water per acre.

Foulk (1966) conducted a drainage experiment to study the effects of soil moisture reduction on larval and adult populations of *L. kerteszi.* Larvae were completely eliminated when moisture declined to 1 percent.

In the spring of 1969, an area was chosen where larvae and adult *L. kerteszi* were very numerous. Soil samples were taken to determine the distribution and abundance of larvae. Just prior to pupation the larvae were found to be concentrated in the top fourth-inch of soil making them readily accessible to an application of larvicide on the soil. It was during this time that four insecticides were applied to 1,100 sq. ft. plots. The results are presented in Table 2.

ADULT CONTROL. In current studies, an area 800 feet wide by 1 mile long was plane-sprayed on May 29, 1969, with Dursban. The chemical was applied at the rate of 1.82 ounces per acre with a dosage of .05 lb./acre. The wind was from the north at 2 miles per hour gusting to 7 miles per hour. Air temperature was 75° F. with relative humidity of 39 percent. To experimentally determine the effects of the treatment, three 1-pint cartons, each containing 35 adult *L. kerteszi,* were placed in area to be treated and one carton with the same number of gnats was placed in a control area. The tops of the cartons were covered with nylon chiffon netting to allow penetration of the insecticide.

In the treated area, an average of 28 (77 percent) of the adults in each carton were dead 3 hours following treatment while only 4 (12 percent) were dead in the control carton, indicating a good penetration of the insecticide.

Before treatment, there was an average of 265 gnats collected per 30-minute collection period on a stickem trap baited with carbon dioxide. The number per collection decreased to 8.3 or a 97 percent

TABLE 2.—Results of larvicide application.

Period	DDT 10 lb/acre	Dursban 1 lb/acre	Abate 2 lb/acre	Baytex 2 lb/acre	Controls
	Average Number of Larvae Per Sample				
4/19/69 to 5/3/69*	35.0	2.8	6.8	1.7	319.0
5/5/69 to 5/22/69	0	0	0	15.8**	13.9
5/25/69 to 6/13/69	0	0	0	0	7.0
6/15/69 to 6/27/69	0	0	10.1	0	5.2

** A second application of Baytex was required on the third week but the other plots treated showed no increase in number of larvae until the eighth week when larvae appeared in the plot treated with Abate.

* Larvae found during this period were in the samples taken two days after the application of insecticides.

reduction for the 2 weeks immediately following treatment, with a slight increase to 29 or an 89 percent reduction for the third week. The number of adult gnats in the treated area did not attain the population level present before treatment. Collections in adjoining untreated sites showed no decrease during this period. This treatment was apparently very effective and will be attempted on a larger scale during the spring of 1970.

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