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THE BLACK GNATS OF CALIFORNIA

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THE BLACK GNATS OF CALIFORNIA[1]

LESLIE M. SMITH[2] and HOMER LOWE[3]

TWO SPECIES of biting gnats of the family Ceratopogonidae (Diptera) occur in California. These are the valley black gnat, *Leptoconops torrens* Townsend, and the Bodega black gnat, *Holoconops kerteszi* Kieffer. They are both vicious biters and are frequently extremely annoying to man, livestock, and poultry. Although the adults are well known to all residents of the breeding areas, the immature stages—egg, larva, and pupa—have remained undiscovered up to the present time. This study was undertaken to discover these immature forms, to determine the breeding areas, and to provide as much biologic information as possible, as a basis for control.

CLASSIFICATION

There are four genera of closely related flies—*Styloconops, Leptoconops, Holoconops,* and *Microconops*—which differ markedly from all other genera of the family Ceratopogonidae. All authorities recognize this distinct group of genera as the *Leptoconops* group. Enderlein (1936)[4] established the subfamily Leptoconopinae to contain these genera. Johannsen (1943) distinguished the adults of the *Leptoconops* group as having 12 to 14 antennal segments and no radiomedial cross vein, whereas the other ceratopogonids have 15 antennal segments and possess the cross vein.

The larvae of *Leptoconops* and *Holoconops,* described later in this paper, show such marked differences from the usual ceratopogonid type of larva that the writers agree with Enderlein and accept the subfamily name Leptoconopinae for this group. The chief characters in which the larvae differ from the other ceratopogonids are: the presence of heavy mandibular rods which extend backward into the first or second thoracic segment; the presence of 21 or more body segments; and a great reduction in the pharyngeal skeleton, with the pharyngeal combs entirely absent.

Only two genera of the Leptoconopinae are known to occur in California. These are the genus *Leptoconops* Skuse, in which the females have 14 segments in the antennae; and the genus *Holoconops* Kieffer, in which the females have 13 segments in the antennae. The females of the valley black gnat, *Lepto-*

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[4] See "Literature Cited" for citations, referred to in the text by author and date.

conops torrens, were named and described by Townsend (1893) from specimens collected near Patterson, New Mexico, June 21, 1892. The females of the Bodega black gnat, *Holoconops kerteszi,* were named and described by Kieffer (1908) from specimens collected at Cairo, Egypt. The males of both species were described by Freeborn and Zimmerman (1934) from specimens collected at Davis and Bodega, California.

DISTRIBUTION

The black gnats are widely distributed throughout the world but occur only in very limited discontinuous areas where suitable larval habitats are found. The Bodega black gnat has been recorded in Egypt by Wiess (1912), at Cairo, Behera, Wadi, Natroun, and Sakkara. In Tunis it was taken at Tabeditt. In North America it has been recorded by Carter (1921) in the vicinity of the Great Salt Lake, Utah, and by Freeborn and Zimmerman (1934) at Bodega Bay, California. The writers found it at Dillons Beach, a resort town near the town of Tomales, California.

The valley black gnat is recorded by Freeborn and Zimmerman (1934) at Uvalde and Dallas, Texas; Las Vegas, Nevada; and in Yolo County, California. Johannsen (1943) records it in New Mexico and Colorado. The writers have collected this species along the western side of the Sacramento Valley from Colusa to Suisun, at Cupertino in the Santa Clara Valley, and at Merced and Tulare Lake in the San Joaquin Valley. There are no records of this species outside of the United States, although a few species of this genus are known in South America.

DESCRIPTION OF THE STAGES OF THE BODEGA BLACK GNAT

The Egg. The egg (fig. 1) is white when first laid, and slowly turns to very dark brown as it matures. The eggshell is unsculptured, but the contents of the mature egg give the illusion of a reticulation on the surface. The length of the egg is 0.34 mm; the width, 0.10 mm. The shape varies slightly in different eggs, but most of them are banana-shaped with one end slightly narrower than the other. They vary from straight to slightly curved and are circular in cross section.

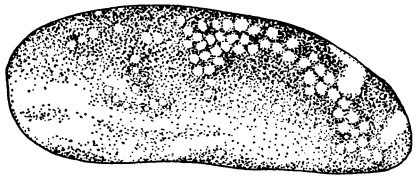

Fig. 1. Egg of the Bodega black gnat.

The Larva. There are four larval instars, alike in all fundamental features except size. The length of the first-instar larva upon hatching is 0.50 mm and the width is 0.13 mm. The second-instar larvae vary in length from 1.5 mm to 2.5 mm, the third from 2.5 mm to 4.2 mm, and the fourth from 4.2 mm to 5.6 mm. The head is thinly chitinized with localized chitinous thickening. Within the head region and extending into the first thoracic segment there is a system of heavily chitinized rods connected with the mandibular processes (figs. 2 and 3). The dorsal process consists of a median rod extending anteriorly for approximately four fifths of the head segment. At its posterior end there is a transverse bar just inside the second segment. It consists of three sections. On the outer extremities of the crossbar

are two additional longitudinal bars, the dorsolateral rods, which extend from the posterior third of the first segment, two thirds of the way into the second segment. These two dorsolateral rods, by gradually sloping to the ventral surface, contact the two ventrolateral rods, which are the heaviest in the system. The two ventrolateral rods extend from the point of contact with the dorsolateral rods forward to short mandibular levers, which are in turn attached to the mandibles. The mandibles are swung by this whole ventral process and brush the food onto a scooplike labrum.

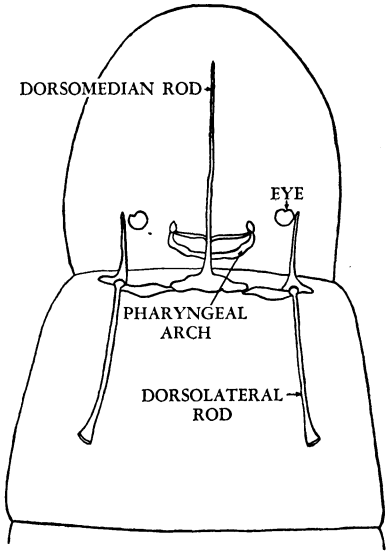

Fig. 2. Head and first thoracic segment of the Bodega black gnat, dorsal view, showing chitinized structures in the dorsal part of the larva.

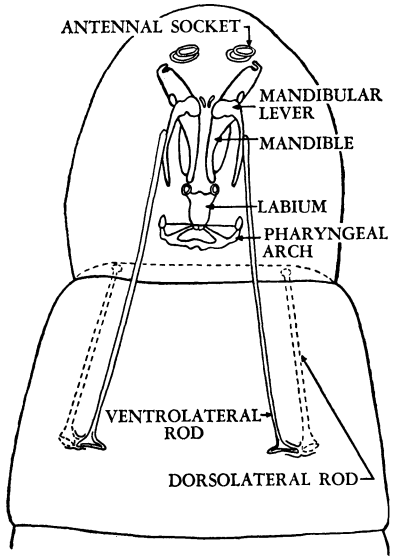

Fig. 3. Head and first thoracic segment of the Bodega black gnat, dorsal view, showing chitinized structures in the lower half of the larva.

Immediately anterior to the mandibles are two bristles which may be easily seen when the mandibles are in motion. At the extreme tip of the head segment are found the antennae, which may be extended or withdrawn into the head so that they appear as two small caps.

The eyes are round and black. They are located between the dorsolateral rods and the ventrolateral bars about three fourths of the way from the anterior end of the first segment.

The thoracic segments have no special characteristics, but each abdominal segment (except the anal) has an intercalary segment, giving the larva the appearance of having twenty-three segments in all. The anal segment terminates in three lobes. The larvae are without spines, hairs, or bristles except for the two located just anterior to the mandibles. Larvae in the first two stages are colorless and transparent, but as they reach the third instar they become orange in color.

Female Pupa. The length of the female pupa (fig. 4) is 2.7 mm and the width 0.6 mm (measurements taken on preserved specimen). The length of the

respiratory trumpet is 0.13 mm. The thorax is very dark brown, the abdomen varies from tan to dull orange. The respiratory tube has two segments. The anterior segment is oval, with the broadest part, possessing fifteen transparent spiracles, located apically. The head is rugose, without armature, other than spines. The antennae extend from a region above the eyes to a region just beyond the middle of the wing pads. The wing pads appear to be crumpled. The legs lie along the anterior border of the wing pads. The first pair and a part of the second appear between the two wing pads, but the third pair is not visible except for the tips, which lie between the tips of the second pair of legs and the most posterior portion of the wings. The segments of the abdomen are visible from the dorsal side; all segments except number ten are armed with sharp recurved spines. These spines are all set on large tubercles and have a very characteristic arrangement. Segments one to seven have two spines in a row anteriorly, and four in a row posteriorly, on both dorsal and ventral sides. On each lateral border of these segments there are two spines. This makes a total of sixteen spines for each segment. Segment eight has only two spines on the dorsal and ventral surface and two on each lateral margin, a total of eight spines for this segment. The ninth segment has two spines, one on each lateral border. There are two tubercles dorsally and ventrally in the same position as the spines of the eighth segment. The last segment is forked for about one half of its length, and is without spines or tubercles.

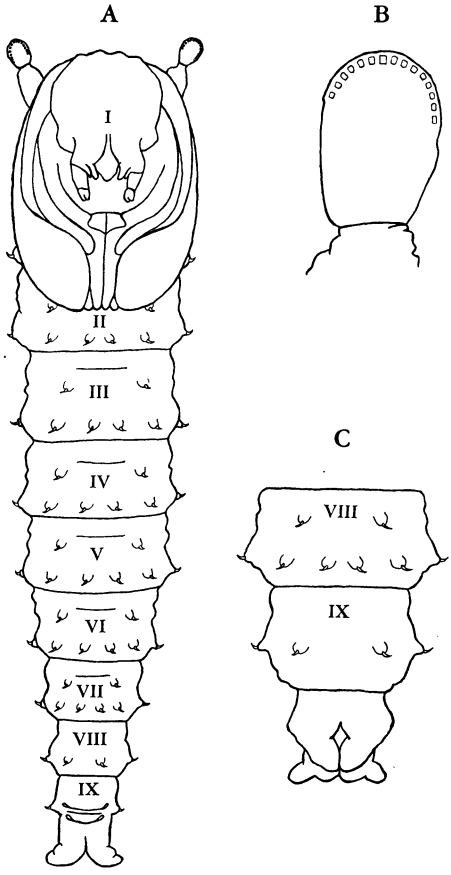

Fig. 4. *A*, pupa of female, Bodega black gnat, ventral view; *B*, respiratory trumpet of the pupa; *C*, posterior three segments of the abdomen of the male pupa, ventral view.

Male Pupa. The male pupa (fig. 4, *C*) is similar to the female, but has a thicker antennal sheath and a different arrangement of spines on the eighth and ninth segments. The arrangement of spines is the same on the eighth segment as it is on the preceding seven segments. The ninth segment has the same arrangement of spines as the eighth segment of the female. The tenth segment terminates in a pair of lateral wings which encase the basistyles and the distostyles of the adult terminalia.

Adult Female. The length is 2.5 mm to 3.0 mm. When seen in the field the adult gnat seems black, but when cleared in Berlese fluid and examined under

a microscope it shows many light-brown portions and the very dark areas are dark brown. The head and thorax are very dark brown; the abdomen is much lighter. The abdomen is also lighter ventrally than dorsally. The wings (fig. 5) are transparent but when folded on the back and seen by reflected light, appear opaque white. The legs are dark brown at the base, becoming lighter at the extremities.

The color of the head is very dark brown. The compound eyes are reniform and have no special characteristics. The eyes are separated in front by a rather large space in which the two large, globular antennal sockets are set.

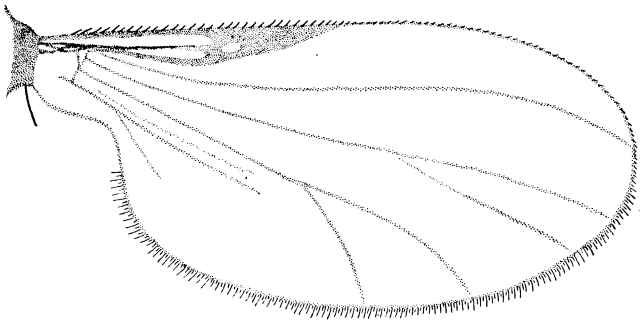

Fig. 5. Wing of female, Bodega black gnat.

The antennae (fig. 6) are dark brown and are made up of thirteen segments. The basal segment is flat and ringlike. There are three bristles on the inner margin of this segment. The second segment is subspherical and has a deep depression on its anterior face for the reception of the third segment. It has a general covering of very fine hairs. The third segment is pyriform. It is about half as large as the second segment and slightly larger than each of the following nine segments. On the anterior third of this segment there is a whorl of six large, erect bristles. The segment has a general covering of very fine hairs arranged in rows. It is much more sparsely covered than the second segment.

Segments four to twelve are globular and have a moniliform appearance. Each segment has a narrow, pale, basilar section, inserted like a pedicle into the circular pit of the anterior portion of the preceding segment. The body of each segment is dark brown and somewhat broader than long. Each segment has a whorl of ten rigid, dark-brown bristles around its center. The bristles are long and stout. There is on each of these segments a fine covering of small hairs arranged in rows, similar to the hair covering described for the second and third segments. These hairs are arranged more sparsely than those on the third segment.

The thirteenth segment has about the same diameter as the preceding nine, but is about three times as long. Just above the base it has the whorl of ten bristles which characterizes the preceding segments. Following these is a series of imperfect whorls. The segment ends in a terminal bristle almost at the apex of the segment.

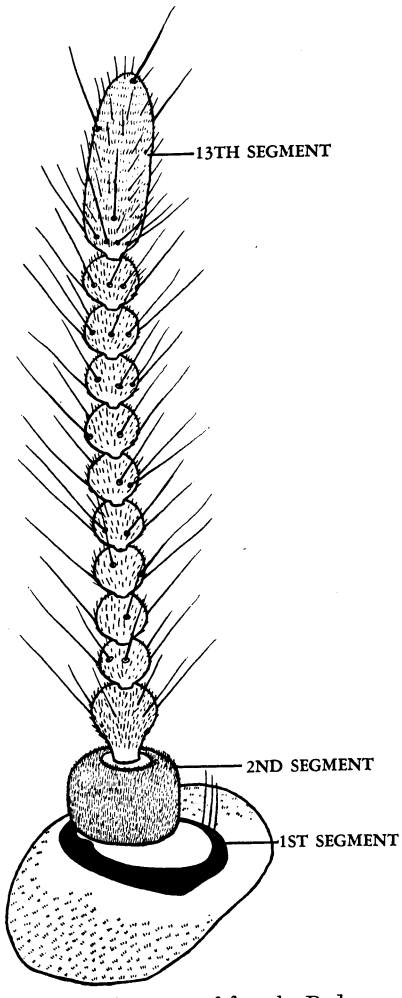

Fig. 6. Antenna of female, Bodega black gnat.

The mouth parts (fig. 7) consist of a labrum, labium, hypopharynx, two mandibles, and two maxillae with their maxillary palpi. The length of the proboscis is 210 μ. The labium does not completely encompass the rest of the mouth parts; the pilosity is not particularly distinctive; the bristles, fine and coarse, which are similar to those that cover the whole body of the insect, are very light in this region. They are most numerous on the labella. The labrum is slightly dilated at its base and bears at its apex apparatus for perforating the skin. This consists of two terminal toothlike structures of a type similar to those found in the genus *Culicoides,* family Ceratopogonidae. The hypopharynx is lanceolate, light in color and soft, but thickens toward the median line. The mandibles are pale, slender structures with ten large, sharp teeth at the apical end to aid in cutting tissues of the host. The maxillae are very light brown in color and are wider and thicker than the mandibles. The number of teeth varies from sixteen to nineteen. The teeth of the maxillae are smaller than those on the mandibles and are set closer together. The teeth of the mandibles are directed outward, the teeth of the maxillae inward.

The palpi are composed of four segments. The basal segment is short and light-colored. The second segment is light and a light-brown area covers most of the distal end, which has a whorl of four large bristles. The third segment is very dark brown, pyriform, and slightly constricted at the middle. It is inserted into a circular depression of the second segment by a narrow pedicle. On the surface nearest the maxilla, in the distal two thirds of the segment, is a deep cavity, about half as long as the segment itself. There is a dark chitinous ring around this cavity, and within the cavity are several platelike sense organs.

The fourth segment is white at its base and dark brown at its tip. There is a terminal bristle and a whorl of six bristles just below the tip. There are numerous whorls of smaller bristles in rather even rows for the complete length of the segment. The fourth segment is about twice as long as the third, but only one third as wide. These four segments of the palpus are shown at the right in figure 7.

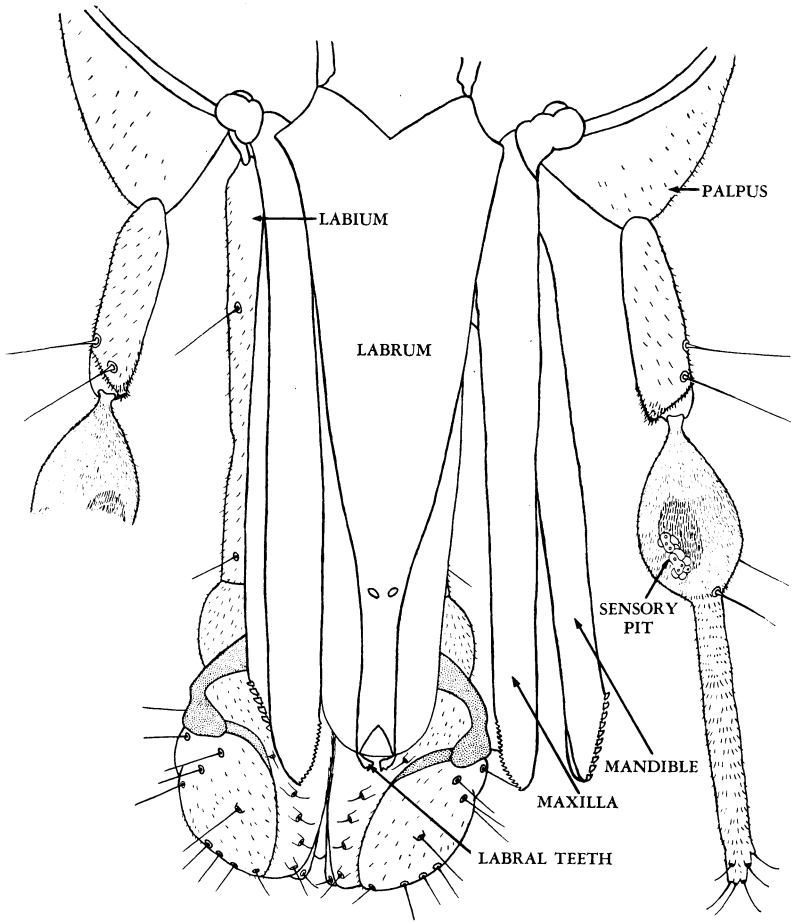

Fig. 7. Mouth parts of female, Bodega black gnat.

The thorax is strongly arched. The prothorax is indicated by two gibbous structures, located dorsally and ventrally. The scutellum and metanotum are small, and the scutellum has four very stout bristles directed caudad. There are three longitudinal rows of stout bristles on the dorsal side of the thorax. Laterally there is a group of sixteen irregularly arranged bristles on each side. The sensory organs in the humeral region are conspicuous and crescentic in shape. Dark brown in color, they are located just ventral to the base of the wing.

The length of the wing (fig. 5) is 1.65 mm and the breadth 0.70 mm. The wings are covered with numerous very small hairs. The halteres are oval and white. The anterior margin of the wing has a row of very closely placed recurved hairs, slightly larger than the small hairs which clothe the general wing surface. The hairs become larger gradually as they approach the distal portion of the wing and are largest on the posterior margin. The arrangement

of hairs on the posterior margin is very characteristic: there is an almost perfect alternation of long and short hairs. It is possible that where the arrangement is not perfect, bristles may have been lost.

The costal vein does not reach the middle of the anterior margin of the wing, but stops approximately at the bifurcation of the fifth longitudinal

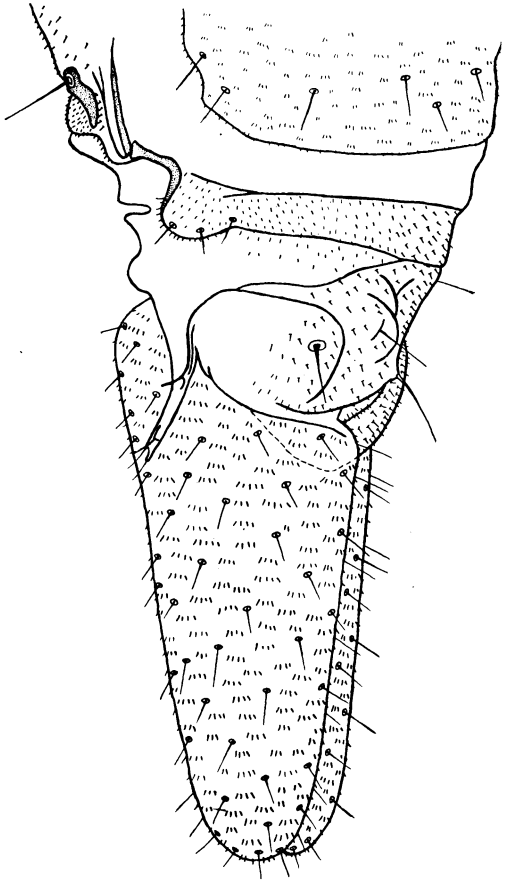

Fig. 8. Terminalia of female, Bodega black gnat.

vein. A wide, dark zone results from the fusion of the costal and subcostal (or first longitudinal) veins, an area which is thus strongly reinforced. There is no trace of the second longitudinal vein, which, however, might be in the confused mass of the united costa and subcosta. The third longitudinal vein is arched and describes a curve parallel to the anterior border. It does not reach the border, falling short almost at the tip.

The fourth longitudinal is approximately rectilinear. The upper branch goes from the axis of the wing to the apex. The basal portion of the lower branch is absent, and the distal end does not reach the apex of the wing. The fifth longitudinal vein is the thickest of the longitudinal veins, and is divided into arched branches which reach the posterior border at its middle part. The

sixth and seventh longitudinal veins are represented by two weak rectilinear veins. In summary: aside from the mass formed by the costa and subcosta, there are three well-defined longitudinal veins, two of which are bifurcate. There are apparently no cross veins. Langeron (1913), after examining the literature on wing structure of this species, came to the same conclusion, suggesting that if cross veins do exist, they must be located at the extreme wing base, and are, consequently, very difficult to see.

The stigma was described by Austin (1921) as "large and very conspicuous, and of a striking orange color." His description was made from specimens taken in Tunis. He did not state whether the specimens were male or female. Freeborn and Zimmerman (1934) described the stigma of the female as brilliant scarlet, but stated also that the color was not constant, varying from

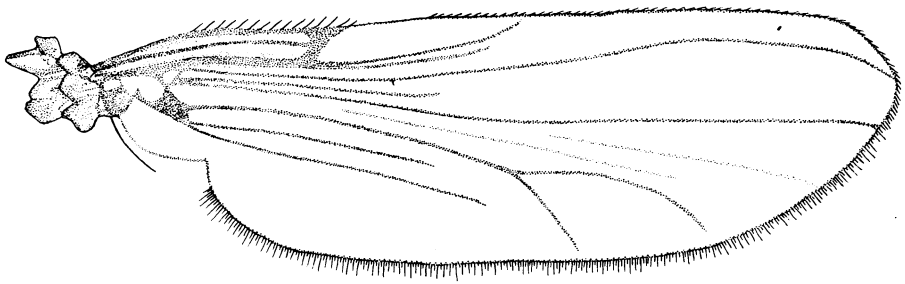

Fig. 9. Wing of male, Bodega black gnat.

orange red through pale yellow to practically colorless. Their descriptions were of specimens taken at Bodega Bay, California. Almost all specimens taken at Bodega Bay by the authors had colorless stigmata. A few females taken at the end of the adult season in October, 1944, and a single female taken in March, 1945, had brilliant orange red stigmata.

The abdomen bears two lamellae (fig. 8) which are attached to the sides of the tenth segment. The lamellae are approximately four and one half times the width of the tenth abdominal segment. They are covered with very small hairs arranged in groups of three or four in a line. There are also some larger hairs dispersed evenly over the entire structure. A smaller pair of lateral structures are attached to the ninth sternite and extend over one fifth of the lamellae. There are two heavily chitinized spermathecae, oval in shape. These are seen in the seventh segment.

Adult Male. The male is darker than the female and is somewhat larger. The length of the male is 3.5 mm to 4.0 mm, the width at the widest region of the thorax, 0.7 mm. The head and thorax are very dark brown; the abdomen is much lighter. Live specimens appear shiny black when taken in the field. The abdomen is slightly lighter dorsally than ventrally. The wings (fig. 9) are clear or opaque white as in the female, and are covered with very small hairs. The legs are dark brown at the base, becoming somewhat lighter distally.

In general the head is very dark brown. The appendages of the head other than antennae and mouth parts are the same as those of the female.

The antennae of the male are fifteen-segmented. The first segment is ring-like and clear, with a heavily chitinized circle at its base. The second segment

is very much enlarged and, when seen from above, appears to be doughnut-shaped. It is clothed with very small hairs. The third segment is pyriform as it is in the female antennae. The fourth to the fourteenth segments are very similar, but become progressively narrower; each is three times as long as its widest portion, and has a swollen ring to which is attached a whorl of very long bristles. Segment fifteen is slightly over twice the length of segment fourteen and is about the same width except at the tip, which is about twice

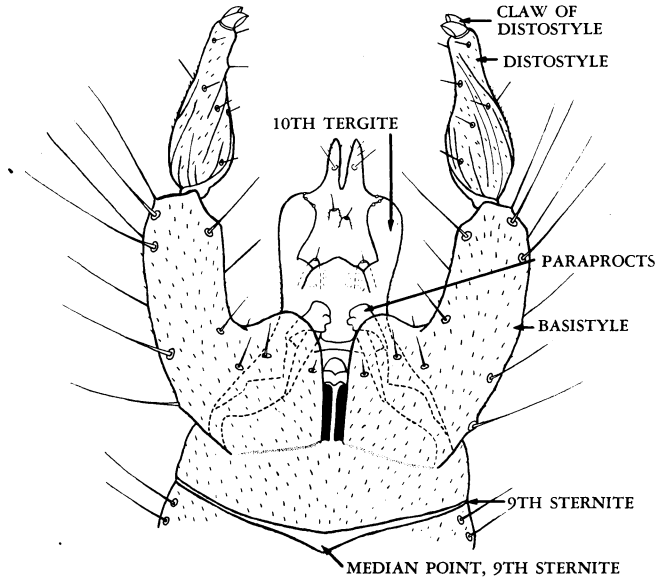

Fig. 10. Terminalia of male, Bodega black gnat.

as broad as the narrowest portion. At the base of the fifteenth segment there is a whorl of the long bristles which are characteristic of all segments from the third to the fifteenth. These give the antennae their plumelike appearance. There are many small hairs and sensory pits located on the fourteenth and fifteenth segments.

The mouth parts are similar to those of the female, but are more slender and are not adapted to the blood-sucking habit of the female. They appear to be strong enough to pierce plant tissue or thin insect integument. The labellae are fleshy and prominent, but thinner than in the female. The palpi have four segments. The basal segment is fleshy, light, and less than half as long as the second. The second segment is light-colored, long and narrow, becoming broader distally. The third segment is slightly swollen two thirds of the way toward its distal end, and long, slender bristles are attached to the distended portion. This segment is dark brown and has an inconspicuous sensory pit. The fourth segment is about the same length as the third segment, narrow, swollen distally, but narrowing again at the apex. The proximal one third of the segment is white, the distal two thirds dark brown. All segments are clothed with very short hairs.

The mandibles and maxillae are more slender than the corresponding structures in the female. The teeth are more delicate and much longer. The labrum has a whorl of long hairs at its tip instead of the two toothlike structures of the female.

The wings of the male (fig. 9) are longer and narrower than the wings of the female.

The abdomen is longer and narrower than the abdomen of the female.

The terminalia (fig. 10) of the male are important in taxonomy. The basistyles are short and stout. There are large basal lobes and apical condyles for articulation with the distostyle. The distostyles are wide basally, becoming narrower toward the distal end, and terminating in two spoonlike structures. There are two median digits located at the distal end of the ninth tergite. The lateral wings of these structures are bent ventrally to form a partially closed cylinder, in which may be seen a fleshy mass terminating in four lobes. This is probably the tenth or anal segment. These lobes are covered with setae. The aedeagus consists of two simple valves. The paraprocts are heavily chitinized structures which originate at the base of the basistyles. The ninth sternite is very narrow, and has a small median point.

DESCRIPTION OF THE STAGES OF THE VALLEY BLACK GNAT

The valley black gnat closely resembles the Bodega black gnat. The points of difference between the two will suffice to describe the valley black gnat, and, at the same time, serve to differentiate the immature stages of these two species. The pupal stage has not been obtained. Eggs were secured only by dissection of gravid females and agreed in all respects with the eggs of the Bodega black gnat.

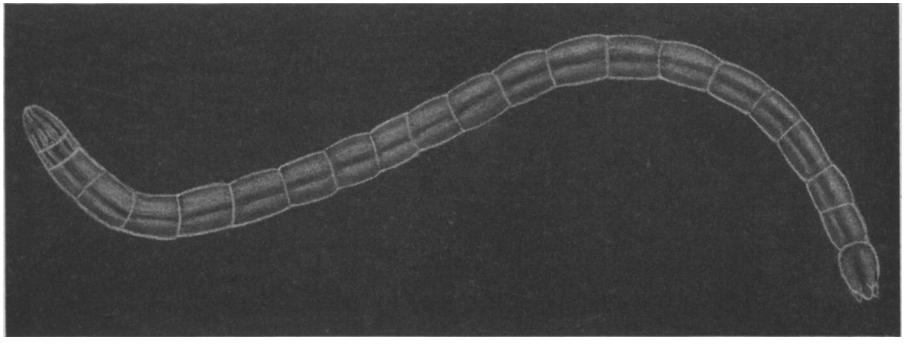

Fig. 11. Larva of the valley black gnat as seen in life by reflected light.

The Larva. Larvae of all sizes have a distinct, slightly chitinized, transparent head and 21 body segments (fig. 11). The prothoracic segment is only half as long as the other body segments, which (with the exception of the last segment) are uniform in length and appearance. The intercalary segments cannot be differentiated from the true segments. They have probably arisen by the equal division of abdominal segments 1 to 9 inclusive. The last abdominal segment terminates in three blunt lobes (fig. 12), one dorsal and two

ventral, with the anus recessed between the lobes. Two ovoidal, thinly chitinized, transparent bladders (gills?) are protruded from the anal opening when the larvae are living in water. The larvae are apneustic, but have well developed tracheal systems. There is a very minute bifurcated bristle on the head between the antennal sockets, but otherwise the larva is without hairs or spines of any kind. The integument of the anal lobes is slightly rugose. Mature larvae average 5.35 mm in length, and a few extra large specimens measure 6 mm.

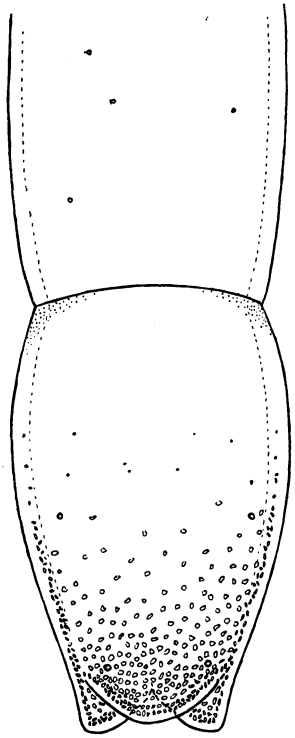

Fig. 12. Last segment of larva of the valley black gnat, dorsal view.

The antennae are one-segmented with a retractile bladder at the tip. The whole antennae is retractible into the head. Eyes are absent; no vestige remains. The color of living larvae as seen by the naked eye is a dense, opaque white, but when studied microscopically, alive in water, the fat-body is seen to be the structure which gives rise to the white appearance; the integument and internal organs are either transparent or translucent and are colorless.

The heavily chitinized mouth parts (figs. 13 and 14), which are easily visible through the head capsule, are the most conspicuous feature of the larvae. They are much more heavily chitinized in the valley black gnat than in the other species. They consist of a pair of concave, tridentate mandibles, so placed—with convex sides apposed—as to preclude biting; a pair of long chitinous rods, the ventrolateral rods, extend into the second thoracic segment. The mandibles are articulated to the rods by strong, heavily chitinized irregular pieces, the mandibular levers. The dorsolateral rods which occur in the Bodega black gnat are not found in the valley black gnat.

There are two vertical pharyngeal arches placed close together near the rear of the head capsule. The anterior arch is continuous with a horizontal U-shaped piece which lies in the floor of the pharynx. These arches appear to be the atrophied remnants of a masticating organ.

A heavily chitinized rod, the dorsomedian rod, extends about two thirds the length of the head. At its posterior end it bifurcates into a broad U; at the anterior end it is cleft and carries thinly chitinized lateral wings.

The antennal arches are forked structures located on either side of the head in such a position that the antennae can be retracted into the arms of the arch. These heavily chitinized arches are probably for the attachment of muscles which retract the antennae.

The labrum has two depressions in its anterior margin, each of which accommodates one mandible as it sweeps food into the mouth. The anterior edge of the labrum is heavily chitinized and is continuous with a thinly chitinous structure which extends posteriorly for about half the length of the head.

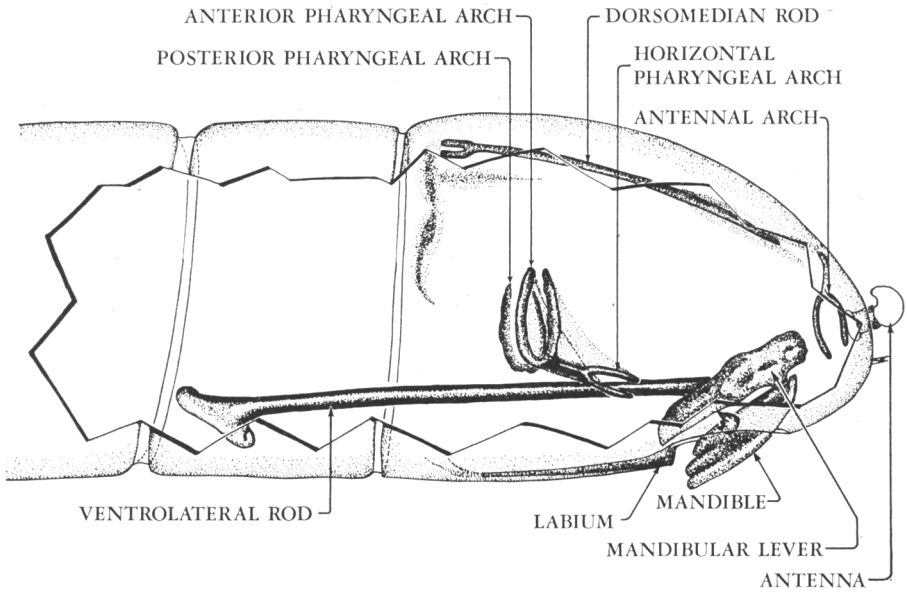

Fig. 13. Valley black gnat larva: cutaway diagram of head and two thoracic segments, with mouth parts and antennal parts removed from the right side of the larva.

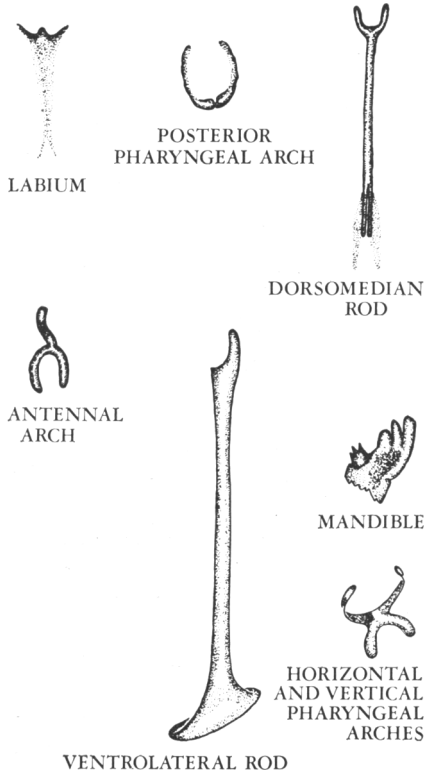

Fig. 14. Chitinized structures from the head of the larva of the valley black gnat.

There are some irregular, heavily chitinized areas of the integument in the posterior dorsum of the head capsule.

The Adult. The female of the valley black gnat closely resembles the female of the Bodega black gnat. The chief character which distinguishes these two species is the number of segments of the antennae—14 segments in the valley black gnat and 13 segments in the Bodega black gnat.

The male of the valley black gnat is slightly smaller than the male of the Bodega black gnat. The only distinguishing characters are found in the terminalia. For a description and illustrations of these characters see Freeborn and Zimmerman (1934).

BIOLOGY OF THE BODEGA BLACK GNAT

Breeding Grounds. The larvae of this species were found at Bodega Bay, living in damp sand along the margins of pools situated in rain gullies, just above the normal high-tide level. Salinity tests were made of the soil in which the gnats were breeding; the method used was that described by Mohr (in Kolthoff and Sandell, 1936), wherein chloride ion is determined volumetrically by precipitation with standard silver nitrate solution using potassium chromate as an indicator. The samples taken in Bodega Bay showed 8,900 p.p.m. Water sampled at the tide pool where the larvae were found showed 640 p.p.m. This sample was taken in March, when there was a considerable amount of rain water in the ditch. No larvae were taken in areas totally free of the chlorides.

In a region 10 yards nearer the bay the salt content was 1,300 p.p.m. No larvae were found here, although conditions of soil and plant life were similar to the area of lesser chloride concentration, where larvae and pupae were found in abundance. The larvae have a preference for brackish water, largely rain water and drainage, with only an occasional infiltration of tidewater. The breeding grounds where the larvae were taken in the greatest numbers were reached only by high tides of 6 feet or over. These tides occurred for a period of 10 days in January, 4 in February, none in March, 2 in April, 5 in May, 4 in June, 11 in July, 9 in August, 1 in September, 5 in October, 6 in November, and 7 in December, making a total of 64 days throughout the year when the breeding grounds were inundated with water of very high saline content. The water from these tides leaves the area fairly rapidly, but the sandy nature of the soil causes the water to penetrate deeply; the organic matter acts as a blotter to hold the moisture and maintain the soil in a semi-saturated condition favorable to the development of the larvae. The area where the larvae are found extends not more than 2 feet from the water's edge. During the winter months there is standing rain water, but in the summer the only added water is tidal. In summer the area of standing water is covered with vegetation. The larvae are not found in the area of standing water; the actual breeding area extends from the edge of the standing water to the end of the moist sand. This area will vary in width according to the slope—the greater the slope the narrower the breeding area.

The soil in which the larvae were found was the "nearly pure sand" referred to by Painter (1926) in his description of the soil in which *Holoconops bequaerti* larvae were found. This description contributed toward the finding

of larvae of *H. kerteszi*, as did his suggestion that breeding grounds occur at the high-tide mark. It was possible to eliminate many areas by confining the search to "nearly pure sand at the high tide mark."

The sand was tested for organic matter by igniting air-dry samples. Samples from the top 2 inches had 11.0 per cent organic matter, samples 2 to 4 inches deep, 2.8 per cent. The organic matter consisted chiefly of decaying plant material. There were many insect parts, such as egg cases, larval and pupal exuviae, and dead adults. The sand was rather dark, and it became reddish upon heating, suggesting the presence of iron compounds.

Methods. Infested sand was placed in a large glass funnel which was set in shallow water. A piece of fine cheesecloth over the stem of the funnel retained the sand. A 60-watt lamp was placed close to the top of the funnel. As the top layer dried out, it was carefully scraped off and thrown away. Gradually all the soil dried and the larvae fell to the bottom of the dish of water. Larvae had no difficulty in passing through the cheesecloth at the bottom of the funnel.

This method failed to yield eggs or pupae, but it was very thorough in removing larvae from the sand and was used to make accurate counts of population density. The method likewise yielded first-instar larvae, which could not be collected by the elutriation method.

The elutriation method was by far the most convenient and satisfactory way of collecting the larvae. A 1-pint jar was filled with soil to be tested and the jar placed in a pan with a white bottom. The ideal pan for this use was a photographic developing tray for 8 × 10 prints. The jar was placed under a faucet with a moderate flow of water, and the soil was stirred from time to time so that all small particles and organic matter were whirled by the force of the water and overflowed from the jar to the pan and then from the pan to the drain. After a period of 10 minutes all larvae had floated out of the jar and into the pan. The heavier particles of sand remained in the jar, which was removed from the pan. All excess water was decanted from the sample in the pan, and this prepared sample was then taken into sunlight where the larger larvae were removed. A gentle rotary motion of the pan separated the larvae from the organic matter which had also floated out into the pan. The larvae were easily recognized by their tendency to curl up like a doughnut. They were pipetted into watch glasses, together with a small amount of organic material; they remained in the watch glasses until they pupated and emerged. They showed no cannibalistic tendencies, and it was possible to keep as many as forty or fifty in a single watch glass.

The smaller larvae and eggs were recovered only by an examination of the organic matter remaining after the larger larvae had been removed. This examination was made under a binocular at 15 magnifications, the organic matter being placed in small lots in a white saucer. The eggs were washed to the edges of the saucer by a rotary movement similar to that used for the recovery of the large larvae.

The pupae were easily seen and separated out with the large larvae. Not all of the pupae were removed by the differential elutriation method because they were too heavy to be washed out of the jar. However, they were clearly visible at the top of the soil remaining in the jar.

Seasonal Cycle. The males in the field congregate in large groups of several hundred to a thousand. The clusters they form vary in size from a cubic foot to 2 cubic yards and, when netted, are found to include few females. The females, which may be numerous in the vicinity, may visit the male swarms, probably for copulation. The females taken in swarms of males were crushed and found to contain no vertebrate blood, so it was assumed that the blood meal was taken after copulation.

Human blood is not the only blood taken by the females. Dogs and cats are probably preferred hosts. When feeding on a dog or cat, the gnat may hide in the thick fur and take a blood meal undisturbed, since these animals are not irritated by the gnat bites and do not develop swellings such as appear on man.

The first large swarms of adults at Bodega Bay occurred in mid-April. Three sweeps of a standard insect net resulted in a collection of 144 males and 3 females. Residents of the area complained that the gnats were biting fiercely every warm day. The pools were without surface water for the first time since December. The sand was moist and conditions appeared to be right for egg laying.

Large swarms of dancing males, together with some females, have been observed 575 yards southeast of the breeding area, and at an elevation of 100 feet above the breeding area. The prevailing winds are northwest. Certain definite locations are selected for swarming, and swarms of males may be found in those areas on all calm, warm days, year after year. The males appear to select a lee, and fly close to, but not into, the streaming air which comes around one side of the windbreak.

Attempts were made to determine the total length of life of adult male and female gnats, but, since the experiments were made on field specimens, the evidence is inconclusive. Under a close approximation of salt-marsh conditions, all the males died within 4 days. They had been taken from a breeding swarm in the field and, therefore, the total length of life cannot be known. The females, which were kept in cheese glasses with a single layer of moist blotter paper at the bottom of the glass, were fed as often as they would take a blood meal. They took as many as 4 meals and lived, in some cases, as long as 11 days. Since these were also field specimens, it is possible that the total life span is considerably longer.

The first eggs were taken from the soil on June 11, and on June 13 two of them hatched. The remaining 18 eggs hatched June 23. This indicates that the incubation period is at least 12 days. Since the eggs and mud were thoroughly stirred up by the method of egg collecting described above, it was impossible to tell whether the eggs were laid singly or in a group. However, it is thought that the eggs are laid singly, since none were ever collected in a mass or even in pairs. The eggs are very light tan at first, gradually darkening as they reach maturity. One batch of 8 eggs, laid by a female in captivity, was laid very close together. After laying them, the female died and was dissected. The remaining eggs numbered 27, making a total of 35. Two more gravid females were dissected after they had died, and the eggs were counted. The total was 48 for one and 54 for the other.

Eggs were found from June 11 until August 24. The presence of large larvae indicated that some eggs had hatched as early as April. The average

number of eggs per 8-quart sample of soil was 83, the number decreasing toward the end of the season. The count included both hatched and unhatched eggs. On August 24 only one egg was found in a sample. The samples were taken from the upper 2 inches of soil, and each sample covered an area of approximately 1 square yard.

Eggs hatching in April, May, June, July, and August gave rise to larvae which pupated in March, April, May, June, July, and August of the following year. Adults emerged almost continuously from early March until August or September, the last swarm of adults occurring in early October. These were very small swarms and were made up predominantly of females which had probably emerged during September.

The larvae of the Bodega black gnat develop very slowly, requiring approximately 8 to 10 months to pass into the pupal stage. It is thought that there are four larval stages, although the second instar has not been obtained in captivity. Eggs have hatched into first-instar larvae; third-instar larvae have molted into fourth-instar larvae; and fourth-instar larvae have pupated; but first-instar larvae failed to molt into second-instar larvae in the laboratory. After hatching, the first-instar larvae measured 0.5 mm in length; they started feeding immediately after emerging from the eggs, which had been taken by the method described above. They lived in water for 3 weeks, feeding on organic material. They did not molt, and finally died. In consequence of this failure of first-instar larvae to molt in the laboratory, the second instar can only be inferred by size. Larvae which would be between the first and third instars by measurement have been taken by elutriation and by the heat-treatment method, but these died before molting.

Feeding larvae have often been observed with a binocular microscope. The mandibles alternately sweep into the mouth; or, at times, the head is moved in a scraping motion. Sand grains, as well as bits of organic matter, are scraped; mounted larvae show diatoms and fine detritus in the gut. Bacteria also are doubtless swallowed.

The larvae are found in thoroughly saturated soil, from 1 to 3 inches below the surface. In one rectangular block of soil, 12×12 inches in area, 166 larvae and 41 pupae were taken from samples 1 to 3 inches deep. Two larvae were taken in the 3- to 5-inch depth, but none in the 5- to 7-inch depth. The first larvae to pupate in the laboratory did so in March, shortly after the first larvae were found in the field.

The pupae wiggle actively to the surface of the sand before emergence, and stand erect on the tips of their abdomens, the rest of the body well out of the soil. They can be taken from the top of the soil in the field just before pupation if a careful scrutiny of the soil surface is made with a large reading glass. The pupal stage averaged 8 days in the laboratory. Pupae have been found in the field from early March to late August, August 24 being the latest date of recovery. They became less numerous in the sample as the season progressed.

BIOLOGY OF THE VALLEY BLACK GNAT

To discover the breeding areas, or larval habitats, of the valley black gnat, emergence traps, described in a previous paper (Smith, 1933), were placed in many localities in the field. Each trap covered 1 square yard of surface soil.

Although traps were placed in many types of environments, especially standing water and its environs, the gnats were found to emerge only from clay-adobe soil, particularly in sinkhole areas where water stood during the winter.

In order to build up a high concentration of larvae at one spot and thus facilitate their discovery later, two large cages were placed in the clay-adobe area near the emergence trap which had caught emerging adults. These cages were muslin-covered wooden frames 2 feet square and 3 feet tall. A smaller wire cage containing a live rat was placed inside each of the muslin cages. During the adult flight period, approximately one thousand female gnats were introduced into each cage. They fed readily upon the caged rats and, when fully engorged, crawled down the cracks in the adobe soil which formed the floor of the large cages.

At the end of the flight period, all surface dust and debris was carefully swept up from the bottom of the cages and examined microscopically for eggs, but none were found. Then the sweepings were moistened and observed from time to time for larvae but none appeared. This indicates that the eggs are not laid on the surface of the soil.

In March, nine months after the flight of the adults, the soil under the cages was carefully dug up and examined for larvae. The first larvae were found at a depth of 20 inches. Continued digging and searching yielded many more larvae and indicated that the adults had successfully matured their eggs on rat blood and had crawled into the cracks of the adobe soil to oviposit.

Larvae were found only in clay-adobe soil. The pH of the soil was 9.6 and the salt concentration 400 p.p.m. The majority of the soil particles were ultramicroscopic and exhibited Brownian movement in aqueous suspension. This soil has a marked capacity to swell when absorbing water; as it dries in the field it shrinks, forming large cracks an inch or more in width. The soil has a tendency to crack into hexagonal columns about 1 foot in diameter, but the hexagonal pattern is rarely achieved. At a depth of about 12 to 14 inches, the large surface cracks enter a system of narrower vertical and horizontal cracks which tend to divide the soil into cubes about 2 inches square. The crack system is a permanent feature of this soil, the same cracks opening each summer and closing again with the winter rains.

Attempts to Rear Larvae in the Laboratory. Many conditions were tested in the laboratory in attempts to rear larvae to adults. Various live foods, including small earthworms, nematodes, collembolans, and small chironomid larvae, were placed in moist dishes with gnat larvae but were not molested. A number of black-gnat larvae were confined in a small dish, but although they were frequently coiled around one another, they showed no tendency to cannibalism. The larvae readily ingested decayed plant material, but during a period of 30 to 60 days the fat body gradually disappeared and the larvae died, apparently of starvation. Larvae lived an equal time submerged in water containing organic matter. In water, they extruded two small disk-shaped pouches from the anus. It seems probable that the normal food of this species is organic detritus with its associated microörganisms—bacteria, fungi, and small nematodes. The failure to maintain fat and to pupate may be due to the relatively high oxygen content of laboratory media, in contrast to the very low oxygen content of clay soil at a depth of 2 feet.

Duration of the Larval Period. A group of 64 larvae, collected in April, were measured in length and were found to be classifiable into one of two well-defined size groups centering on 3.8 mm and 5.4 mm, as shown in figure 15. After the flight period of the adults had intervened in May and June, the larvae were almost as abundant in the soil as before. Measurements of 205 larvae collected in August showed two size groupings centering on 3.5 mm and 5.1 mm, as also shown in figure 15. These curves indicate: (1) that the minimum larval period is two years in duration, (2) that the summer is spent

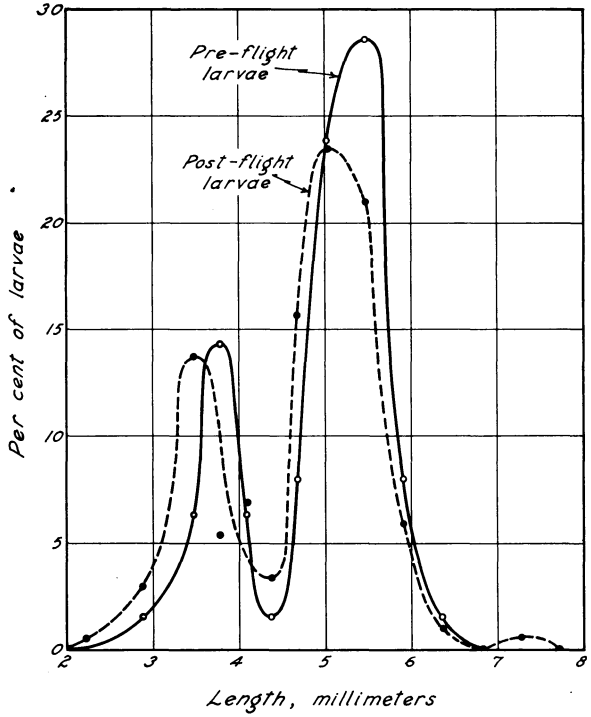

Fig. 15. Valley black gnat: lengths of larvae collected in the field just prior to and just after the flight of adults.

in complete aestivation, and (3) that many mature larvae do not transform into adults, but instead enter a diapause. Since the male and female adults are about the same size, the small larvae cannot logically be considered as one sex and the large larvae as the other. The only logical explanation is that the smaller larvae have fed through one winter and the larger larvae have fed through two or more winters. When larvae are found in the soil during the summer, they are in smooth, round burrows. Their bodies are usually bent double near the middle to form a closed U. They are practically motionless. When placed in water or wet soil they remain motionless for 3 days, then become active and crawl about. They seem to be in a state of immobile aestivation which can be broken by 3 days of contact with water. When larvae are brought into the laboratory in large unbroken clods of soil and no water is added, they remain in aestivation and are immobile.

Further evidence of diapause can be deduced from figure 15. The number of individuals in the first year of their development (80) is much smaller than those in their second year (187). This is the reverse of what would be expected if no diapause occurred. Without diapause the first-year larvae would be more numerous than second-year larvae, since the latter would have been reduced somewhat by natural mortality. If, however, some mature larvae go into a diapause, then large larvae would accumulate in the soil in greater numbers than small larvae. The smaller larvae are more difficult to find than the larger

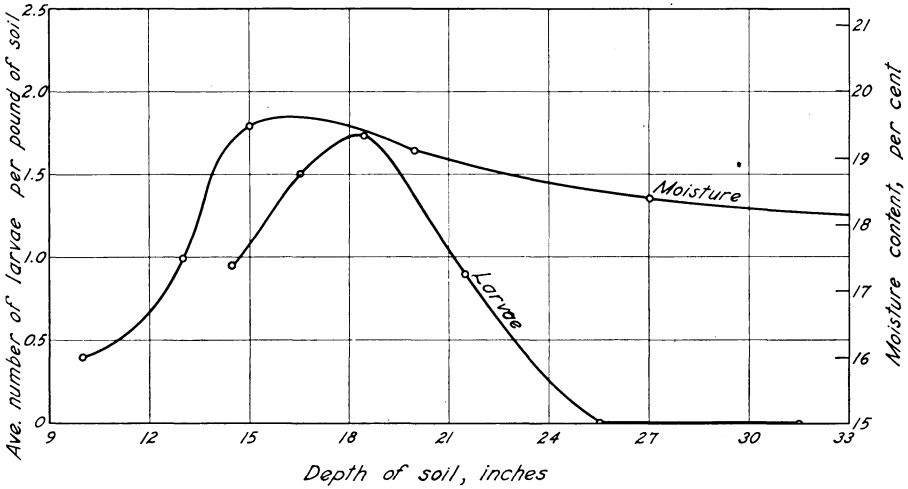

Fig. 16. Valley black gnat: depth of larvae in the soil in the field, and moisture content of the soil.

ones, but not sufficiently so to reverse an expected ratio of about 8 small to 6 large to the actual ratio of 8 small to 18 large. On the basis of these ratios, it is possible to assume that mature larvae had been going into a diapause for the past three years and that some larvae had lived in a mature condition in the soil for that length of time.

Moreover, if mature larvae did not diapause there would have been none in the soil after the flight period of the adults. Actually, in 1944, the ratio of small to large larvae in the preflight period was 1 to 2.31, and in the post-flight period was 1 to 2.20. This represents a loss of only 5 per cent of large larvae, which probably pupated and emerged. The small emergence in 1944 is confirmed by the opinions of long-time residents of the area, who stated that this gnat season was less annoying than usual.

As final evidence of diapause and aestivation, the following test was performed. On July 27, 1944, large clods of soil were collected containing mature larvae which had failed to emerge as adults 2 months earlier. These clods were trimmed to fit 1-gallon battery jars. No water was added. Glass covers were sealed on the battery jars with putty. On March 1, 1946, these jars were opened and live larvae found in the same number as at the start of the test. Their fat bodies were somewhat reduced as a result of long starvation. Since no

water was added it is probable that they did not come out of aestivation but remained dormant during the 19 months of this test.

Vertical Distribution of Larvae in the Soil. During August, 1944, a hole was dug in the breeding area and all larvae counted and their depth recorded. In this test 99 pounds of soil was examined minutely and 85 larvae were found. Their location in depth is shown graphically in figure 16. The moisture content of the soil at the time of digging was also measured and graphed. This graph shows that the optimum depth for larvae was 18 inches and that none were found below 25 inches. However, in other excavations, larvae have occasionally been found down to 38 inches.

Horizontal Distribution of Larvae. The larvae occur in sinkhole areas of clay-adobe soil. Water from winter rains collects in these depressions, and

TABLE 1

HORIZONTAL DISTRIBUTION OF LARVAE

Hole no.	Date sampled, 1944	Distance from bottom	Direction from bottom	Elevation above 0.0	Larvae per pound
		yards		*feet*	
1	July 27	18	South	1.0	1.30
2	August 4	13	South	1.0	1.38
3	August 14	11	North	0.7	0.16
4	August 19	0	Center	0.0	0.05
5	August 28	9	South	0.8	0.00
6	August 29	22	South	1.1	0.48
7	September 1	15	South	1.0	0.56

may stand there at a depth of from several inches to 2 feet during most of the winter. The relation of the distribution of larvae to these rain ponds was studied by digging 7 holes, each 3 feet square and 30 inches deep. An area 13 acres in extent was surveyed and contoured on a 2-inch vertical interval. The bottom of a depression 3 by 45 feet was designated 0.0 feet elevation. About 75 pounds of soil from each hole was carefully examined for larvae. The data are given in table 1.

During the winter of 1943–44, rain water accumulated to a depth of 3 or 4 inches and the center of the depression was under water about half of the winter. The fact that some larvae were found in the center of the depression, as well as the behavior of the larvae in water in the laboratory, indicates that they can tolerate submergence for a long period of time. On the other hand, the larvae at 1.0 foot elevation and above were probably never submerged at any time. The horizontal distribution of the larvae is believed to be a product of the requirements of the ovipositing female, as discussed later in this paper.

Pupation. Just prior to the flight period of the adults, usually early in May, some of the mature larvae leave their smooth-walled, cylindrical burrows and lie free between the permanent crack faces of closed cracks. As the soil dries out and the cracks begin to open, some environmental stimulus such as reduced humidity or increased oxygen content probably stimulates the larvae to pupate. Larvae oriented on crack faces occur at the usual depths, as mentioned earlier.

Extensive search has failed to yield pupae or pupal skins. It is believed that the pupal period is very short, probably about 5 days, in this species. (It has previously been shown that the pupal period of the Bodega black gnat is about 8 days.) Mature larvae have been kept in the laboratory under a variety of conditions in an attempt to induce pupation. These conditions included constant high and low temperatures, variable temperatures, wet and dry conditions and varying rates of desiccation; but none of the larvae pupated. It now appears that the conditions necessary for pupation are a constant temperature of about 68° F, a decreasing moisture content of the soil, and a low oxygen pressure.

Adults. The flight period of the adults is from 4 to 6 weeks, beginning usually in the middle of May. Variations in season from year to year may shift the flight period as much as 2 weeks one way or the other. The emergence from any one spot probably does not extend over more than 3 weeks, as shown by the following catch from a single trap which stood continuously on the same square yard of soil:

Date 1945	Males	Females	Rainfall, inches
May 15	0	0	0.11
May 20	0	0	0.00
May 21	3	0	0.00
May 22	6	3	0.00
May 24	7	8	0.00
May 26	10	9	0.00
May 28	13	14	0.00
May 29	12	15	0.00
May 30	1	2	0.09
May 31	1	0	0.05
June 1	2	1	0.01
June 2	21	39	0.00
June 3	10	8	0.00
June 4	5	1	0.00
June 5	0	0	0.00
June 7	3	3	0.00
June 8	0	2	0.00
June 9	1	1	0.00
June 10	0	1	0.00
June 11	0	0	0.00

The rainfall and cold weather of May 30 to June 1 retarded the emergence of the gnats. Ordinarily, the great majority of the gnats would probably have emerged within a 10-day period. The sex ratio of the emerging gnats, averaged for all traps, was 1 male to 1.14 females.

The gnats crawl out of the cracks in the soil about 8 o'clock in the morning and climb up on vegetation to sun themselves until about 10 o'clock, when the temperature reaches the point at which they fly. Prior to this time many gnats can be swept from the vegetation with an insect net, but none are flying. Dancing swarms of males have never been found in the Sacramento Valley, but large swarms of several hundred each are common in the Santa Clara Valley. Females have been observed to bite under natural conditions as late as 8 p.m. on warm still evenings.

Feeding, and Symptoms on Man. Unfed gnats are voracious and fearless; they cannot be frightened away from the host. They usually run about for a few seconds on the host in an exploratory fashion. They then settle down with the legs well spread and braced. The mouth parts seem to saw for about 1½ minutes, then the abdomen quickly fills with blood, becoming considerably distended. The host feels no sensation during the first 30 to 60 seconds of the bite; after that a slight tingling is noticeable. Defecation occurs as the gnat's abdomen distends; a clear colorless fluid is extruded. Sometimes this droplet is tinged with the newly ingested blood. After feeding, the gnat is very easily frightened away, or may leave voluntarily; but if not disturbed, it may remain at the site of the bite, cleaning its body. A pin-point hemorrhage remains under the skin of the host at the locus of the bite, showing that one or more capillaries have been cut. The feeding process of the Bodega black gnat is similar.

In about 10 to 15 minutes there appears a raised area, hard and white, about ½ cm in diameter, still characterized by the minute red dot in the center. Itching is now pronounced. One and one-half hours after the bite, the hard white area is partially reduced and has become inflamed. A diffused, red blotchy area 1 to 2 inches in diameter appears around the central swelling. Three hours after the bite, the diffused red area disappears, leaving the central ½-cm area red and resembling a flea bite. Itching has disappeared. Six hours after the bite is inflicted, all swelling and most of the inflammation has disappeared, and itching has stopped. At this stage, it is difficult to locate the bites. Eighteen hours after the bite, the spot is marked by a hard inflamed conical swelling about ¼ cm in diameter. The hemorrhagic center has faded but can still be seen. Itching has returned and is moderate. On many persons a small clear blister forms at the locus of the bite on the second day and disappears a day or two later. Itching is intense for about 5 days, especially early in the morning.

The time required to complete feeding is usually 2 minutes, but occasionally takes as long as 4 minutes. A gnat which has once fully engorged will not feed again, but will drink water eagerly.

Gnats have been observed feeding on chickens, turkeys, dogs, cats, and rats. Townsend (1893) reports them feeding on horses. It is probable that they will feed on any warm-blooded animal. On such hosts they burrow quickly into the fur or feathers as soon as they alight.

One female, newly emerged from the soil, fed on a male of her species in captivity, and later, when dissected, was found to contain mature eggs. In the absence of warm-blooded hosts, this species might maintain itself by this means.

Longevity. Without food, the adults live only 6 to 8 hours. Water does not prolong their lives. Females which were fed on human blood lived a maximum of 5 and an average of 4 days. Their death was believed to be due to egg pressure and ruptured oviducts: when dissected, the abdomen was found to be full of eggs and often the oviducts were ruptured.

Eggs. Various attempts to simulate field conditions and secure egg deposition in the laboratory failed. In these tests human blood and rat blood were used as food. Gravid females were dissected and the mature eggs were found

to be very similar to those of the Bodega black gnat, previously described. The ovaries contained from 60 to 70 eggs in various stages of development.

Summary of the Life Cycle. The study of the horizontal distribution of the larvae, together with the study of the physical structure and behavior of the clay-adobe soil in which they live, makes possible a deduction regarding the oviposition habits of the female. It seems likely that a fully engorged, mated female enters the crack system and does not again emerge. She no doubt remains quiescent, deep in the soil, for 3 or 4 days, while maturation of the eggs takes place. She then either lays all of the eggs in one spot or wanders about in the crack system, laying eggs at several places. With the advent of the rains, water flows through the crack system, doubtless for some distance. Eggs may be floated or washed about.

The eggs may hatch soon after the fall rains have wetted the soil. The young larvae probably burrow through the mud in the crack faces, which abound in organic matter that has fallen into the cracks during the summer. With the advent of the dry season, the half-grown larvae burrow into the solid soil and assume the doubled position for aestivation. When the rains of the second winter have wetted the soil, the larvae again become active, burrowing rapidly through the mud but remaining at a depth of 18 to 26 inches. By the following May, the larvae are mature and may orient themselves on the closed crack faces. As the cracks open, pupation occurs, and after a short pupal period the adult crawls out via the cracks and searches for food.

If environmental conditions are not exactly right, the larvae leave the crack faces, enter the solid blocks of soil, and again assume the aestivating position. Mature larvae can probably delay pupation for at least three years. The survival value of this diapause is obvious. In years when rainfall occurs in mid-May, the cracks do not open on schedule; if the adults were to emerge in the soil, their avenue of escape would be closed.

Methods of Identifying Breeding Grounds. Any control measures aimed at reducing the numbers of gnats will probably have to be applied in the breeding areas. Consequently, the discovery and delimitation of such areas is of prime importance. Direct sampling of the soil and visual search for larvae are of little value, for the following reasons: (1) The size of the larvae makes them almost invisible to the unaided eye, and the use of magnifying lenses greatly extends the time required to examine a given sample. (2) A visual search through heavily infested soil may reveal one or two larvae per hour. At this rate, many hours of searching would be required before an area could be said to be free from larvae. (3) The depth at which larvae occur may vary with soil type and moisture content. (4) Only trained personnel can find the larvae, even when present in numbers. (5) Test holes can be dug through clay-adobe soil during the dry season only with great difficulty.

Two other methods of identifying breeding grounds have been used: one method is to trap emerging adults, the other to screen larvae from the soil. Certain difficulties were encountered in the screening process. The peculiar nature of the soil made it impossible to pass water suspensions through a fine-mesh screen. The soil particles invariably clogged the openings. Moreover, no screen was available which would strain out active larvae, since they crawled readily through the openings of silk bolting cloth as used in flour mills. After

sundry trials, it was found possible to strain out the larvae by the following method. The soil was soaked overnight in buckets of water. It was then stirred vigorously with a wooden paddle and a wetting agent (Vatsol OT) added at 1 to 10,000. The slurry was then poured through a 12-mesh screen to remove lumps, and finally through a 64-mesh copper screen. The soil particles then passed quickly through the screen, whereas the larvae, still in immobile aestivation, fell against the screen broadside and failed to pass through. Considerable organic matter and coarse sand also remained on the 64-mesh screen, so the larvae and the organic matter were separated from the sand by elutriation. Finally, the larvae were picked out of the organic matter under a binocular microscope. This method was less tedious than visual inspection, and, with proper screening equipment, would be much faster.

The use of emergence traps in the field appears to be the most feasible method of identifying breeding areas, but the actual operation of the traps is beset with many difficulties. The gnats are so small that coarse-meshed materials such as screen or cheesecloth will not confine them. Consequently, traps must be covered with some dense fabric such as muslin or paper or wood sheeting. These materials, however, retard evaporation of water from the soil under the trap. In consequence the cracks fail to open and the larvae go into a diapause. To avoid inducing diapause, the traps must be placed after a few gnats have emerged. Trap records indicate that the critical time has then passed and adults will continue to emerge.

To prevent the gnats' returning to the soil again after having been trapped, the catching vial at the top of the trap should be provided with a cone having a small perforation at its tip. To insure against escape through the cloth, the traps must be made very tight; if folds are left at the seams, the adults will readily burrow into the folds and force their way out.

It seemed possible that adults, emerging under a trap, might make their way laterally through the crack system and escape from the trap. To prevent this, a sand seal 9 feet in diameter was prepared around each of several traps. The dry sand was allowed to run freely into the crack system, and, when the cracks would take no more sand, it was spread over the 9-foot circle to a depth of about one inch. This device did not increase the efficiency of the traps.

SUMMARY

There are two species of biting gnats of the family Ceratopogonidae in California. These are the valley black gnat, *Leptoconops torrens* Townsend, and the Bodega black gnat, *Holoconops kerteszi* Kieffer. The valley black gnat passes the larval stage in clay or clay-adobe soils situated along the western side of the Sacramento Valley and in isolated deposits in the San Joaquin Valley. The Bodega black gnat passes the larval stage in damp sand with some organic matter, at or just above high-tide level in the mouths of fresh-water streams which enter Bodega and Tomales bays.

A study of the morphology of the larvae showed that the "*Leptoconops* group" is widely divergent from typical ceratopogonids and warrants the acceptance of the subfamily name Leptoconopinae (Enderlein, 1936).

Adults of the Bodega black gnat occur from mid-April until early October, in a continuous flow from the soil. Females may feed as many as four

times. Males form large swarms, dancing in the lee of windbreaks. Eggs are laid on the surface of damp sand where the salt concentration is about 640 p.p.m. The larval stage lasts for 8 to 10 months. Pupation occurs in the sand; pupae wriggle to the surface and stand vertically before the adult emerges. The pupal period is 8 days. Adult females captured in the field lived a maximum of 11 days, with blood meals. Males do not feed; they lived a maximum of 4 days after capture in the field.

Adults of the valley black gnat occur for 4 to 6 weeks, beginning usually in the middle of May. Females feed only once; males do not feed. Unfed gnats live only 6 hours in captivity; with a blood meal, females live a maximum of 5 days. The larvae occur in clay-adobe soils at a depth of 15 to 30 inches. Egress and entrance is dependent upon the drying and cracking of the soil. The larval period is at least two years in length. Larvae spend the summers in immobile aestivation. If the soil does not crack on schedule, the mature larvae enter a diapause. Some evidence is given to indicate that larvae may diapause for at least three years. Larvae are found in summer in soil with a moisture content of 17 to 20 per cent, a salt concentration of 400 p.p.m., a pH of 9.6, and a temperature of 65° to 68° F. Methods of identifying breeding grounds consist of trapping adults as they emerge from the soil, and washing larvae from the soil.

Both species feed viciously on man, domestic animals, and birds. The bite usually produces a transient inflammatory swelling and often an intense itching which may continue for about 1 week.

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