

A STUDY OF THE GENUS NEMOBIUS  
(ORTHOPTERA: GRYLLIDÆ)

BY

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REPRINTED FROM  
ANNALS OF THE ENTOMOLOGICAL SOCIETY OF AMERICA  
Vol. XXIV, No. 2.

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COLUMBUS, OHIO,  
June, 1931.

# A STUDY OF THE GENUS *NEMOBIUS*. (ORTHOPTERA: GRYLLIDÆ).\*

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The genus *Nemobius* is one of the largest of the family Gryllidæ and has world-wide distribution. The most comprehensive work on the American species of the genus is a revision by Hebard (1) which cleared up the synonymy and made it possible to identify the species with greater assurance. His classification is based largely on the characters of the ovipositor, for few reliable male characters were known at that time.

In studying the mating habits of these crickets, the writer discovered that the concealed genital armatures of the males which are protruded while mating provide excellent characters for the identification of most of the species. A study of their structure throws further light on the relationship of our native species. While they do not clearly differentiate races or some closely related species, they make it possible to identify several species with greater certainty with the male sex than with the female.

In order to point out some of the important male characters it is necessary to describe the genitalia and originate some terms for the rigid parts of a protrusible organ that is described more fully in connection with the mating habits. When not in use this organ lies in a horizontal position above and concealed by the subgenital plate. In recently killed specimens, it can easily be pulled out by an insect pin with a slightly bent point, which can be hooked on to the basal supporting structure. On drying, there is a tendency for the organ to pull back into the body unless the attached membrane has been greatly stretched or ruptured. This does not apply to specimens which have been previously dried and relaxed.

The entire structure is roughly cylindrical in shape. The basal part of the dorsal† face, is the main supporting structure.

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\*Published with the approval of the Director of Research as paper No. 44 of the journal series.

†All terms of orientation in the discussion of this structure apply to the horizontal position assumed when withdrawn into the body.

The attached lateral pieces may be termed claspers since they are provided with muscles that draw the ventral edges together. The ventral face is hollowed to form a longitudinal

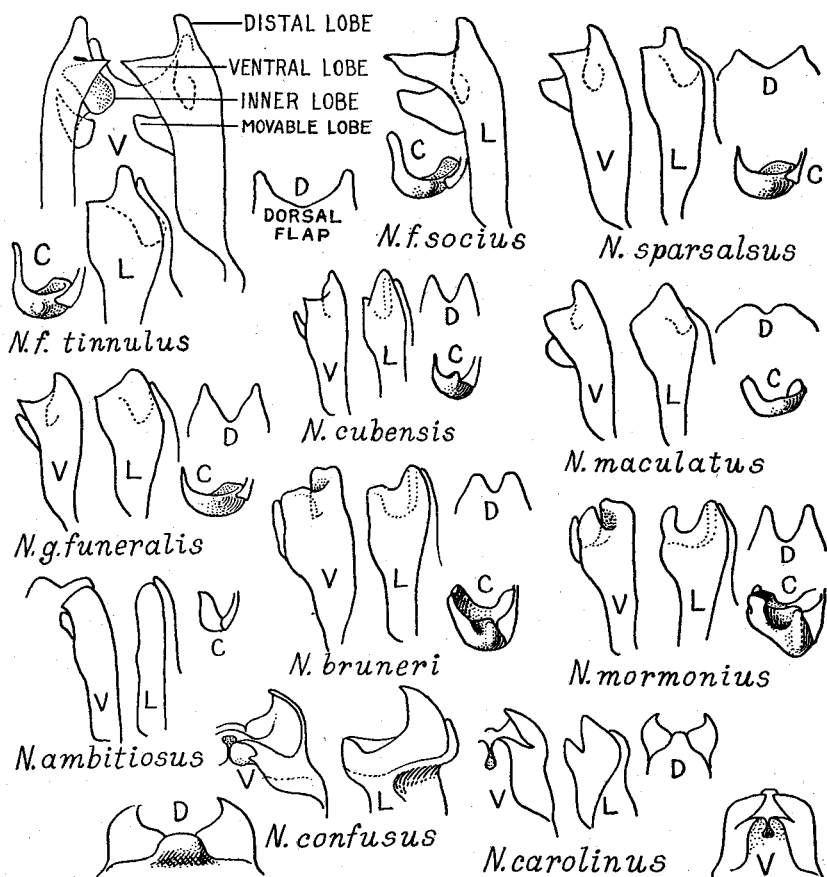


FIG. 1. Male genitalia: right claspers and dorsal flaps. V, Ventral view. L, Lateral view. C, Caudal view. Ventral view of *tinnulus* is of both claspers from a slightly lateral position to show inner lobe of the left. Inner lobes in other ventral and lateral views, indicated by dotted lines.

groove between the claspers. At the distal extremity each clasper is hollowed out on the mesal or internal face and in most of the species has a distal lobe, a ventral lobe which in some species is a sharp tooth, an inner lobe on the mesal face and a movable lobe which is rather loosely attached to the mesal surface, proximad to the inner lobe. The distal extension of

the main supporting structure on the dorsal side fills in the space between claspers on that side and may be called the dorsal flap. The outline of its distal margin furnishes important specific characters.

The ventral groove is provided with thick cuticle, which retains its shape, but between that and the bases of the claspers are areas of thin integument which collapse on drying. The extent to which the claspers are drawn together will affect their appearance and often the internal and movable lobes are hidden. For this reason the ventral and lateral views of the claspers shown in Fig. 1 are drawn from an arbitrary position as if the tips of the ventral lobes did not quite reach the median line although in many specimens they will be found to overlap considerably or may be widely separated.

#### RELATIONSHIP OF THE SPECIES

The characters of the male genitalia substantiate with few exceptions, Hebard's grouping of species found in the United States. No specimens were available for examination of *Nemobius carolinus brevicaudus* Bruner, *N. carolinus neomexicanus* Scudder and *N. eurynotus* Rehn & Hebard.

Those species having the disto-ventral spurs of the caudal tibiae equal in length; namely, *carolinus* Scudder and *confusus* Blatchley have a distinct type of male genitalia. The claspers are very short and are attached diagonally to the dorsal support. The distal lobe is hollowed on the mesal face and is claw-like in shape. The ventral lobe is also claw-shaped but attached to a fold of thin integument which meets the one on the opposite side forming a diaphragm in the ventral groove. This fold, apparently, takes the place of the movable lobe in the other species. The dorsal flap is reduced to a small, rounded, arched extension of the dorsal support.

Among the species having unequal disto-ventral spurs on the hind tibiae, *N. ambitiosus* Scudder seems to stand in a class by itself. It has a unique feature which was called to the writer's attention by A. N. Caudell, of having a bald shining face. The bristles of the head are limited to the occiput, while in other species they reach as far as the median ocellus. The male claspers lack distinct distal and inner lobes, but have the usual form of movable lobe. The dorsal flap is long and has a very shallow median notch.

Of the remaining species, those having the longer and straighter ovipositors, namely, *fasciatus* (4 races), *griseus* (2 races), *sparsalsus* Fulton and *maculatus* Blatchley, have a common feature in the male sex in the shape of the inner lobe of the clasper which is difficult to see without dissection. This is flattened and concave on the mesal face; and extends dorsocephalad beneath the dorsal flap. In *maculatus*, it is reduced to a small projection on dorsal edge of the clasper, and this species differs further in having blunt ventral lobes on the clasper, and a short rounded dorsal flap with a small rounded median notch.

The male genitalia of *N. griseus griseus* E. M. Walker and *N. griseus funeralis* Hart are very much alike, and are characterized by the broadly rounded distal lobe of the clasper, when viewed from the side. The clasper of *sparsalsus* has a very broad base and short ventral lobe. The dorsal flap has a very shallow notch, and the lateral angles are not prolonged. The genitalia of the races of *fasciatus* are described under the discussion of that group.

Among the species with short ovipositors, *cubensis* Saussure, *palustris* Blatchley, *bruneri* Hebard and *mormonius* Scudder, the dorsal edge of the inner lobe of the clasper takes the form of a prominent longitudinal ridge on the mesal face, extending directly cephalad from the distal lobe. *Cubensis* and *palustris* have almost identical male genitalia. In specimens of *palustris* examined the dorsal edge of the inner lobe was more prominent and extended more nearly to the tip of the distal lobe than is shown in the ventral drawing of the clasper of *cubensis*. In both species the ventral lobe is very thin and sometimes bends inward on drying.

The male genitalia of *bruneri* and *mormonius* show similarities but are distinct enough not to be confused. Both have the movable lobes very narrow at the tips where they are parallel to the mesal edges of the ventral lobes. At the base the movable lobes are thin walled and extend across the mesal faces of claspers forming a diaphragm. In this they are supplemented by the cephalic end of the inner lobe of the clasper which curves sharply around to the ventral side and partly closes off the space between the two claspers, caudad to the basal portions of the movable lobes.

In *mormonius* the notch between the ventral lobe and the distal lobe is very deep, the inner lobe forms a large part of the above described diaphragm and the cephalic margin extends to the base of the ventral lobe. The dorsal flap has narrower lobes and a deeper notch than in *bruneri*. In *bruneri* the cephalic edge of the inner lobe is not prominent and it recurves almost to the apex of the ventral lobe.

It is evident that *mormonius* is a distinct species showing closest relationship to *bruneri* and not a geographical race of *cubensis* as formerly considered. My specimens from the Bright Angel Trail of the Grand Canyon, Arizona and two male specimens from Las Vegas, Nev. loaned by Hebard belong to the same species. The male allotype of *mormonius* designated by Hebard was from Las Vegas. The designated type was from St. George, Utah. The two localities are only a little over a hundred miles apart and both in the Colorado basin so it is unlikely that the female would be a different species. The specimens examined have a pale face with a faint trace of a pattern similar to the dark pattern found in *bruneri*. There is a darker band across the occiput from eye to eye. This is present in *bruneri* but is broader and does not quite reach the eyes. The pronotum has a pattern similar to *bruneri* but with less contrast in the colors. The legs also lack conspicuous markings.

Two male specimens from Brownsville and Dickinson, Texas, loaned by Hebard as specimens of *mormonius* have the genitalia as in *bruneri* although the coloration is more like *mormonius*. The placement of these specimens involves the relative specific value of color characters as against the morphological characters of the male genitalia. I prefer to depend on the latter for in other species covering a wide geographical range there is little variation in their structure.

The determination of the geographical limits of *bruneri* and *mormonius* and the relationship of the two species will require a study of the male genitalia of a large number of specimens.† Hebard (1) pointed out the resemblance to *bruneri* of the Texas specimens he placed under *cubenses mormonius*. Further

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\*Since writing this paper the writer has examined specimens, loaned by Hebard, from localities ranging from Beauregard Co., La., to Brownsville and Del Rio, Texas, all of which were similar to the above mentioned Texas specimens in coloration and genital structures.

study may show that they comprise a geographical race of *bruneri* or that they are a connecting link between *bruneri* and *mormonius*.

### THE RACES OF *N. FASCIATUS*

This species seems to be in the process of splitting up into races which are not well defined morphologically but are definite entities in nature. Three of the races have been recognized and named. The fourth has apparently escaped description as a new species or variety by earlier entomologists, while both typical *fasciatus* and the race *socius* are credited with more than one synonym. This is explained by the more secretive habits of the race, resulting in fewer specimens in collections. In order to give this race a name for further discussion of the problem it is here defined as a new subspecies.

*Nemobius fasciatus tinnulus*\* new subspecies. Type; male; Raleigh, N. C., September 16, 1928. Types to be deposited in the U. S. National Museum.

#### *Nemobius fasciatus tinnulus* subsp. nov.

A male was selected for the type because that sex presents more characters to distinguish it from the other races of *fasciatus*. It differs in the following features: dorsal field of tegmen relatively broader, (Fig. 2, A); in life the lateral margins of dorsal fields held nearly parallel; longitudinal or proximal portion of stridulatory vein forms nearly a right angle with the file; length of the file, as far as the perpendicular branch on the distal side (1.5 mm.) greater than the remaining portion of the lateral field (1.2 mm.); distal margin of dorsal field broadly rounded; length of exposed dorsal field 5.4 mm.; greatest width 2.9 mm. Allotype; female; same data as type.

Length of ovipositor as far as perpendicular portion of base on dorsal side, 7.5 mm.; length to extreme base on ventral side, 7.9 mm.; length of hind femur, 7.5 mm. Tip of ovipositor with 9 teeth on dorsal margin; toothed margin with a slight curvature, (Fig. 2, D). Color notes: By comparison with Ridgway's "Color Standards and Nomenclatures," the ground color of the head above the median ocellus is close to orange cinnamon; an obscure pattern between the upper portions of the eyes, snuff brown; face below ocellus kaiser brown; pronotum snuff brown, slightly darker on dorsal portions of lateral lobes, ventral portion of lateral lobes cinnamon buff; legs and ventral side of body with a ground color of cinnamon buff, but on the legs almost entirely obscured by buffy brown; on the hind femur the brown is in the form of numerous oblique dashes. In the male the sides and

\*Tinnulus = Tinkling, clinking. So named because of the quality of the song.

dorsum of abdomen nearly entirely black. In the female, concealed portion black; exposed portion buffy brown with a rather broad black median stripe; sides with large black patterns on the cephalic portions of the segments; lateral portions of dorsum with two small black spots on each side near the caudal border of each segment.

The male tegmina are darkly infuscated over the areas shaded in the illustration, (Fig. 2, A). Paratypes selected; 1 male, 1 female, same data as type; 1 male, 2 females, Raleigh,

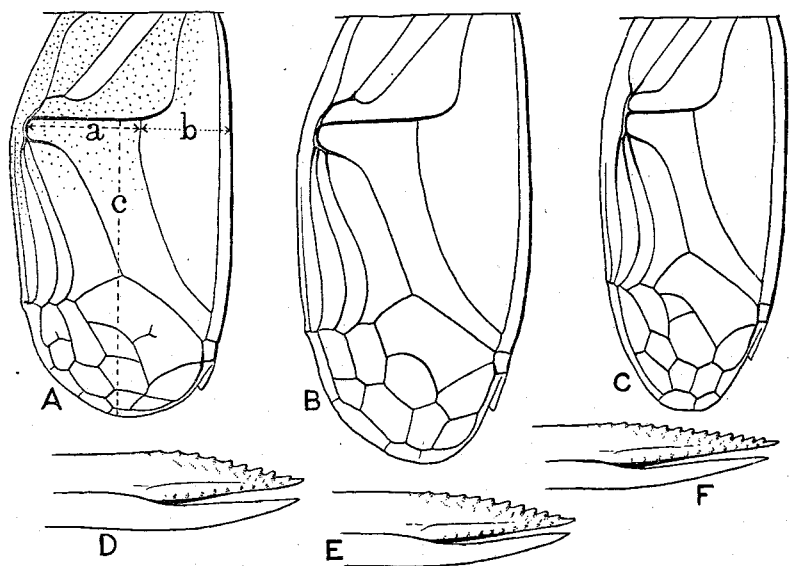


FIG. 2. Tips of ovipositors and male tegmina. A, *N. fasciatus tinnulus*, type. D, *N. fasciatus tinnulus*, allotype. B, E., *N. fasciatus fasciatus*, (Raleigh, N. C.). C, F., *N. fasciatus socius*, (Raleigh, N. C.).

October 8, 1928; 1 male, 1 female, Raleigh, October 15, 1930; 1 male, 1 female, Plymouth, N. C., October 25, 1928.

This woodland race was first observed at Mt. Pleasant, Iowa, where it attracted the writer's attention by its characteristic type of song. It was not found in any other part of Iowa. At that time it was regarded as a purely physiological race of *fasciatus* and its habits were commented on in an earlier publication (2). In North Carolina it is common in woods over a large part of the state. In addition to the localities represented by the paratypes, it has been taken in N. C. at Reidsville, in the north central portion and at Sparta and



Burnsville in the mountain regions. In the U. S. National Museum, specimens from Falls Church, Va. (A. N. Caudell) and Thompsons Mills, Ga. (H. A. Allard) appear to belong to this race.

The subspecies *tinnulus* represents one extreme in the evolution of the *fasciatus* (De Geer) group with *socius* Scudder as the other extreme. The race *abortivus* Caudell from the northern prairie regions seems to be an offshoot in another direction toward *N. griseus*. After studying the races *tinnulus*, *fasciatus* and *socius* in Iowa and North Carolina, both in the field and the laboratory, the writer has formed a different conception of them than that of geographical races based on the relative length of the ovipositor and hind femur. It is true that *socius* in the southern states where it is the commonest race has a relatively short ovipositor but in northern grass marshes there exists a form which is similar to *socius* in habits and in appearance, with the exception of the ovipositor length. The woodland specimens from Mt. Pleasant, Iowa which I am referring to *tinnulus* also have longer ovipositors than the southern specimens but they agree in other characters and in habits. On the other hand, I have recently found in restricted environment near Raleigh, crickets which have as long ovipositors as *fasciatus* in the north and which have other morphological characters and song habits agreeing with that race. The problem is complicated by the fact that the above crickets which appear to be *fasciatus* have a very restricted habitat while in the north, it is the most widely distributed race. In North Carolina, *socius* is widely distributed and tolerates a rather wide range of environmental conditions while the cricket in the north that resembles it has a restricted environmental range.

If we are to recognize any subspecies of *fasciatus* we have at present two choices for the basis of separation. The first is the single female character of relative ovipositor length which offers no more clear cut line of demarkation than any of the characters in the second choice and leaves in both groups physiologically distinct races. The second choice is a combination of characters including the shape of the male tegmen and the relative proportions of some of its areas, the number of teeth in the stridulatory vein, slight differences in the tip of the ovipositor, and some differences in coloration applicable to

both sexes. These differences are correlated with physiological differences recognizable in song habits, seasonal history and in the choice of environment. The above characters are not a direct result of environmental influence for all races have been bred from the nymph in the laboratory under identical conditions and all remain true to type both in structural characters and song. Also in certain border line areas two races may be found intermingled but apparently not intergrading. There appears to be inherent differences between the races which cause them to choose different environments.

My studies have led me to place greater confidence in the second basis of separation as outlined above and to consider the subspecies of *fasciatus* as ecological races rather than geographical. This conception greatly extends the recognized range of *socius*. It is admitted that the characters described below will not suffice to place many specimens from a miscellaneous collection into one of the three subspecies. But neither can this be done on the relative length of the ovipositor. The advantage of the geographical conception of the subspecies is that they can be classified by the locality labels. If locality labels also bore ecological data, they would help in the same way with my classification. Thus it is apparent that certain song and habitat differences noted by Allard (3) in Mass. are those of the races *fasciatus* and *socius*.

I believe that the three subspecies are physiologically distinct and that any individual belongs to one of the three, but that morphologically they have not diverged far enough to make exact classification possible. For this reason I see no reason why any of these crickets should not be referred to merely as *Nemobius fasciatus* in any general discussion where fine distinctions are not involved.

The following outline of racial characters will aid in determination of the subspecies. With a series of specimens taken from a single type of habitat the average condition found will probably indicate the race.

Male right tegmen: Spaces mentioned are shown in Fig. 2, A. Space a, length of stridulatory vein between the crest of the vein which it joins at the inner margin and the perpendicular branch near the middle. Space b, from the above mentioned branch to the outer margin of the dorsal

field. Space c, from the stridulatory vein to tip. Measurements of the extremes in millimeters.

No. of Specimens	Locality	space a	space b	space c	a minus b (algebraic)
<i>Tinnulus.</i>					
8	Raleigh, N. C.....	1.3 to 1.5	1.1 to 1.3	3.4 to 3.9	.1 to .3
5	Mt. Pleasant, Iowa.....	1.3 to 1.5	1.2 to 1.4	3.6 to 4.2	0 to .3
7	Reidsville, N. C....	1.2 to 1.4	1.2 to 1.3	3.5 to 4.	0 to .1
<i>Fasciatus.</i>					
8	Iowa, (mostly from Ames).....	1.1 to 1.2	1.0 to 1.3	3.4 to 4.2	-.1 to .2
12	Raleigh, N. C.....	1.3 to 1.4	1.3 to 1.5	3.8 to 4.4	-.2 to 0
3	Burnsville, N. C....	1.0 to 1.3	1.1 to 1.2	3. to 3.5	-.1 to .1
<i>Socius.</i>					
20	Raleigh, N. C.....	.7 to 1.0	.9 to 1.3	2.8 to 4.2	-.4 to -.1
8	Ames, Iowa.....	.7 to 1.0	1.0 to 1.3	3. to 3.8	-.3 to -.1
4	Geneva, N. Y.....	.8 to .9	1.1 to 1.2	3.3 to 4.	-.4 to -.2
5	Chadbourne, N. C.	.8 to 1.0	1.1 to 1.3	3.4 to 3.8	-.4 to -.2
6	Phelps Lake, N. C.	.8 to .9	1.0 to 1.2	3.2 to 3.8	-.4 to -.2
5	Fort Collins, Colo..	.8 to .9	1.2	3.3 to 3.5	-.4 to -.3
7	Albuquerque, N.M.	.9 to 1.1	1.2 to 1.4	3.4 to 4.2	-.4 to -.2

The male tegmina in *tinnulus* are generally large compared to the size of the body although only wingless forms have been found. In *socius* the tegmina are relatively smaller except in the macropterous forms which are sometimes found. In the former race, the tegmina are broader in comparison to the length and the tips are more broadly rounded. The tegmina of *fasciatus* are intermediate in all respects. Winged forms of the last race also occur.

The number of teeth in the stridulatory file varies considerably between the three races. Unfortunately, this cannot be determined without removing one of the tegmina and mounting it on a slide for examination under high magnification. There seems to be some variation within each race, correlated with size of tegmen, but a very small *tinnulus* has more teeth in the file than a very large *socius*. Counts made of various specimens are as follows:

*Tinnulus*—Raleigh, N. C., 228, 239; Sparta, N. C. (smallest, exposed portion 3.4 mm.) 187; Mt. Pleasant, Iowa, 208.

*Fasciatus*—Ames, Iowa, 185, 197; Grandfather Mtn., N. C. (small, 4.6 mm.), 184; Raleigh, N. C. (largest, 6 mm.), 192, 194.

*Socius*—Raleigh, N. C., 105, 129, 145, (smallest) 115; (largest) 140; Ames, Iowa, 113, 117, 126; Geneva, N. Y., 127, 139.

Typical examples of the male claspers of *tinnulus* and *socius* are shown in Fig. 1. The greatest difference is in the ventral lobe which is acutely pointed in the former and rounded in the latter. In *fasciatus* an intermediate condition is found. There is some variation in all three races so that the character is of no greater diagnostic value than the others mentioned.

The table below gives the measurements of the ovipositor (dorsal edge to expanded basal portion), hind femur, and the individual difference of the first minus the second, expressed as minus quantity when the femur is longer than the ovipositor.

No. of Specimens	Locality	Ovipositor	Femur	Ovipositor minus Femur (algebraic)
<i>Tinnulus.</i>				
10	Raleigh, N. C.....	6.2 to 7.8	6.2 to 7.6	-.6 to .6
6	Reidsville, N. C.....	7.0 to 7.8	6.8 to 7.8	-.2 to .7
4	Sparta, N. C.....	6.4 to 8.1	5.4 to 6.8	.9 to 1.7
3	Mt. Pleasant, Iowa.....	7.6 to 8.8	7.3 to 7.7	0 to 1.3
<i>Fasciatus.</i>				
18	Ames, Iowa.....	6.2 to 8.2	6.4 to 7.6	-.6 to 1.4
8	Mt. Pleasant, Iowa.....	7.0 to 9.0	6.6 to 8.2	0 to .8
6	Pointe au Baril, Ont.....	8.0 to 9.1	6.5 to 7.0	1.0 to 2.5
7	Burnsville, N. C.....	6.2 to 7.2	5.7 to 6.6	.2 to .8
26	Raleigh, N. C.....	7.8 to 9.4	7.2 to 8.8	0 to 1.0
<i>Socius.</i>				
29	Ames, Iowa.....	6.4 to 8.6	6.1 to 7.8	-.2 to 1.0
12	Sparta, N. C.....	5.8 to 7.8	6.2 to 7.4	-.4 to .7
21	Raleigh, N. C.....	5.2 to 7.4	5.8 to 7.6	-.7 to 0

The above figures show that there is no correlation between relative length of ovipositor and hind femur, and the races as here defined. Considered geographically, there is some correlation but there is so much variation in one locality that the extremes greatly overlap. Thus by lumping all specimens from Raleigh, N. C. and all from Iowa we would get a range of -.7 to 1.0 for Raleigh and -.6 to 1.4 for Iowa.

In the shape of the tip of the ovipositor there is a slight difference between the races, typical examples of which are shown in Fig. 2. In *tinnulus* and *fasciatus* there is a slight curve to the dorsal outline of the toothed portion, intensified by the fact that there is a considerable increase in the size of the teeth toward the tip. There are usually 8 or 9 teeth visible in profile in *tinnulus*, 9 or 10 in *fasciatus* and 11 to 13

in *socius*. In the last the toothed portion is straight and none of the teeth are very large. These characters are often destroyed by the use of the ovipositor. In many specimens all of the teeth have been worn completely away.

The coloration of all three races varies so much that little dependence can be placed on it as a character. On the average *tinnulus* is more tawny. The head is pale or dark reddish brown but in either case the dark markings, if present at all, are inconspicuous. The face below the median ocellus is only slightly darker than above, if at all. The dorsum of the pronotum is more uniform in color and usually pale, but if dark, the lateral portions are only slightly paler and not conspicuous stripes. In *fasciatus* the usual color is dull brown to nearly black with head markings and lateral stripe on dorsum of pronotum more distinct. The face below the median ocellus is usually considerably darker than the ground color above. In *socius* the color is often almost entirely black but if paler, the markings are quite contrasted. The head stripes may be reduced but usually they are black and the face below the ocellus is often black. The dorsum of the pronotum is generally dark or black with distinct buffy lateral stripes. The dorsum of the exposed abdominal segments in pale specimens has a continuous pale median line bounded by black lines while light specimens of the other two races have the median line black with at most a pale median dot at the caudal border of each segment. This difference applies to the whole abdomen in nymphs.

#### SEASONAL HISTORY.

The seasonal history of *socius* at least in the Piedmont and Coastal Plain of North Carolina differs from that of *tinnulus*. The former begins to mature before the middle of June, and small nymphs of a second generation appear in the latter half of July. In the laboratory nymphs hatched out within two weeks after adults had been placed in a cage. Nymphs may be found until late fall and it is entirely possible that there may be a partial third generation. No adults have been found of *tinnulus* until after the first of August in the past two years. There is no evidence of more than one generation. No observations have been made on the seasonal history of *fasciatus* in this region for it was not discovered here until the

middle of October, 1930. In Iowa the earliest record I have for adults of *socius* is July 5, 1926 and for *fasciatus* August 3 of the same year but no effort was made to determine the earliest appearances. On August 1, 1929 near Pomeroy, Ohio an effort was made to find all three races but *socius* was the only one that could be heard singing.

After *socius* the earliest species to mature in N. C. are *carolinus*, *cubensis*, and *funeralis*. Adults of all three may be found at Raleigh about the first of July. In the southeastern part of North Carolina adults of *carolinus* and *cubensis* were found on June 22. All three species probably have more than one generation during the summer. Near Raleigh adults of *confusus* have been taken as early as July 29 but none of *palustris* earlier than August 12 at which time there were many still immature. The earliest catch of *bruneri* is September 10 but at that time only a few nymphs were present.

#### CROSSING EXPERIMENTS.

At the borders of woods, *tinnulus* and *socius* are sometimes found intermingled over very limited areas. Some experiments were performed to see whether they might mate with each other. Female nymphs of both kinds were collected and kept in cages until maturity. Then they were caged with males as outlined in the table below. After a number of days the females were killed and the seminal receptacles dissected out. When filled with sperms the receptacle is distended and glistening white, otherwise it is collapsed and translucent. All unfilled ones were examined under high magnification to see if any sperms were present.

In the five experiments where the crickets were caged with their own kind seminal receptacles were completely filled. Of the seven experiments where they were caged with another race only, two showed no traces of sperms in the receptacle. In three of the four experiments where the male was caged with females of both kinds, the receptacle of the female of different race showed no trace of sperms and in the fourth, only a few, as if from one mating.

In two larger cages several females of each race were placed with males of the other race. The cages were kept in a screened insectary over winter and the soil watered occasionally. No

offspring were obtained the following summer. No check was run with crickets mated with their own race so the results are entirely negative.

Females	Males	Number of Days Together	Condition of Seminal Receptacle
Tinnulus.....	Tinnulus.....	13	Filled.
Tinnulus.....	Tinnulus.....	8	Filled.
Tinnulus.....	Tinnulus.....	14	Filled.
Tinnulus.....	Tinnulus.....	14	Filled.
Socius.....	Socius.....	24	Filled.
Tinnulus.....	Socius.....	8	Filled.
Tinnulus.....	Socius.....	18	Empty.
Tinnulus.....	Socius.....	18	Filled.
Tinnulus.....	Socius.....	18	Filled.
Tinnulus.....	Socius.....	14	Empty.
Socius.....	Tinnulus.....	37	Filled.
Socius.....	Tinnulus.....	37	Filled.
Socius and Tinnulus.....	Socius.....	6	Socius filled; Tinnulus empty.
Socius and Tinnulus.....	Socius.....	24	Socius filled; Tinnulus empty.
Socius and Tinnulus.....	Tinnulus.....	6	Socius empty; Tinnulus filled.
Socius and Tinnulus.....	Tinnulus.....	24	Socius with few sperms; Tinnulus filled.

During the summer of 1930 similar experiments were run with the addition of *fasciatus* from the mountains. All three races have been caged with their own kind and the two other races. They have been kept in large glass jars with previously heated sand and soil in the bottoms. No offspring appeared during the fall so the jars will be kept at outdoor temperatures until spring.

#### MACROPTEROUS FORMS.

Individuals with long hind wings greatly exceeding the tegmina have been found in the following species: *fasciatus fasciatus*, *fasciatus socius*, *griseus griseus*, *griseus funeralis*, *cubensis*, *carolinus* and *mormonius*. Blatchley's (4) record of a macropterous specimen of the last species from Yuma, California is probably correct but the Texas macropterous specimens mentioned by Hebard (1) may prove to be *bruneri* if the

male genitalia are examined. The macropterous individuals are often attracted to lights at night in large numbers. They probably serve to disseminate the species.

In looking through collections, it was noticed that there are some individuals both male and female, with longer tegmina but without wings. An examination of some of these specimens showed that they do not have the usual vestigial wings but that the wings have been broken off at the base. They have a peculiar development of the metanotum and first abdominal tergite which is found only in macropterous forms. (Fig. 3.)

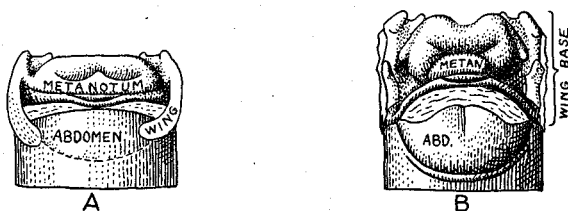


FIG. 3. Metanotum and first abdominal tergite of (A) micropterous form and (B) macropterous form with wings broken off.

This summer I had placed a macropterous *fasciatus* male with a female in a cage. A few days later the male had no wings and there was no trace of them in the cage. I thought that the female had probably chewed them off. The next macropterous individual that I found, which happened to be a male *funeralis*, I placed by itself in a cage. The next day it had no trace of wings and they could not be found in the cage. It must have broken them off in some way and devoured them. It seems reasonable to conclude from these observations that the wings of macropterous forms are not kept throughout their life and that such individuals settle down to an earthly existence, possibly after having migrated to new territory.

#### SONG HABITS.

The males of the genus *Nemobius* are persistent singers both by day and night. Their songs are neither very loud nor of very musical quality. With the exception of two species which sing alike all have characteristic types of song which can be recognized in the field by anyone who has learned their peculiarities. The best way to study the song habits is to



cage a few pairs where they will be away from the confusion of other insect sounds. In this way I have learned the songs of all the eastern species with the exception of *N. griseus griseus* E. M. Walker.

In recording the peculiarities of an insect song for the purpose of identifying it later in the field, the most important feature is the time element, which can be measured with greater accuracy than pitch, tone quality or loudness. The songs of various species of insects present so much diversity in length and frequency of notes, meter and rhythm that only modifications caused by extremes in temperature are apt to confuse them.

The question may arise as to why anyone should want to recognize the song of a *Nemobius* or any other insect. It may be for the same reason that many people learn the songs of birds, simply for the pleasure of knowing what causes the sounds. Another reason is that this knowledge facilitates the study of interesting problems in ecological distribution, by enabling the investigator to know where the various species live without the difficult task of finding them. From the collector's standpoint there is the added value that rare species may be located by tracking down the unusual song.

When singing the male *Nemobius* raises the tegmina to about a forty-five degree angle with the body and spreads them apart a little. They are then vibrated in a transverse direction. As with most crickets the right tegmen in *Nemobius* is always uppermost. The two tegmina are not identical. The right is slightly more infuscated and has a rougher surface. The left only has a narrow bead or raised edge on the inner margin where it comes in contact with the stridulatory vein of the right. Both have a well developed file or series of minute transverse ridges on the under surface of the stridulatory vein.

Several species of *Nemobius* produce more than one type of notes. One type which may be termed the calling song is produced when the male is alone or not sexually excited and is the one most frequently heard. The other which I have termed the mating song is used when the male is actively courting the female. During this song he is generally facing the female and puts on something akin to a dance by jerking the body backward and forward in time with the sounding of the notes. If the female departs during this performance he will

again resume the calling song. Old males often have a weak song as if the file had become worn with use.

The following key applies to the calling songs at temperatures of 70° F. or higher:

- I. Made up of repeated short notes never much over a second in length and never so rapid but that the individual notes can be plainly heard.
  1. Sharp metallic chirps, with constant rhythm, 6 to 9 per second.  
*N. fasciatus tinnulus* n. subspecies.
  2. Notes of rougher quality, observable variations in rhythm, 3 to 7 per second.  
*N. fasciatus socius* Scudder.
  3. Longer notes, one-half to one second in length.
    - a. Non-rhythmical, occasional notes 2 to 3 seconds long.  
*N. sparsalsus* Fulton.
    - b. Rhythmical but not very constant, notes of more uniform length.  
*N. ambitiosus* Scudder.
    - c. Each note begins as a low buzz with two undulations, audible only a few feet away, then increases in volume to the end, intervals between notes very brief; rhythmical, but not constant.  
*N. confusus* Blatchley.
- II. Sound continuous for several seconds at a time.
  1. Notes and rests of about equal duration, usually 5 to 15 seconds.  
*N. cubensis* Saussure.  
*N. palustris* Blatchley.  
*N. palustris aurantius* R. and H.
  2. Song interrupted at irregular intervals, usually 5 to 10 seconds, by breaks of less than a second duration.  
*N. griseus funeralis* Hart.
- III. Song usually continued for indefinite period.
  1. Of shrill tinkling quality without modulations.
    - a. With evident tremolo; at lower temperature song becomes a rapid series of sharp chirps, but at summer temperatures these are at a rate estimated at 12 to 15 per second.  
*N. fasciatus fasciatus* (De Geer).
    - b. A thin high pitched sound with a tremolo so rapid that it can scarcely be detected at summer temperature.  
*N. bruneri* Hebard.
  2. With modulations.
    - a. A weak tinkling sound with regular rhythmical undulations 5 to 7 per second.  
*N. maculatus* Blatchley.
    - b. With a droning quality, variable in volume, part of the time louder and with rapid undulations, at other times weaker, lower pitched, without undulations.  
*N. carolinus* Scudder.

The song of *N. fasciatus fasciatus* is one of the loudest in the genus. The calling song is a continuous high pitched tinkling metallic sound. One can imagine that it might be produced by a small bell attached to the end of a length of spring steel that vibrates with about 10 to 15 swings per second. The sound is actually a series of short distinct chirps but at 80° F. or above this quality can scarcely be recognized. On cool days the chirps are plainly apparent and can be estimated

by tapping a paper with a pencil point at as near the same rate as possible for a period of a few seconds moving the pencil along so that the dots can be counted and the number per second computed. Estimates were thus made of Iowa specimens at 50° F., between 5 and 6 chirps per second, at 61° F., about 8 or 9. Specimens from North Carolina mountains chirped close to 7 times per second at 60° F., at least 8 per second at 66° F. and over 9 per second at 68° F. Specimens from Raleigh, N. C. appear to have a slightly higher rate than the mountain specimens.

In watching a male singing it appears as if each chirp were produced by a single movement of the tegmina. The movement is too rapid to be visible. The tegmina seem to be held motionless at the outer limit of the swing indicating that they must be held stationary in this position for a brief period between each stroke.

There are two variations of the mating song. When a male is facing a female it sometimes sings as described above in short phrases about one and one-half to three seconds duration, with rests of about half a second. At other times the male chirps louder and at much slower rate, about 5 to 6 per second, without regular rhythm and accompanies some of the notes by jerks of the body backward and forward.

The song of *N. fasciatus* could be confused only with *N. bruneri* and *Anaxipha exigua*. The former is generally weaker and with a much more rapid tremolo, which is clearly evident only at rather low temperatures. The latter is similar in movement but much more musical and bell-like in quality than any *Nemobius*.

The song of *N. fasciatus tinullus* differs from typical *fasciatus* only in the frequency of chirps. Instead of appearing like a continuous sound the separate chirps are evident at all temperatures. By estimating the rate as previously described, when too fast to count, specimens at Mt. Pleasant, Iowa were found to chirp at the following rates per second: 7 and 8 at 80° F., 5 and 5.7 at 66°, 4.4 at 65°, 4.3 and 5 at 61°, and 3.8 at 59°. Specimens from Raleigh, North Carolina gave the following rates: 7 at 82° F., 8 at 79°, 7 at 75°, 6 at 69°, 5.5 at 67°, 5 at 66°, 4 at 60°; from N. C. mountains: 7 to 8 at 80°, 5 at 66°. In the mating song the notes sounded at about half the above rate, less rhythmically but sharper and more emphatically.

The song of *N. fasciatus socius* differs from the other two races in tone quality and in the method of production. In place of brief sharp chirps, the notes are longer and appear to be a combination of a low buzzing sound and a weak shrill sound. When the movement of the tegmina is observed at ordinary summer temperatures it appears to be a single slow inward movement for each note. When observed at lower temperatures it becomes apparent that each movement is accompanied by a rapid vibration of the tegmina, with a short amplitude. With the temperature near 60° F., there is a perceptible quaver in the notes, which are longer and slower than at higher temperatures. In cool weather the notes seem to be clearer and the shrill quality is more evident. It seems probable that vibrations caused by the teeth in the file produce the shrill element in the sound and that at high temperatures this passes beyond the range of human hearing leaving the buzzing sound caused by the tegminal vibrations as the most audible element of the sound.

Males of *socius* show considerable variation as to the frequency of notes and the same individual may vary the rate from time to time. Rates per second observed at different localities are as follows: Ames, Iowa, 2.5 to 3 at 77° F., 4 at 80°; Raleigh, N. C., 3 to 5 at 86°, 4 to 6 at 88°, Ripley, W. Va., 3 at temperature probably over 90°; Geneva, N. Y., 3 to 5, crickets in the sunlight and temperature well above 80° in the shade. At 66° a Raleigh male sang only 7 notes in 5 seconds.

The presence of a female influences the rate of notes even when the male is not singing his characteristic mating song. Three Raleigh males caged alone had somewhat different usual rates. At 86° F. they ran about 3, 4 and 5 notes per second respectively. When females were placed in the cages it was noticeable that after a few minutes all three were singing faster. The third increased to about 7 per second, the second to nearly 8 and the first only to 4 or 5. The mating song is similar to the above except that there is a brief pause after a series of 5 to 9 notes and the last note of each series is slightly prolonged with a decrescendo movement. This note is accompanied by a backward jerk of the body.

In a cage containing a large number of *N. socius* a slightly different note is frequently heard, especially among new arrivals from the field. As they meet when crawling about the cage

they will stop and sound one or two loud notes of about a second duration. It seems to result more often from the meeting of two males.

The song of *N. sparsalsus* has almost no rhythm. Notes of a half to one second duration may be repeated for a time with some regularity at a rate of about 3 in 5 seconds but, at intervals, longer and louder notes of 2 or 3 seconds duration are thrown in. The song is not loud considering the size of the cricket and the quality is like a shrill sound and buzz combined. Individual notes, especially the longer ones, remind one of *N. cubensis* in that they increase in volume and pitch. The mating song is brief chirps at the rate of 3 or 4 per second. These generally come in series of 2, 3, or 4 with slightly longer pauses between. Longer notes are frequently mixed in with the short chirps.

The song of *N. maculatus* is comparatively weak. It is a continuous buzzing trill with a constant rhythmical undulation in volume having a frequency about equal to the chirping rate of *tinnulus*. On cool days a very rapid tremolo is apparently corresponding in time to the strokes of the tegmina. The undulations or beats each cover a number of strokes. An Iowa specimen at 61° F. had thirty-six beats in ten seconds; at 70° about six per second. No distinct mating song has been observed.

The song of *N. griseus funeralis* is the most monotonous of any of the genus. It is a low weak buzz with a faint shrill overtone. It can be identified by the frequent breaks or pauses of a small fraction of a second that come at intervals of 5 to 10 seconds with little regularity. At times it may continue for 15 to 30 seconds without a break. As the sound is resumed after each break it starts with reduced volume and pitch in a crescendo movement covering a third to half a second after which a uniform tone is maintained. The mating song is very brief sharp chirps of possibly a fifth of second duration, produced without regular rhythm at an average rate of 14 in 10 seconds at 78° F. During this song the male jerks its body forward and backward.

The song of *N. bruneri* somewhat resembles that of *N. maculatus* in its extremely rapid tremolo but lacks the beats. It is as if the song of typical *fasciatus* were speeded up to such a high frequency that the tegminal strokes are barely perceptible.

It is a continuous trill like that of *Oecanthus nigricornis* but weaker and higher pitched. The pitch must be close to the upper limit audible to the human ear. Only one type of song is produced.

The writer heard *N. mormonius* singing along the edge of a small stream on the Bright Angel trail in the Grand Canyon, and described it in his notes as a continuous trill resembling the song of *Oecanthus nigricornis*. At that time he did not know the songs of the other species and could not make critical comparisons.

The songs of *N. cubensis* and *N. palustris* are very much alike. Both have notes of several seconds duration with approximately equal intervals of rest. The pitch is very high and the quality may be described as a thin whistle, meaning that the sound is not a pure musical tone. The song of *palustris* seems to be a little clearer than that of *cubensis*. Each note very gradually increases in volume until it ends abruptly. At Geneva, N. Y. on a hot day the notes of *palustris* were observed to be 5 to 10 seconds in length and the rests 5 to 10 seconds. At Raleigh, N. C. no difference in the song could be noticed. The species here has paler colored legs, head, and pronotum and is close to if not identical with *N. palustris aurantius* Rehn and Hebard.

The song of *N. cubensis* observed at Raleigh, N. C. had notes and rests usually from 8 to 15 seconds in length but some notes were as short as 2 seconds and others as long as 30 seconds. As a rule each male, when singing regularly has a fairly constant length of note. One at Carolina Beach had notes regularly 10 seconds long. No special mating song has been observed for either of the above species.

The song of *N. ambitiosus* was determined from living specimens collected in Dixie Co. and Alachua Co., Florida, by T. H. Hubbel. It has a rather low pitched song compared to some of the other species and the quality is rather musical and pleasant. When the crickets arrived, April 2, it is probable that none had been in the adult stage very long judging by the fact that many were still nymphs. For a while they all sang at a rather slow rate of about 6 notes per 10 seconds. Each note has a slight crescendo movement and ends abruptly. There is also a noticeable tremolo effect. A week after they arrived one was observed to have speeded up the song and was found to be

singing to a female. The rate was very changeable from 10 to 20 notes per 10 seconds at a temperature of 77° F. Sometimes the notes were very brief and weak, about one per second, at other times they were drawn out to nearly two seconds each with very brief pauses between so that the song was almost continuous. On another day, at 77° F., one was singing 15 to 16 notes in 10 seconds and another 9 to 12. At 61° F. one sang 5 notes in 10 seconds and another at 58° 6 notes in 10 seconds. At these temperatures the notes were very weak and distinctly tremolo. Only one male from Dixie Co. lived and it never sang at as fast a rate as the others. At 87° it had 8 notes per 10 seconds and at 80° only 7 notes.

The song of *N. carolinus* reminds one of the distant droning of some species of cicadas. The tone quality is like that of *N. griseus funeralis* and *N. confusus*, a low buzz with a thin shrill overtone. At times it has a rhythmical beat like the song of *maculatus* but a little more rapid. It sounds as if the singer were quivering with nervous energy. If one listens to a single song closely, the beat will be found to die out and the song will run along at reduced volume, sometimes seeming about to die out. Then it will gain in force again and tremble as before. Rarely males will be heard that seldom sing without beats but usually there is a regular repetition of the two phases of the song, sometimes one second for each period and sometimes longer. Sometimes when starting to sing this species will sound a few notes which increase in volume and then die out. No special mating song has been observed, although the song as described above has been heard many times both in Iowa and North Carolina and the two sexes have been caged together.

The most unique song in the genus is that of *N. confusus*. It has a constant meter of two brief weak notes and a longer louder one. Some individuals have been heard with three of the weak notes. The weak notes can be heard only a few feet away so that at a little distance the song seems to be a repetition of a single note, the loud one. The three notes are really not distinct but are a single note with two short rises in volume and then a greater increase till the end of the note after which there is a brief pause before the next is started. It is a droning buzzing trill like the song of *carolinus*. The rate of song varies somewhat. One in Iowa, at 70° F., was observed to

start at a rate of one complete note per second and at times increased to two per second. At Raleigh, N. C. one sang with 9 to 10 notes in 10 seconds at  $75^{\circ}$  and 10 to 12 notes at  $80^{\circ}$ . No special mating song has been observed, although males have been caged with females.

#### MATING HABITS.

Preliminary to mating the male faces the female and sings. In many species it has a special mating song for such occasions. At the same time it performs something like a dance by jerking

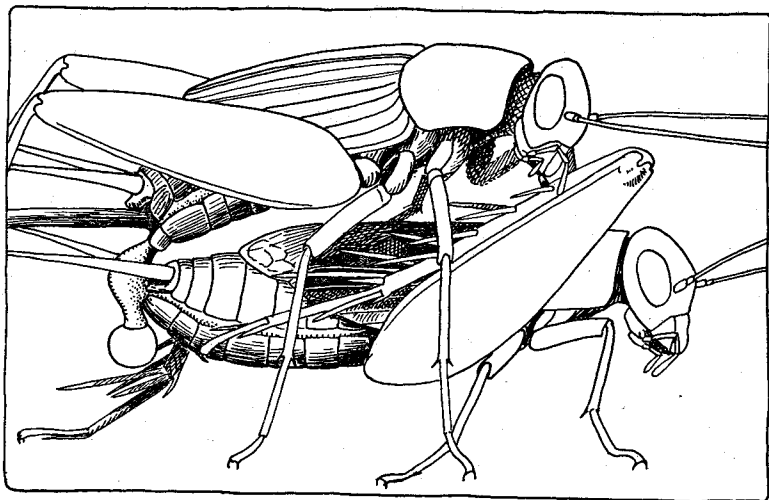


FIG. 4. Female (upper) feeding on secretion of specialized spine on male hind tibia during mating.

the body backward and forward without changing the position of the feet. The genitalia are protruded as shown in Fig. 5, D, but the spermatophore is not formed until a short time before mating takes place. It appears in a partially formed condition as a slightly elongated drop of milky white viscous liquid which is pushed out of the genital opening. It soon becomes spherical and remains suspended from the concavity formed by the extremity of the fleshy ventral portion of the genitalia.

Shortly after this the male turns around, drops the tegmina and backs toward the female. At the same time it raises one hind femur with the tibia closed upon it and brings it forward so far that it is inverted. The female crawls over the male



and begins to bite at the specialized proximal internal spine on the hind tibia. This brings the female far enough forward that the male can push the claspers into the opening between the ovipositor and subgenital plate (Fig. 4). They remain in this position usually from 15 to 25 minutes, the female all the time biting at the spine, sometimes running the mouth along the tibia but always coming back to the proximal internal spine. When she leaves the male, the spermatophore remains attached to her and later she removes it and eats it.

The specialized structure of the proximal internal spine of the male hind tibia, has been published on by Pantel (5) but he did not know its function. It stands perpendicular to the tibia and is much thicker and shorter than the same spine in the female. The base is dark while the apical portion is white and thin walled. In some specimens it has a dark slightly hooked tip, but in the majority, the apical portion has been removed probably by a female cricket (Fig. 5, A, B). Parts of some of the neighboring spines are sometimes missing also. Speaking of the internal structure of the modified spine Pantel says that the "hypoderm forms a massive tissue, a sort of muff of thick wall with cavity very much reduced." The constitution of the contents of the cavity he says is "undecipherable in my preparation." What he found in the cavity was probably a viscous secretion. If a male cricket is etherized and one of the mutilated modified spines is touched with the point of a pin, a viscous liquid usually adheres to the point and will pull out into a thin thread. After repeating this a few times, the supply seems to become exhausted.

There can be little doubt but that the function of the modified spine is that of an alluring gland similar to the metanotal gland in *Oecanthus*. Females have sometimes been observed to bite at the spine when no mating is taking place, but the male does not permit the female to continue this unless a spermatophore is being formed.

The fully formed spermatophore (Fig. 5, G) has a spherical body about one and a third millimeters in diameter and with a flattened curved tube about two and a half millimeters long. Near the tip there is an expanded portion, molded in the groove between the claspers. The extreme tip curves slightly in the opposite direction. The walls and tube are composed of a clear hard substance. A capillary opening extends through the tube to the tip.

The formation of the spermatophore is a complicated process which is difficult to understand. When it first appears on the male it is sometimes possible to etherize the cricket without dislodging the spermatophore. If it is examined in place, we find the forming tube as a narrow ribbon of viscous liquid extending along the groove between the inflated lips on

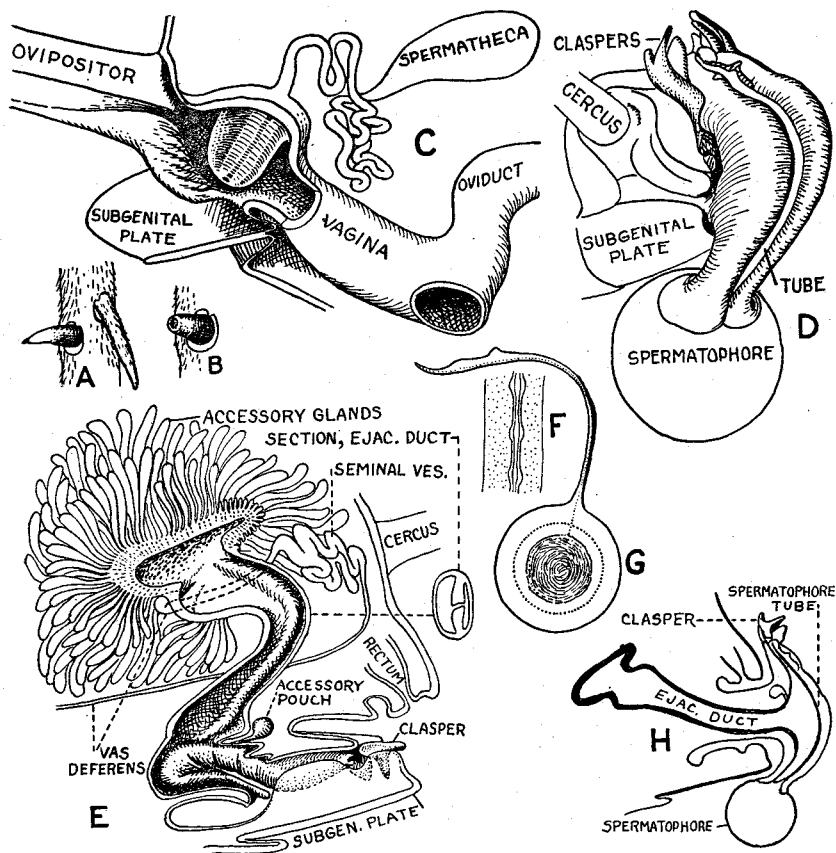


FIG. 5. A, Specialized spine of male hind tibia (left) and unspecialized spine (right). B, Specialized spine as usually found with tip removed. C, Female genital organs, showing knob-like invagination of dorsal wall of vagina. D, Male external genitalia during formation of spermatophore, caudo-lateral view. E, Male genital organs in resting position, as if cut through the median line. F, Portion of spermatophore tube in semi-liquid condition showing included capillary tube of different substance. G, Spermatophore, showing central sperm mass (shaded), surrounding liquid and hardened outer wall. H, Diagram of approximate position of male organs during spermatophore formation.

the caudal aspect of the genitalia, from the body of the spermatophore to the distal end of the rigid groove between the claspers (Fig. 5, D, H). If this strip is examined under a microscope while still in a semiliquid condition there appears to be within it a thin walled capillary tube of different substance, which is easily broken by handling as if it were also in a semiliquid condition (Fig. 5, F). This tube extends into the body of the spermatophore.

If the body of the spermatophore is compressed under a cover glass while still a milky liquid, the sperm mass is found to be already present. The surrounding substance becomes clear in a few minutes and under the microscope becomes granular in appearance. Thin streams of liquid carrying granules are seen moving away from the edge. The substance appears to be a colloidal solution in which a clotting action is taking place, with a squeezing out of a liquid phase toward the center.

The normal development of the spermatophore can be followed best by suspending it under a cover glass without crushing it. As soon as it clears the sperm mass can be seen surrounded by a thin membrane. For several minutes the sperms can be seen swimming around in the mass all going in the same direction. The outer surface of the spermatophore, which is like a thin membrane at first gradually becomes thicker and harder. The sperm mass is surrounded by a layer of liquid. By contraction of the outer wall a pressure is developed which breaks the thin side where it is flattened by the cover glass and the sperms pour out. The thin membrane surrounding them collapses and empties. The central cavity is then filled with a liquid in which some further clotting takes place, forming suspended particles and fern-shaped concretions.

When the spermatophore has been allowed to harden normally on the male the pressure developed by hardening and drying will force the sperms through the capillary tube. If this inner tube becomes dislocated, as usually happens when the spermatophore is removed before completely formed, the contraction of the outer wall results in a gaping split, releasing the contents. If immersed in water, the outer wall takes up water, expands, and the split closes again.

While the spermatophore remains attached to the female, the sperms pass into the seminal receptacle or spermatheca. The tip of the spermatophore tube must enter a small hole in a

knob-like invagination of the dorsal wall of the vagina, situated above the base of the subgenital plate between a pair of fleshy pads attached to the ventral rods of the ovipositor (Fig. 5, C). This knob has a thin but somewhat rigid wall and is about the right size to be grasped by the male claspers, which would bring the tip of the spermatophore tube close to the hole in the apex of the knob. A tube passes through the knob, and with many convolutions leads to the spermatheca.

The complicated male organs are shown as if cut directly through the median line in Fig. 5, E. There are a large number of accessory glands which undoubtedly secrete the substance of the spermatophore wall. A dorsal group of these are very small, short tubes. The large common duct has lateral invaginations which meet and divide the space into two passage ways. Near the base of the claspers there is a pair of thin walled pouches of unknown function. The ventral thin walled portion of the external genitalia is much inflated in use and is folded up when withdrawn into the body.

#### ECOLOGY.

As previously pointed out the recognition of the characteristic type of song for each species of *Nemobius* has greatly simplified the study of their distribution. I would frequently check up on my memory by capturing a specimen if there was any doubt about the identity of the song. Once the songs have been thoroughly learned, it is only necessary to listen carefully to determine what species are present and their approximate abundance in any locality.

There is a surprising exactness about their distribution. Once the rules have been learned one can look at a varied landscape and enumerate what species of *Nemobius* will be found in the various parts of it. Some species range widely and others are narrowly restricted in their environment. Unlike many insects these crickets are not bound by specific plant food relations, but their occurrence is rather closely related to the plant community. Without experimental verification the following factors seem to influence the choice of habitat: moisture, ground cover, food supply near the ground level, temperature or sunlight and shade relations. If a combination of factors favorable to any one species is generally found in a plant community, the local distribution of the cricket will follow that community.

The species which are commonly associated with certain plant communities in North Carolina are given below, taking up first the successional stages originating from an abandoned field, as outlined by Wells (6).

1. Crab grass (*Syntherisma sanguinale*) *Nemobius fasciatus socius*. This passes into an association of tall weeds with consequent elimination of grass, becoming an unfavorable habitat for *socius* when complete.

2. Broom-sedge (*Andropogon virginicus*) *Nemobius griseus funeralis*. This stage follows the tall weeds. Some *socius* may be found in it, but *funeralis* is often the only species especially on sterile soils where the clumps of *Andropogon* are well separated.

3. Pine woodland, (*Pinus taeda*, *P. echinata*) *Nemobius fasciatus tinnulus*. In the intermediate stage, before the pines have crowded out the *Andropogon*, *N. funeralis* may still be found between the pines. As soon as the pines attain size enough to cast considerable shade, *tinnulus* comes in.

4. Oak woodland (*Quercus marylandica*, *Q. stellata*) *Nemobius fasciatus tinnulus* and *N. confusus*. The latter, which is never abundant, can tolerate deeper shade than the former.

5. Mesic forest (*Quercus*, *Carya*, *Acer*, *Fagus*) *Nemobius maculatus*, *N. confusus*, *N. Carolinus*. The last may be found in locally moist places in any of the successional stages leading up to the climax, but becomes more numerous and widely distributed in the climax forest.

6. Salt marsh (*Juncus roemerianus*, *Spartina stricta*) *Nemobius sparsalsus* and *N. cubensis*.

7. Fresh water marsh (*Typha latifolia*, *Scirpus* spp.) *Nemobius cubensis*, *N. carolinus*, *N. fasciatus socius*. The last is not found under tall marsh plants.

8. Swamp forest (*Nyssa aquatica*, *Taxodium distichum*) *Nemobius carolinus*.

In the northern states *N. fasciatus fasciatus* is the most common species. It is found in all grass land except very wet marshy places where *socius* is found. This relation has been observed in New York and W. Virginia, Iowa, Colo., and the mountain sections of Virginia, and North Carolina. In Iowa where its distribution was studied more thoroughly, it attains greatest abundance in the blue grass (*Poa pratensis*) pastures, which are commonly found in small valleys. On the borders of marshes and near small sluggish streams it sometimes occurs with *socius* but does not extend into the wet undrained ground.

Near Raleigh, N. C. it was found during October and November 1930 in a few small areas on fertile flood plains along the Neuse River. These places were partially shaded and had a greater development of mesic grasses than is com-

monly found in the Piedmont. The dominant grass species were *Agrostis perennans*, *Muhlenbergia sylvatica* and *Poa pratensis*, all northern grasses approaching their southern limits here. In one large pasture on the river flood plain, *fasciatus* was found around the borders where there were trees and a few could be found near single trees in the open, but the rest of the area was inhabited by *socius*. In another place it was abundant among the above mentioned grasses on a high bank over the stream, where there were scattered trees and *Crataegus* bushes. In this small narrow strip there were almost no *socius* present but a hundred feet back from the stream in treeless portions of the field *socius* was common and *fasciatus* rare.

The most important environmental factors for *fasciatus* seems to be a good growth of grass without excessive moisture. It is tolerant to a degree of shade that does not interfere with the growth of grass and in the south may even demand shade.

*N. socius*, as recognized in this paper, is associated in the northern states with poorly drained grass land such as low prairies, pond and marsh borders, and low moist meadows and pastures. Restricted to such situations it has been observed in New York, Ohio, West Virginia, Iowa, Colorado, New Mexico, and in the mountains of Virginia and North Carolina. It was the only race found in the moist meadow along the stream at Pingree Park, Colo. at an altitude of over 9000 feet. In Iowa it could be found along small sluggish streams, often with *fasciatus*, and a few scattered individuals were observed in well watered lawns where *fasciatus* was dominant. It was found most abundant in a low undrained prairie bordering a marsh but not in the central area under the taller marsh plants.

In the Piedmont and Coastal Plain of North Carolina *socius* is more abundant and more widely distributed. It occurs in all short grasses and clovers such as those found in lawns, pastures and abandoned fields. In very sterile soils where grass grows sparingly, it is rarely found and *funeralis* takes its place. For some reason it can tolerate a much dryer habitat in the south, but as in the north it attains greatest abundance in low moist meadows and borders of marshes.

In the Piedmont and Coastal Plain of North Carolina *N. fasciatus tinnulus* is found in nearly all oak and pine woods except on the xeric sand ridges where no species of *Nemobius* has been found. It becomes most abundant in the more open

woods where some grass is growing. In the mountains the mesic forest type prevalent there is not favorable for it, and it becomes largely a forest border species. At Mt. Pleasant in southeastern Iowa it occurred where the woods were open enough to permit grass to grow. To sum up, the favorable factors for this race seem to be moderate moisture, a ground cover of dead leaves, the presence of grass or other low food plants, and possibly shade.

*N. sparsalsus* has only been found in salt marshes. When first found it was abundant out in the *Spartina* zone at the edge of the sound at low tide. At another time, during a high tide when the marsh was almost entirely flooded it was even more abundant among *Juncus* at the water's edge, apparently having been driven back by the water. No explanation can be offered for the restricted habitat of the species.

*N. maculatus* is strictly a forest species. Near Raleigh, N. C. it has been found only in the mesic type of forest which occurs there mostly along streams. It lives among the dead leaf ground cover on flood plains and hills but not in sloughs. In Iowa it seems to be somewhat more abundant along the edge of woods where there is grass as well as leaves on the ground, but occurs also in dense forest both on hills and flood plains. The species seems to be tolerant to a moderate range of moisture conditions but demands dead leaf cover or shade or both.

Specimens of *N. griseus griseus* were collected for the writer by E. M. Walker who writes that the species is extremely local in Ontario and that "it seems to prefer dry sandy pastures, covered with short grass, sedges (2 or 3 inches high), *Antennaria*, and the low-growing mosses of such situations." In this choice of a xeric habitat it is not unlike its southern relative.

*N. griseus funeralis* can tolerate more xeric conditions than any other species found in North Carolina. It has been found most commonly associated with broom-sedge (*Andropogon*) but not in very dense stands for this grass apparently serves as shelter rather than as a food plant. Where small grasses such as *Aristida oligantha* or small clovers like *Lespedeza* grow between clumps of *Andropogon*, it is found in greatest numbers but never becomes very abundant. A few have been found in crab grass (*Syntherisma*). It is very secretive in habits and seldom comes out from under the plants and for this reason has been a rare species in collections.

*N. bruneri* is a stream border species both in North Carolina and in Iowa. It is not found on small deeply shaded streams for it seems to demand at least a small amount of sunlight. It is most readily found on gravel bars, in company with *Paratettix* and *Gelastocoridae*. When disturbed it quickly jumps from the shelter of one rock to another. It has also been found on sandy banks where some grass or accumulated dead leaves furnish a shelter.

The near relative of the last species, *N. mormonius* is also found along streams, but in the arid west where it occurs such places are about the only situations where a species of *Nemobius* could be expected to exist.

*N. cubensis* is largely a marsh species, living both in fresh water marshes and in the *Juncus* zone of salt marshes. It is not confined to excessively wet places for it can also be found along stream banks and in other moist situations where it is protected by a thick covering of honeysuckle, high grass, or bushes. It has never been found by the writer on *Sphagnum* in company with the closely related *palustris*. Where patches of the moss grow along side of tall grasses *palustris* will be found in the former and *cubensis* in the latter.

*N. palustris* seems to be strictly an associate of *Sphagnum* and is found no where else. It can live in a jar and develop from the nymph to adult with no other food than *Sphagnum*. The eggs are deposited in the moss when they have a choice between that and soil.

The writer has not observed *N. ambiguus* in the field for it has not been found in North Carolina. Two lots of living specimens sent by T. H. Hubbel were accompanied by notes on their habitats. The habitat of the first lot from Dixie, Co. Fla., was described as "open sunny grove of *Quercus catesbaei* on whitish sandy soil, little undergrowth, much bare sand exposed, xerophytic habitat." The second habitat at the University of Florida Biological Station, Newman's Lake, Alachua Co., Fla., was described as "magnolia-oak-hickory-sweet gum hammock on sandy ridge, mesophytic habitat, forest floor covered with dead leaves and herbage, several inches of leaf mold over sandy loam." Hubbel also called attention to the fact that nymphs from the first habitat were grayish in color while those from the second were darker and more brownish in color. The most striking difference was in the color of the abdomen. Those from the sand ridge had a grayish white



ground color with several rows of paired, black spots in the median portion except the fourth segment which was entirely black. In the other lot the median area was sepia with only one paired row of black spots at the margins of the area. The remainder of dorsal area was of paler ground color with three paired rows of spots. The fourth segment was only slightly darker than the others. No striking difference was discovered between the adults of the two lots.

The nymphs of a second generation reared in the laboratory at Raleigh under identical conditions showed the same striking difference in color. This would indicate that there is some inherent difference between the crickets from the xeric habitat and those from the mesic environment. Further study might show that we have in this species another example of physiological differentiation taking place.

The most widely distributed species from the standpoint of plant associates is *N. carolinus*. The most important factor controlling its distribution seems to be moisture. Locally moist spots in an otherwise xeric habitat may have a colony of these crickets. It is an inhabitant of gullies, and seepage spots, in any plant community. With ordinary soil moisture it lives only under the protection of a dense cover of honeysuckle, thick bushes or matted grass. It is found most abundant in marshes and wooded ravines and sloughs. In swamp forest it is the only species found and in *Sphagnum* it is the only associate of *palustris*. In woods in southeastern Iowa it was abundant on level spots near the streams but on the slopes was replaced by *confusus*. Along open stream borders it is associated with *bruneri*.

*N. confusus* is another species confined to woods but it prefers the well drained slopes and uplands. It is never very abundant but is most often found in deciduous forest where it lives in the dead leaf ground cover. A few have been found in pine woodland, hiding under the bed of needles. Near Raleigh a large number were found in a patch of partridge berry (*Mitchella repens*) growing in an oak woods. Unlike *tinnulus* it is not partial to the more open grassy places and does not demand the more mesic forest type as in the case of *maculatus*. In southeastern Iowa it was found in oak forest, climax forest and sparingly near forest borders and under shrubby growths, always among dead leaves.

## SUMMARY.

The discovery of specific characters in the male genitalia makes it possible to identify the males of the genus as readily as the females. Evidence furnished by such characters changes the status of *N. mormonius* Scudder from that of a subspecies of *N. cubensis* Saussure to a distinct species with closest relationship to *N. bruneri* Hebard.

*N. fasciatus tinnulus* new subspecies, is described and the conception of the status of *N. fasciatus fasciatus* (De Geer) and *N. fasciatus socius* Scudder is changed from that of a geographic one based on the relative length of the ovipositor, to a new conception of the above three subspecies based on certain characters in both sexes and which is correlated with physiological differences manifested in ecological distribution, seasonal history and song habits.

The song habits of the most of the species and subspecies found in the United States are described. Many species have a special song heard only when they are mating.

It has been found that the macropterous forms may remove their wings voluntarily.

The specialized proximal internal spine of the male hind tibia functions as an alluring gland. The formation of the spermatophore and the genital anatomy of both sexes is described.

In their ecological distribution the species of *Nemobius* are not bound by specific plant food relations, but are influenced by other factors which may confine them to certain plant communities. The observed environmental relations of all the species studied are described.

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