Stridulatory Mechanisms and Sound Production in *Conotrachelus* (Coleoptera: Curculionidae)[1]

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ABSTRACT

The elytral stridulitra and the plectra on the sixth abdominal tergite are described and illustrated for both sexes of *Conotrachelus naso* LeConte, *C. posticatus* Boheman, and *C. carinifer* Casey, as is the stridulitrum of the male *C. nenuphar* (Herbst); the female of *C. nenuphar* has no plectrum. The stridulations are described and illustrated by audiospectrographs for the first 3 species. Demonstrable differences exist between the stridulations of these species, and between the sexes of each. Individual weevils are capable of several speeds and frequencies of stridulations. Sound production can be induced by agitation of the weevils, or by rough handling.

Earlier workers have done much to bring attention to the types of sound-producing structures and the importance of sound production and its reception in insects of various orders (for a review see Frings and Frings 1960). Relatively little has been written about sound production in Coleoptera in general, and even less about weevils in particular.

During a study on the biology of 3 species of *Conotrachelus* that infest acorns (Gibson 1964), stridulation by the insects was noticed when they were handled. This stridulatory behavior was investigated, to determine how and when the sounds were produced and to learn something of the character of the sounds.

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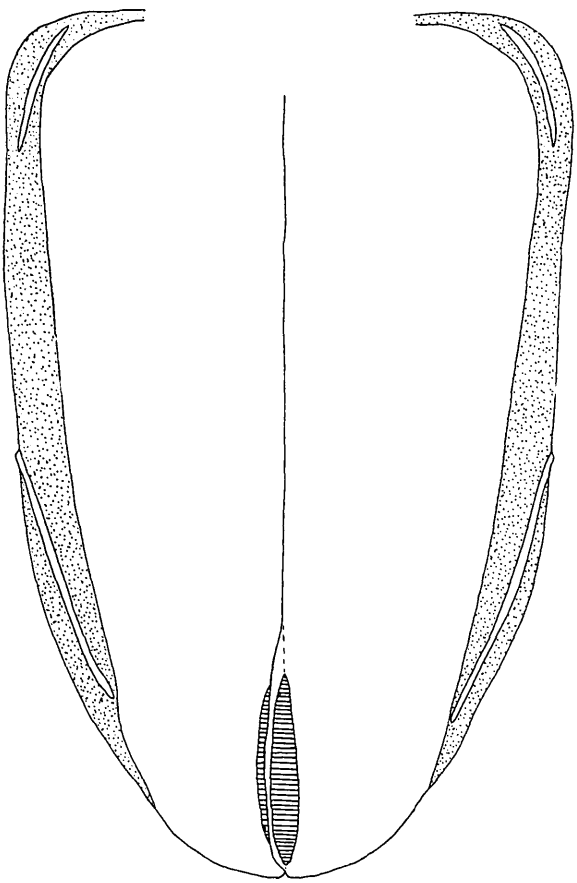

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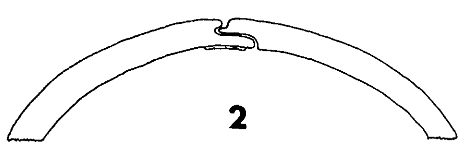

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FIG. 1.—Elytra of *Conotrachelus naso*, ventral view, showing stridulitra.
FIG. 2.—Cross-section of elytra of *C. naso* in the area of the stridulitrum.

Riley (1871) was the first and only one to date to mention that any member of the genus *Conotrachelus* produces sounds. Regarding *C. nenuphar* (Herbst), the plum curculio, he wrote, "The beetles often make a creaking noise by rubbing the tip of the abdomen up and down against the wing covers (elytra)." He stated further that "a horny, slightly raised plate about one-third as long as the wing cover, and transversely and obliquely ribbed by numerous parallel ridges, can be found on the wing covers of the plum curculio," and that "the dorsal apex of the abdomen or pygidium forms a yellowish, roughened plate, with the sides horny and emarginate so that when the abdomen plays up and down, these horny edges grate or scrape at right angles against the rasp." He noticed the sounds in the evening, when the weevils were most active, and stated that the sounds are used as distress, fear, and pleasure calls.

PROCEDURES

Recordings and audiospectrographs were made for 1 ♀ each of the 3 acorn-infesting species, *Conotrachelus naso* LeConte, *C. posticatus* Boheman, and *C. carinifer* Casey. Comparisons of these audiospectrographs showed that there were demonstrable differences between the sounds produced by these 3 weevils. No live specimens of *C. nenuphar* were available at the time.

The next step was to determine the parts of the insect that produced the sounds. While it was watched under a microscope, a live weevil held between the thumb and forefinger was agitated by gentle squeezing and rolling; this elicited stridulation. The only parts of the insect that could be seen moving during this procedure were the last 3 abdominal segments. The sound produced, however, was of such low intensity that it could only be heard when the weevil was held next to the ear, and thus simultaneous watching and listening were impossible in the early experiments. This difficulty was overcome by placing the microphone of a Magnamite recorder next to the weevil while it was under the microscope, and listening to it through the earphones of the recorder.

Studies soon showed that both the abdomen and the elytra were necessary for sound production. If the left elytron was removed, no sound was produced; but if the right elytron was removed, the sound was produced normally. Also, stridulation was affected when the left hindwing was removed. Subsequently, it was found that no sound could be produced if only the tip of the left elytron was removed.

Examination of the left elytra of the several species under the highest magnification of a dissecting microscope, with proper illumination, revealed the presence of the stridulitrum (Ashlock and Lattin 1963) near the tip of each. Discovery of the abdominal plectra soon followed.

Table 1.—Average dimensions (mm) of stridulitra of *Conotrachelus* spp., and approximate number of teeth on each.

		Stridulitra		
Species	Sex	Length	Width	No. teeth
naso	♂	1.10	0.17	138
naso	♀	1.00	.15	130
posticatus	♂	0.95	.15	100
posticatus	♀	.95	.15	120
carinifer	♂	1.15	.19	150
carinifer	♀	1.10	.11	120
nenuphar	♂	.90	.11	100
nenuphar	♀	.80	.11	80[a]

[a] About half of the female *nenuphar* inspected lacked teeth on the stridulitral ridge.

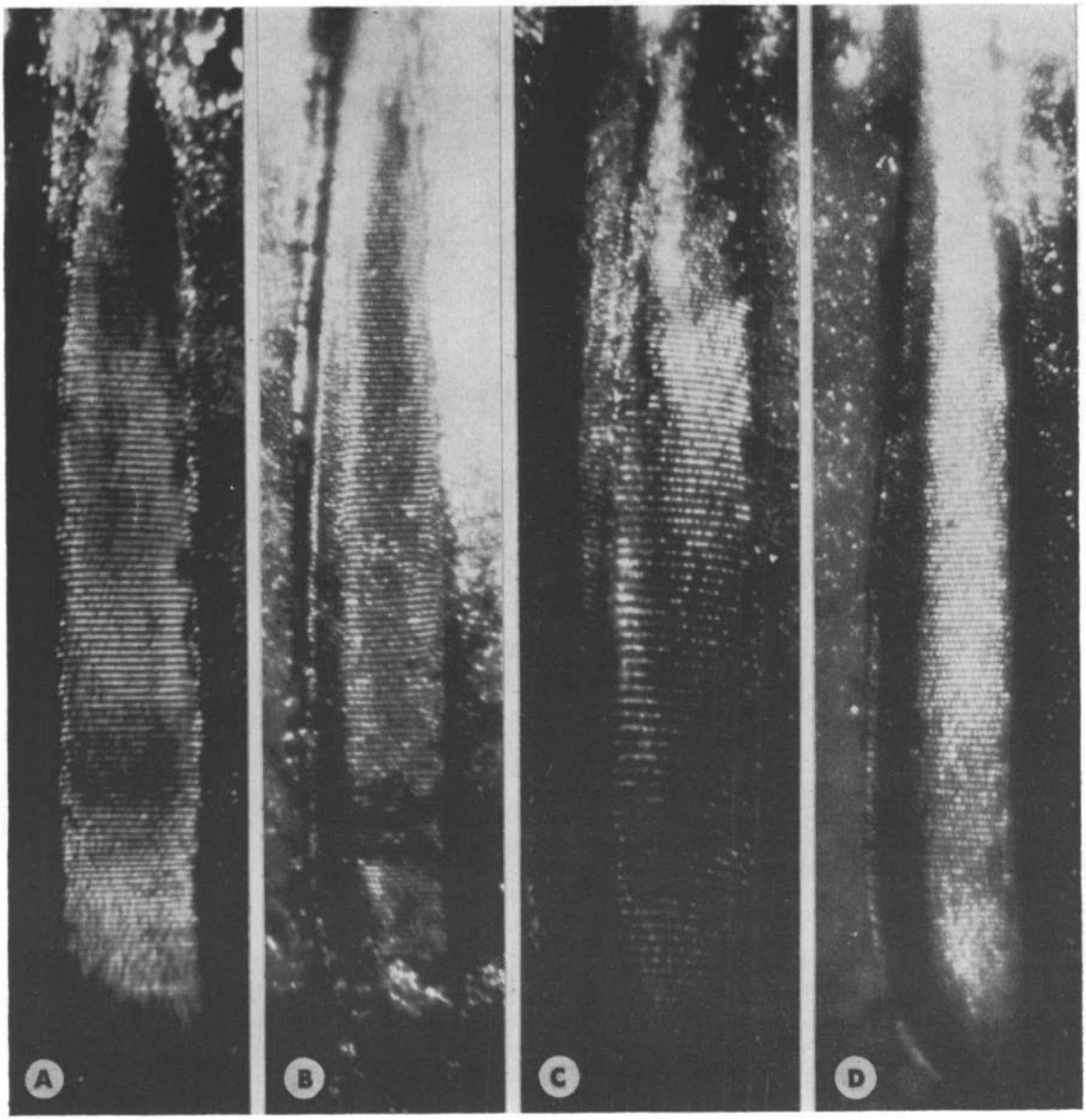


FIG. 3.—Stridulitra of *Conotrachelus* species. A, *C. naso* ♂. B, *C. naso* ♀. C, *C. posticatus* ♂. D, *C. posticatus* ♀.

SOUND-PRODUCING MECHANISMS

The stridulitrum is situated on a flange of the left elytron (Fig. 1) which extends under the right one (Fig. 2). Stridulitra usually are larger in the males than in the females; also the males often have a small stridulitral area on the right elytron (Fig. 1) which is slightly separated from the stridulitrum of the left elytron (Fig. 1). This is true in *C. naso, C. posticatus, C. carinifer,* and *C. nenuphar*. The length and width of the stridulitrum and the number of teeth it bears differ between sexes and species (Table 1).

In *C. naso*, the stridulitral teeth are nearly uniform in height and spacing throughout the length of the stridulitrum, both in the male (Fig. 3A) and the female (Fig. 3B). In *C. posticatus* males (Fig. 3C), the spacing and height of the teeth gradually increase threefold from the anterior to the posterior portion, but in females (Fig. 3D) the teeth are nearly uniform in spacing and in height. In *C. carinifer,* again, the teeth are almost uniformly spaced in both males (Fig. 4A) and females (Fig. 4B), although the male appears to have slightly more teeth anteriorly than posteriorly. In the male of *C. nenuphar,* the teeth are uniformly spaced on the anterior three-fourths of the stridulitrum, but those on the posterior one-fourth are larger and longer, and are more widely spaced. Stridulitra of females of *C. nenuphar* vary from those with no teeth at all to those with uniformly placed teeth on the posterior two-thirds; and anterior one-third is almost always entirely without teeth.

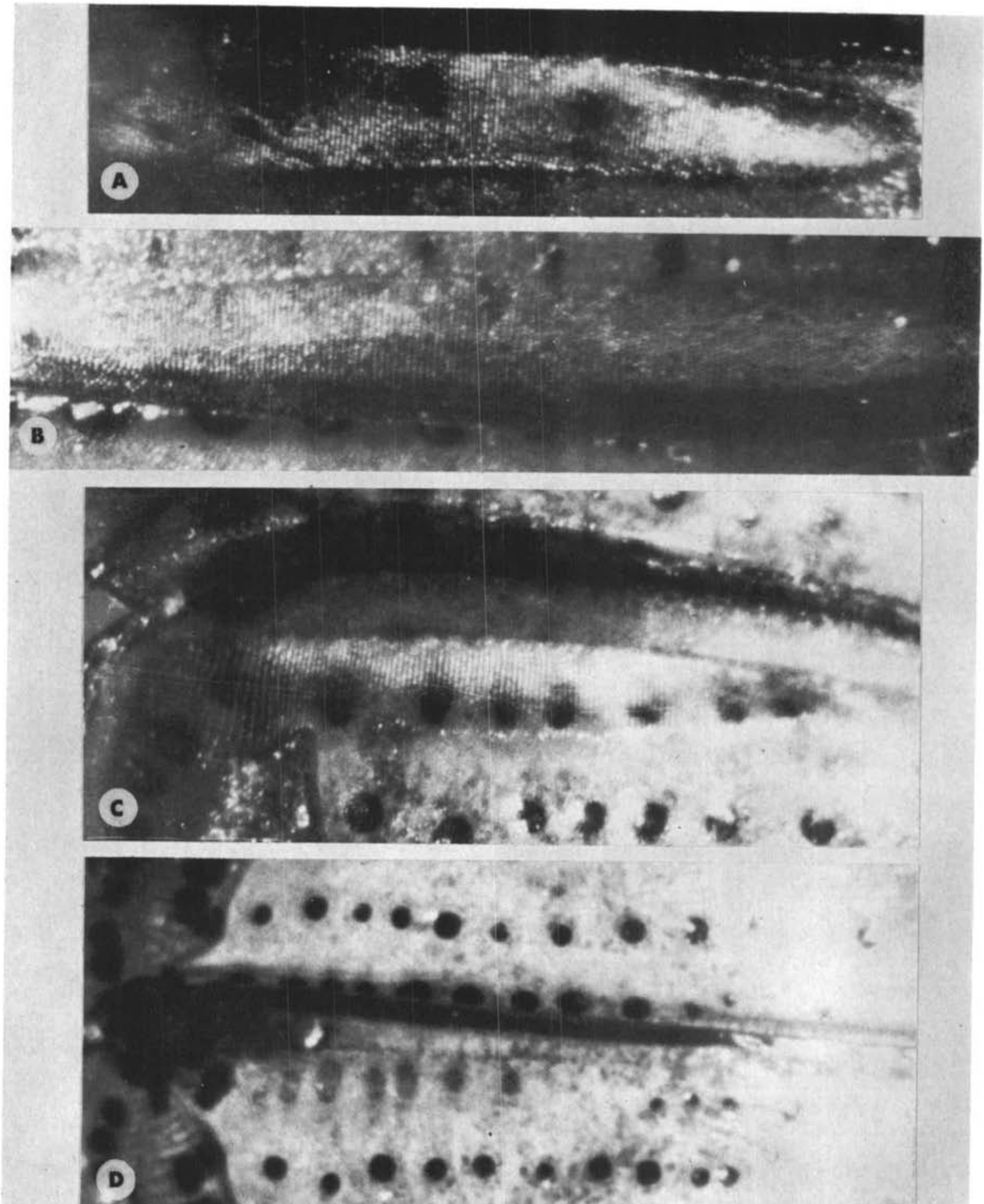


FIG. 4.—Stridulitra of *Conotrachelus* species. A, *C. carinifer* ♂. B, *C. carinifer* ♀. C, *C. nenuphar* ♂. D, *C. nenuphar* ♀.

The plectrum is situated on a median, sclerotized, anteriorly projecting, smooth portion of the sixth abdominal tergite (Fig. 5, Ia). This tergite comprises 3 distinct area types. That designated as "I" (Fig. 5) is hard, sclerotized, and roughened—except in the portion designated as "Ia." Area "II" is membranous. The pair of lateral areas marked "III" are thinly sclerotized, flexible, and light tan in color.

In *C. naso* (Fig. 6), *C. posticatus* (Fig. 5, 7), and *C. carinifer* (Fig. 8), both sexes have similar plectra, composed of 2 pairs of tubercles, with the posterior pair about twice as large as the anterior pair and somewhat more widely separated. Males of *C. nenuphar* have a plectrum consisting of only 1 pair of tubercles, situated farther back on the sixth tergite than the plectra of the other 3 species (Fig. 9); females of *C. nenuphar* apparently have no plectrum, as no tubercles are apparent on the specimens in my collection.

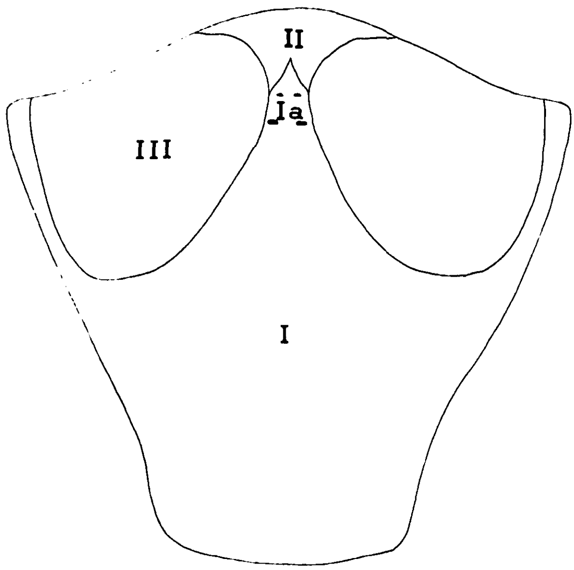


FIG. 5.—Sixth abdominal tergite of *C. posticatus* ♀.

SOUND PRODUCTION

In sound production, the plectrum is moved from its normal resting position (Fig. 10) and struck against

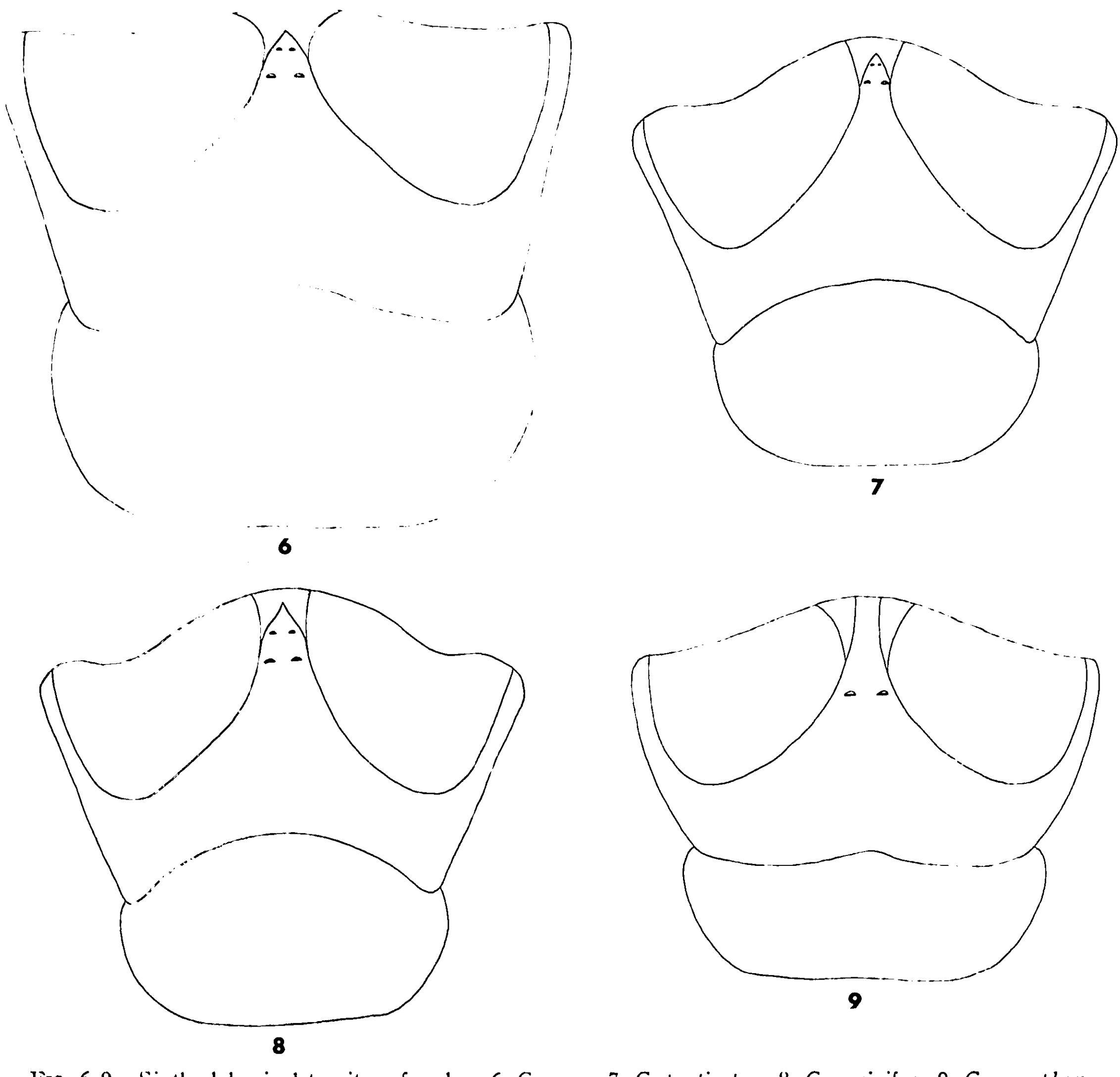
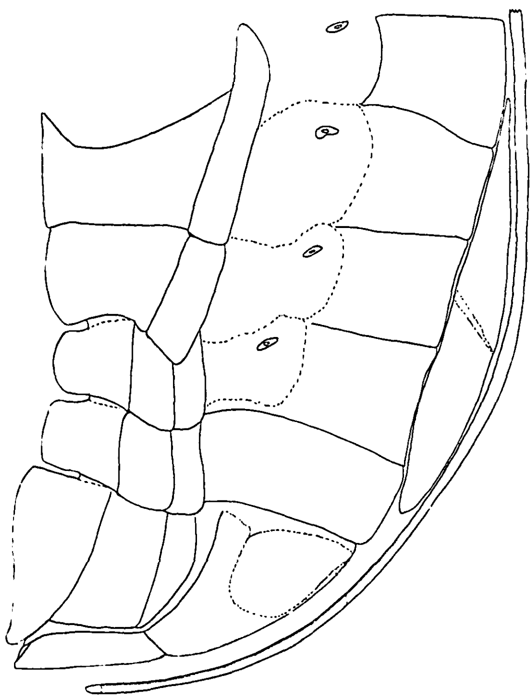


FIG. 6–9.—Sixth abdominal tergites of males. 6, *C. naso;* 7, *C. posticatus;* 8, *C. carinifer;* 9, *C. nenuphar.*



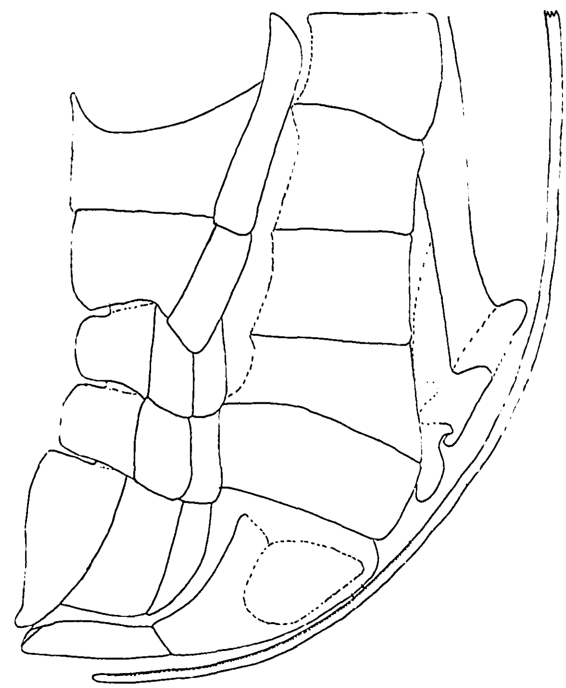


FIG. 10 (left).—Abdomen of *C. naso* ♂ in normal position, lateral view.
FIG. 11 (right).—Abdomen of *C. naso* ♂ in stridulatory position, lateral view.

the stridulitrum. A stridulation involves 2 parts—a backward stroke and a forward stroke. The backward stroke is initiated by constricting the anterior 4 abdominal pleural areas, so that the haemolymph is pushed into the posterior abdominal segments. These actions cause the portion of the sixth tergite bearing the plectrum to be puffed upward and outward, and, at the same time, move the sixth abdominal tergite and the pygidium into the stridulatory position (Fig. 11). With the abdomen in this position, the last 3 abdominal sternites are flexed downward and the plectrum is moved backward along the stridulitrum. Then, with the tergites still in the stridulatory position, the last 3 sternites are returned to the normal position and the plectrum performs its forward stroke against the stridulitrum.

The number of teeth that are struck varies with the stroke. During slow or normal stridulation by *C. naso,* approximately 8–22 teeth are struck on the backward stroke, 18–48 on the forward stroke. The number varies in the other species. During rapid stridulation, only one-half to two-thirds as many teeth are struck as during slower stridulation.

CHARACTER OF THE SOUNDS

Audiospectrographs show that the flex- or backward-stroke stridulation (Fig. 12A, 13A, 14A) differs in character from return- or forward-stroke stridulation (Fig. 12B, 13B, 14B). This is especially true in *C. naso,* where the stridulations produced by the 2 strokes are completely different(Fig. 12). In *C. posticatus* (Fig 13) there is a superficial resemblance between the sounds produced by the 2 strokes; however, closer examination shows that the sounds produced by the backward and the forward strokes, respectively, more nearly resemble those produced by the oppositely directed strokes in *C. naso.* The backward- and forward-stroke stridulations of *C. carinifer* are nearly alike (Fig. 14).

The forward-stroke stridulation is partly controlled by the wings (Fig. 15–17). Stridulation of a male *C. naso* was little affected by removal of the right elytron, (Fig. 16) but was seriously affected by the removal of the left hind wing (Fig. 17).

The stridulatory sounds differ between the sexes and between species. The stridulation of the male *C. naso* (Fig. 15) differs from that of the female (Fig. 18) in tone, especially on the forward stroke. *C. posticatus* exhibits this sexual tonal difference also. As only 1 ♀ *C. carinifer* was alive during the recording period and no males were available, no comparison was made between the sexes of this species. As was previously noted, no live specimens of *C. nenuphar* were available at the time of recording.

The stridulations of the 3 species covered a range of nearly 10,000 cycle/sec during normal and fast stridulations, but most of the sound was below 6000 cycle/sec. Each weevil is capable of several speeds and frequencies of stridulation.

Three audiospectrographs (Fig. 18–20) of 1 sec of sound each, made with the same female *C. naso,* show some differences in speed and frequencies. In the fast stridulation (Fig. 18), most of the sound is

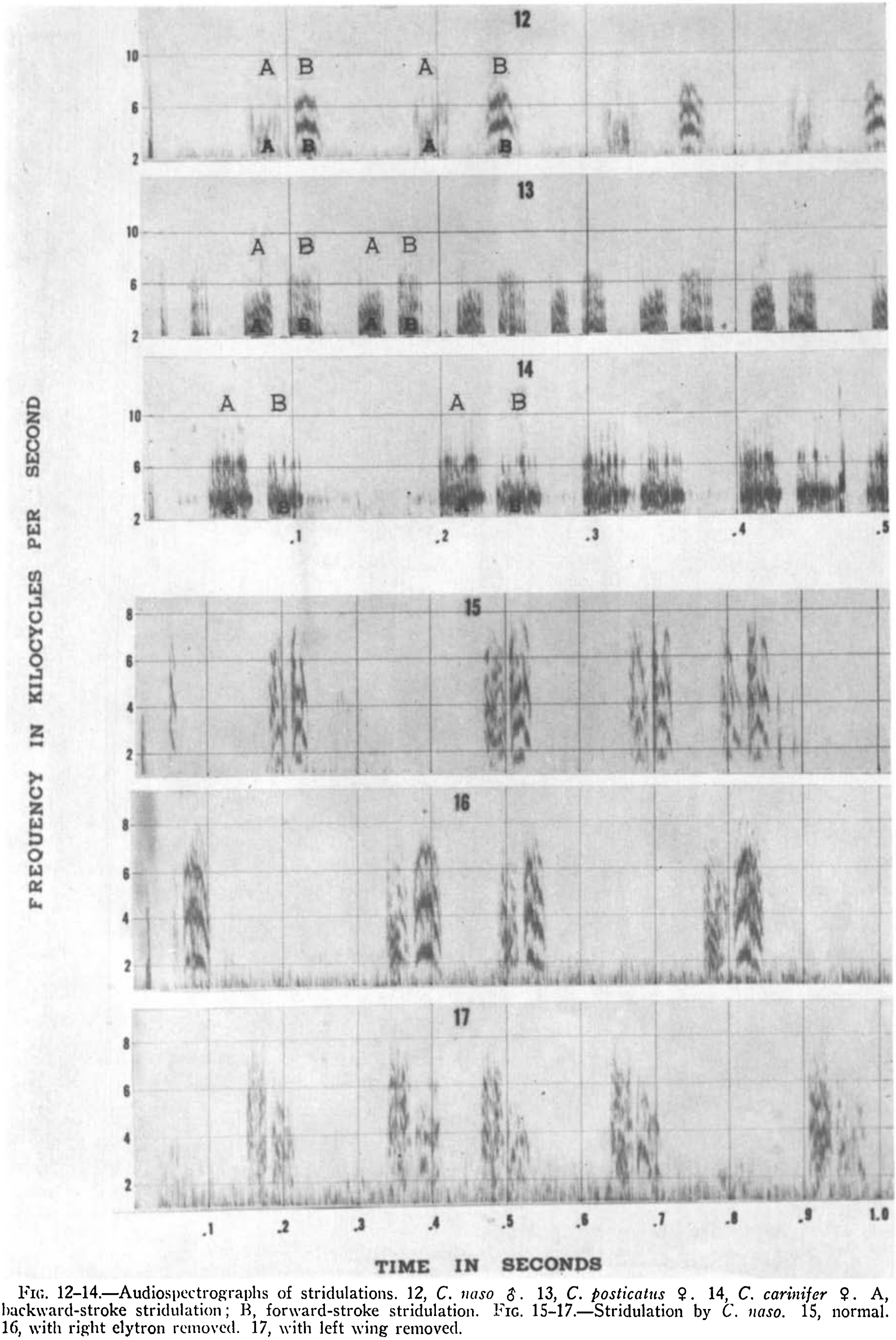


FIG. 12–14.—Audiospectrographs of stridulations. 12, *C. naso* ♂. 13, *C. posticatus* ♀. 14, *C. carinifer* ♀. A, backward-stroke stridulation; B, forward-stroke stridulation. FIG. 15–17.—Stridulation by *C. naso*. 15, normal. 16, with right elytron removed. 17, with left wing removed.

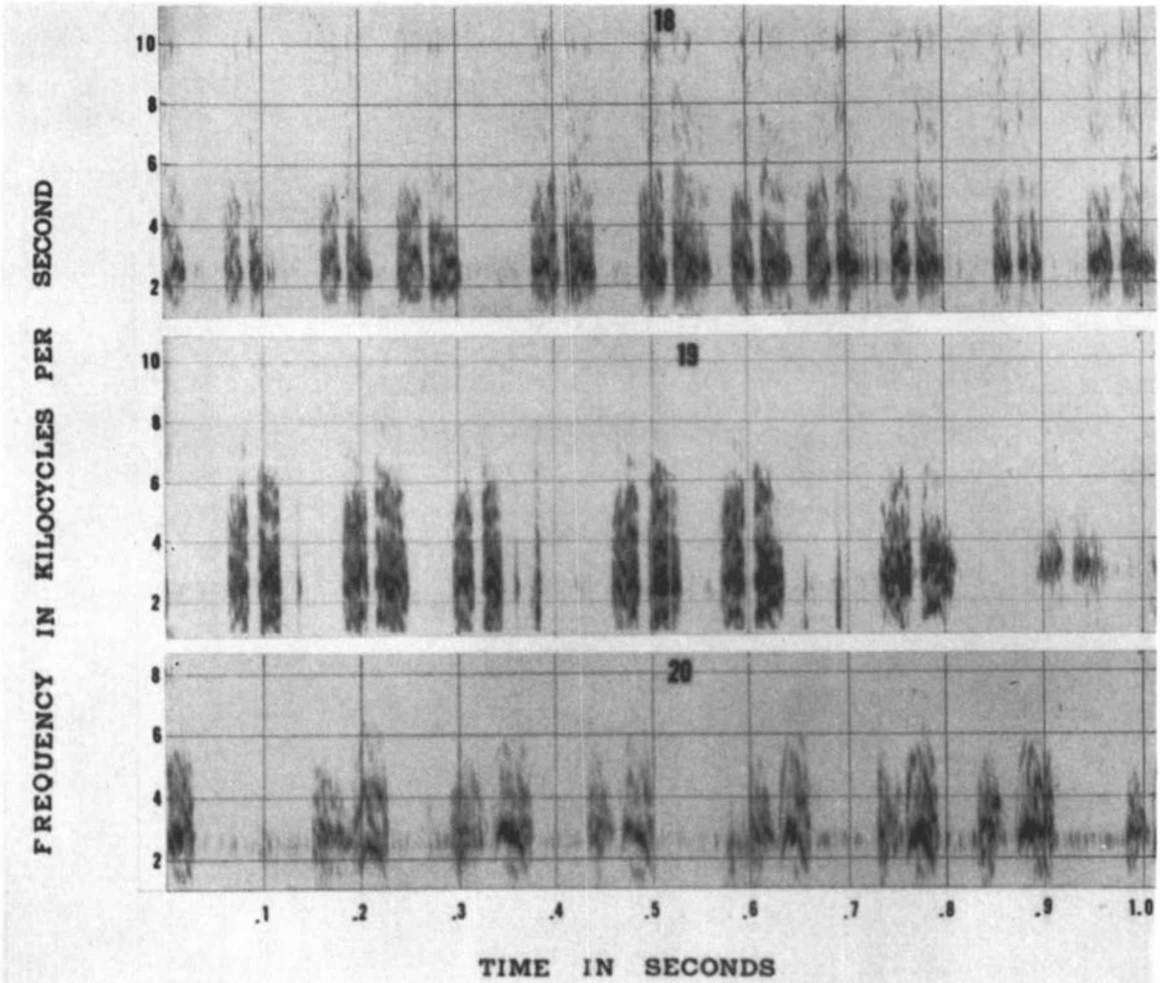


FIG. 18–20.—Audiospectrographs of stridulation by *C. naso* ♀. 18, fast. 19. "normal." 20, slow, deliberate.

below 4000 cycle/sec, though some is slightly above 10,000 cycle/sec. A slower, more normal stridulation (Fig. 19) shows almost all of the sound below 7000 cycle/sec; also, softer sounds toward the end of the audiospectrograph are below 4000 cycle/sec. A slower, more deliberate stridulation (Fig. 20) is lower in pitch, and has more teeth struck per stridulation than in faster stridulations. The backward and forward strokes of the slower stridulations usually are not conspicuously separated by a slight pause, unlike those of faster stridulations.

Audiospectrographs of a female *C. posticatus* (Fig. 21–23) also show differences in speed and frequencies. The fast stridulation (Fig. 21) has sound mostly below 7000 cycle/sec, with some up to 10,000 while a faster but softer stridulation (Fig. 22) has all the sound below 6000 cycle/sec. The backward and forward strokes are not separated by a pause, but are slurred together. A slower, more deliberate stridulation (Fig. 23) has about the same frequency as the fast one (Fig. 21), but more teeth were struck per stroke.

Audiospectrographs of a female *C. carinifer* (Fig. 24–26) show a greater diversity than those of either *C. naso* or *C. posticatus*. The fast stridulation (Fig. 24) has the sound fairly evenly distributed up to 12,000 cycle/sec, and has no pause separating the backward and forward strokes. More normal stridulations (Fig. 25) have most of the sound below 5000 cycle/sec, have the backward and forward strokes separated by a pause, and have more teeth struck per stroke than during the combined strokes of the fast stridulation. Slower, more deliberate stridulations (Fig. 26) have most of the sound below 7000 cycle/sec, have more teeth struck per stroke, and have the backward and forward strokes separated by a pause.

The species differences in stridulations of females are more apparent when the audiospectrographs are made on a different scale. On comparing *C. naso* (Fig. 27), *C. posticatus* (Fig. 29), and *C. carinifer* (Fig. 30), we find that the normal stridulations differ in the number of teeth struck per stroke, in areas of tone intensity, and in number of strokes per second. Similarly, the fast stridulations of these species (Fig. 30, 31, 32, respectively) differ in these same characteristics.

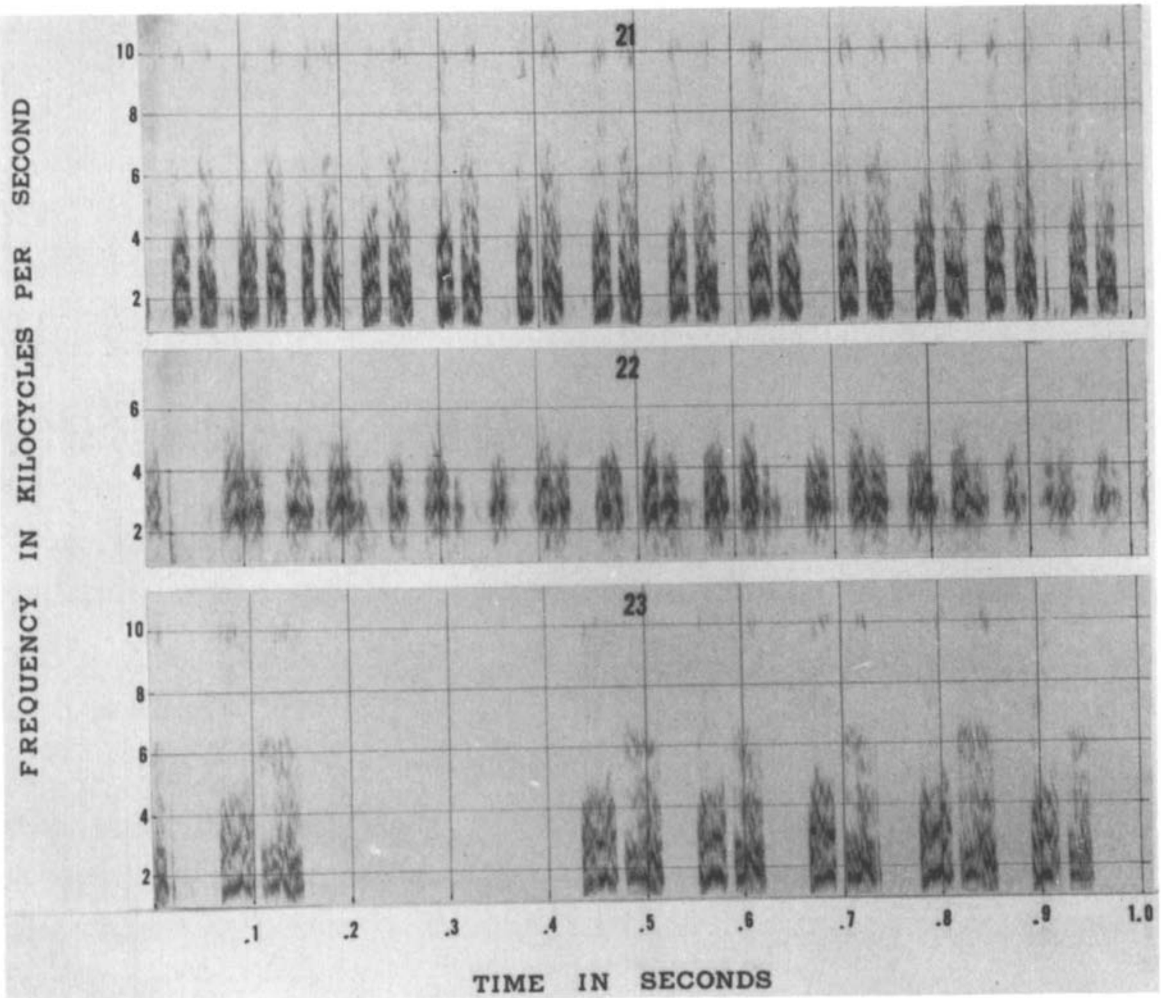


FIG. 21–23.—Audiospectrographs of stridulation by *C. posticatus* ♀. 21, fast. 22, fast, soft. 23, slow, deliberate.

DISCUSSION

During the recordings, the weevils could be induced to stridulate almost at any time simply by touching them, holding them between the thumb and forefinger, or gently squeezing or rolling them. The only weevils seen stridulating without being induced to do so were several individuals of *C. nenuphar*. When about 500 of this species were placed in a plastic humidity chamber, about 10 inches in diameter, several males began to fight, rolling about and stridulating continuously during the time of contact. Although the other 3 species were placed in as heavy concentrations, no fighting or stridulation was observed.

Removal of the left wing affected the forward-stroke stridulation, as was noted above, but the means by which it does so was not determined. Perhaps the wing acts partly as a resonator, but the structure of the stridulitrum makes this doubtful. Perhaps the effect on stridulation was caused solely by the physical amputation, or perhaps the wing acts as a bridge.

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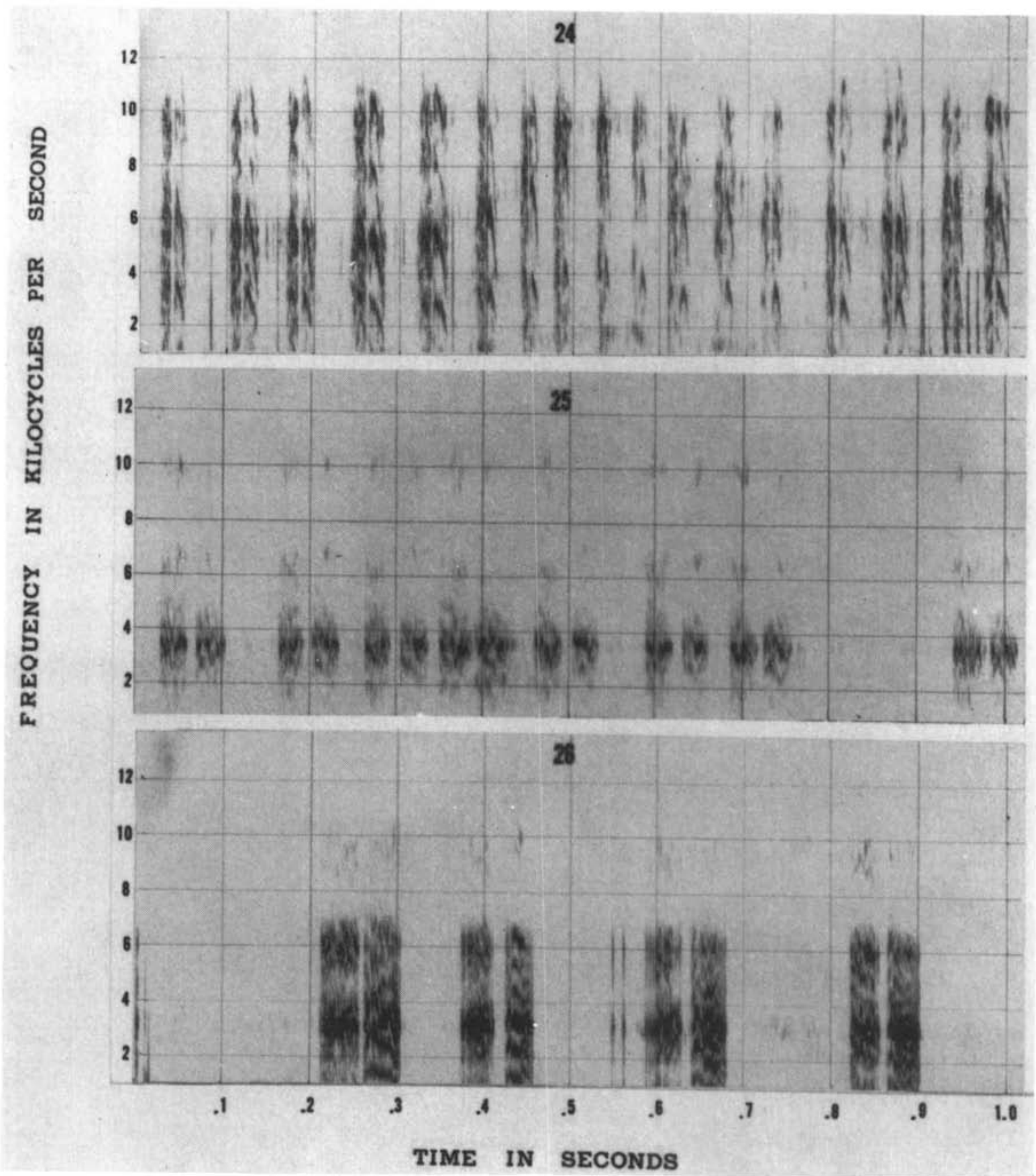

FIG. 24–26.—Audiospectrographs of stridulation by *A. carinifer* ♀. 24, fast. 25, normal. 26, slow, deliberate.

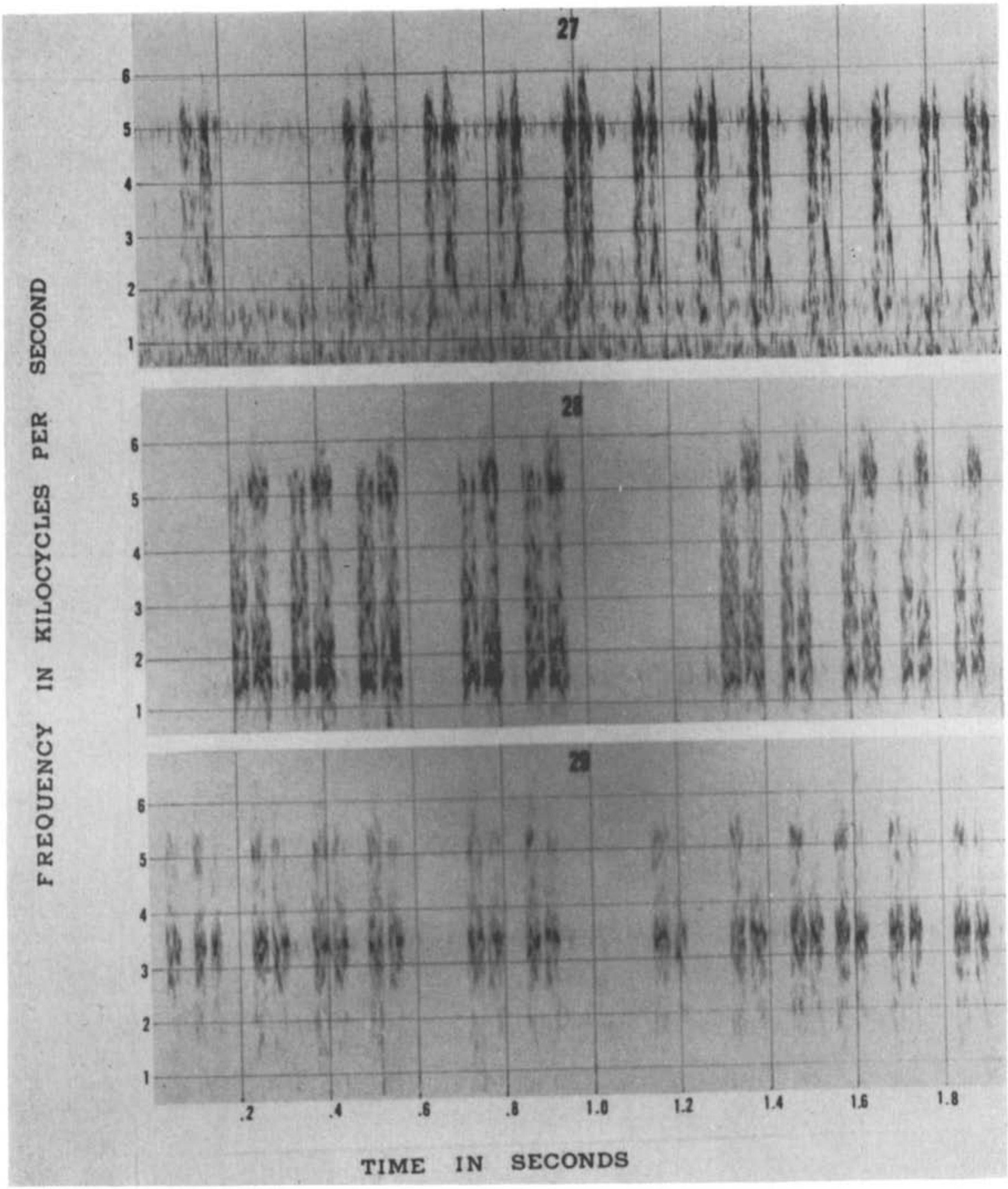

FIG. 27–29.—Audiospectrographs of normal stridulation by *Conotrachelus* females. 27, *C. naso*. 28, *C. posticatus*. 29, *C. carinifer*.

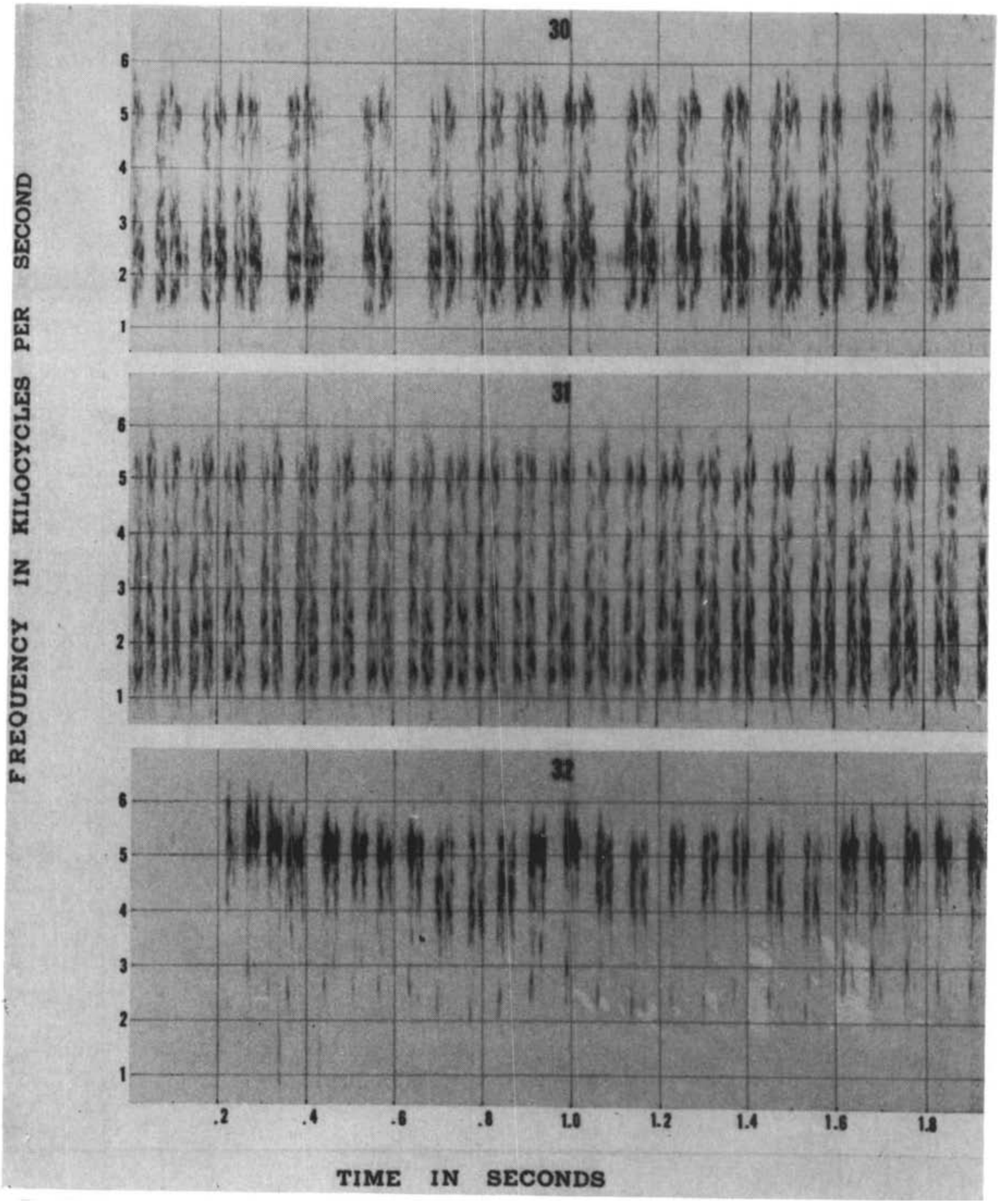

FIG. 30–32.—Audiospectrographs of fast stridulation by *Conotrachelus* females. 30, *C. naso.* 31, *C. posticatus.* 32, *C. carinifer.*