Sound-Synchronized, Ultra-High-Speed Photography: A Method for Studying Stridulation in Crickets and Katydids (Orthoptera)[1]

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Male crickets (Gryllidae) and katydids (Tettigoniidae) produce calling songs by rubbing together the file and scraper of their specialized forewings. These songs consist of sequences of pulses. The pulse rhythm is often complex, and some songs have periodic variations in intensity and tonal quality (Alexander 1960).

The variations in forewing movements that produce differences in rhythm, intensity, and quality are poorly understood. The only noteworthy work in this direction is that of Pierce (1948) who used photography to determine the pattern of forewing movement during calling of 6 species of crickets and katydids. Since he was limited to film speeds of 64 frames/sec or less, he could only analyze songs produced by slow or repetitious wing movements. His films had no sound track, but he used indirect evidence to associate particular portions of the wing-movement cycle with the production of sound pulses.

This paper describes a method that is suitable for studying the relationships of forewing movements and sound production in crickets and katydids, no matter how rapid, variable, or complex the song.

The Communication Sciences Laboratory, University of Florida, has photographic equipment routinely used in making ultra-high-speed motion pictures of the functioning human larynx (Moore et al. 1962, Dew and Moore 1965). The same instrumentation can be used for studying the forewing movements and associated sound production in crickets and katydids. Fig. 1 is a block diagram of the apparatus. The insect is placed in a glass-topped cage, and an optically flat mirror reflects its image into the front lens of a Fastax® ultra-high-speed camera (Wollensak®, WF-14) which utilizes a revolving prism geared to the film advance rather than a conventional shutter mechanism. The camera speed is determined by a WF-301 Goose Control Unit which allows a framing rate of up to 8000 pictures/sec. (More recently developed cameras are capable of speeds up to 32,000 frames/sec.)

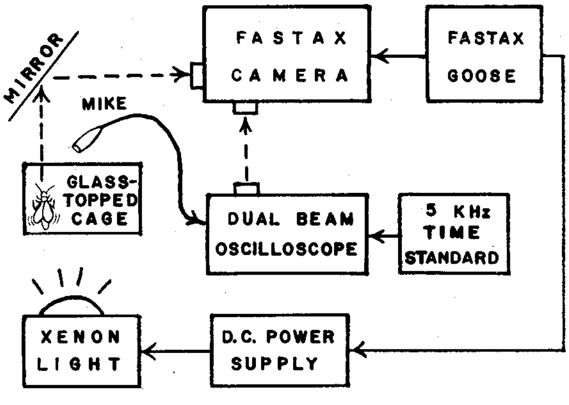

FIG. 1.—Block diagram of setup to produce sound-synchronized, ultra-high-speed photographs.

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A Wollensak (WF-360) Xenon Lamp System powered by d-c storage batteries brilliantly illuminates the subject. Special filters are used to reduce the heat and UV and IR light waves generated by the lamp.

The sound produced by the insect is transduced by a condensor microphone system and led to 1 beam of a dual-beam oscilloscope. The 2nd beam is driven by a 5 kHz square wave used as a time standard. The face of this oscilloscope is photographed by the side lens of the Fastax, and both the sound wave and the time standard as well as the wing movements of the subject appear on the film (Fig. 2). Several films may be used; Eastman Tri-X® negative film is one which produces satisfactory photographs at relatively low cost.

Forewing movement can be determined by frame-by-frame analysis of the film. Fig. 3 shows such an analysis of the calling song of *Oecanthus celerinictus* Walker at 26°C. The song is a continuous trill of ca. 69 pulses/sec. Only the closing stroke of the wingstroke cycle is acoustically effective (Fig. 2 and Walker 1962).

This technique is applicable not only to crickets and katydids but to other sound-producing insects. The principal limitations are that the insect must perform in bright light while stationary and the sound-producing structures must move in view of the camera.

In addition to clarifying the mechanics of sound production, this technique may yield new clues to phylogeny. For instance, if different sounds are produced by the same technique of forewing movement, homology should be suspected. On the other hand, if similar sounds are produced by different forewing movements, the similarity is more likely a result of convergence than descent from a common ancestor with such a sound.

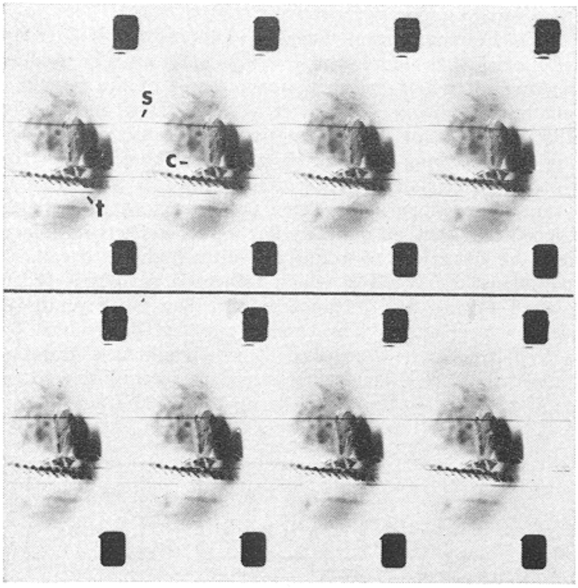

FIG. 2.—Strips of film at 3958 frames/sec showing tree cricket, c (*O. celerinictus*), sound track, s, and timing mark, t (5 kHz square wave; i.e., each mark = 0.1 msec). In the upper strip the wings are closing and the sound track shows sound production. In the lower strip the wings are silently opening. (In tree crickets the forewings are held perpendicular to the body axis during singing.)

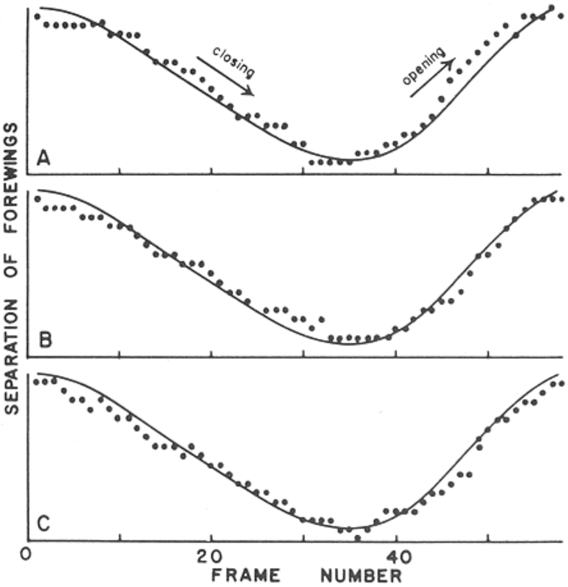

FIG. 3.—Forewing movement of *O. celerinictus* during 3 consecutive wingstroke cycles (A, B, C) within a calling song at 26°C. Lateral separation of the forewings was measured in millimeters during frame-by-frame projection of the film. Each wingstroke cycle lasted ca. 14 msec and was photographed 57 times (about 4000 frames/sec). The curve superimposed on each cycle is the curve that best fit (by eye) the 9 cycles analyzed. Note the slower, acoustically effective closing stroke and the more rapid, silent opening stroke.

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