ACOUSTIC TRAPS FOR AGRICULTURALLY IMPORTANT INSECTS

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ABSTRACT

Development of sound-baited traps for insects has lagged behind that of light- and chemical-baited traps. The principal successes for acoustic traps have been with mole crickets (Gryllotalpidae), field crickets (Gryllidae), and ormiine flies (Tachinidae). The crickets are attracted to the conspecific calling song and the flies to the calling songs of their hosts. Electronic sound synthesizers facilitate routine operation of acoustic traps, and increasing the intensity of the sound far above the levels of the natural call greatly increases the numbers trapped. Acoustic traps are most likely to be useful for species that exhibit long-range phonotaxis under natural conditions. Acoustic traps are unlikely to be cost-effective for control but have proved valuable in studying behavior and ecology, collecting specimens, and monitoring populations.

RESUMEN

El desarrollo de trampas cebadas con sonido está más atrasado que trampas de luz o cebadas con productos químicos. El éxito principal de trampas acústicas ha sido con los topogrillos (Grillotalpida), grillos de campo (Grillida) y con moscas Taquínidas. Los grillos son atraidos a los cantos coespecíficos y las moscas al canto de su hospedero. Los sintetizadores electrónicos de sonido facilitan la rutina de la operación de trampas acústicas, y aumentan la intensidad del sonido mucho más que los niveles del llamado natural, aumentando el número de atrapados. Es más probable que trampas acústicas sean más útiles para especies que demuestren una fonotaxis de largo alcance bajo condiciones naturales. Es improbable que el costo de trampas acústicas valga la pena, pero han demostrado ser valiosas en estudios ecológicos y de comportamiento, en la colección de muestras, y en el chequeo de poblaciones.

Traps baited with lights or chemicals are widely used to collect insects and to monitor their populations. Light traps catch a wide variety of insects that generally are attracted in small numbers; why light attracts insects and from how far are poorly understood (but see Baker 1985). On the other hand, chemical traps generally trap one or a few kinds of insects, frequently in large numbers; this is because chemical baits simulate specific sex pheromones or chemicals released by particular foods. Individuals are often attracted from 100 m or more. Acoustic traps are similar to chemical traps in that they generally catch one or a few species, often in large numbers. Acoustic baits simulate the mating call of the captured species or of the prey or host species.

In this paper I review the development and use of sound-baited insect traps, compare the principal components of successful traps, and consider potential uses and limitations of acoustic traps for agricultural insects.

A History of Sound Traps for Insects

Kahn & Offenhauser (1949; also Offenhauser & Kahn 1949) were apparently first to field test a sound-baited trap. In a swamp in Cuba, they used a recording of the flight sound of an *Anopheles albimanus* female to attract mosquitoes to a high-voltage electrified screen. Their equipment was crude by today's standards—they played a 78 rpm acetate disk on a record changer. Nonetheless, they killed more mosquitoes in the peak 10-minute interval of trapping than a nearby cattle-baited trap caught in a week. Because phonotaxis in mosquitoes is mainly a matter of males seeking a mate by homing on the female's flight sound, the mosquitoes Offenhauser & Kahn killed were principally males—rather than blood-seeking, disease-carrying, egg-laying females. In spite of this limitation, Belton (1967) and, more recently, Ikeshoji and co-workers (Ikeshoji et al. 1985, Ikeshoji 1986, Ikeshoji & Yap 1987) further developed and field-tested sound traps for mosquitoes. Such traps could reduce mosquito populations by reducing fertility of females, either by removing or chemically sterilizing attracted males.

The first acoustic traps developed for agricultural insects were for the mole crickets, *Scapteriscus acletus* and *S. vicinus*, which are important pests of pastures and crops in the southeastern United States (Ulagaraj & Walker 1973, Walker 1982). These traps (e.g., Fig. 1) broadcast the real or imitation calling song of the male and attract and catch flying mole crickets of both sexes. A standard trapping station, consisting of one *S. acletus* trap and one *S. vicinus* trap, generally yields thousands of mole crickets in a year; catches of hundreds during one evening are not uncommon. The record catch of *S. acletus* for one station in one night is 3,297; for *S. vicinus*, 2,174 (Walker 1982, and unpublished). Forrest (1983a) and Chukanov & Zhantiev (1987) trapped mole crickets of other species (*Scapteriscus* spp. and *Gryllotalpa* spp.) that flew or walked to reproductions of their calling songs.

A major use of acoustic traps for mole crickets has been to acquire living material for research. Adult mole crickets are exceedingly difficult to collect by other means, and large-scale laboratory rearing has thus far proved impractical. Sound trapping has made possible much of the research on the biology and on chemical and biological control of *Scapteriscus acletus* and *S. vicinus* (Walker 1984).

Field crickets are a second group of agriculturally important insects that have been caught with sound-baited traps. Campbell & Shipp (1974, 1979) and Campbell (ms. in review) developed traps for *Teleogryllus commodus*, an important pest of pastures in Australia and New Zealand. As in mole crickets, the bait was the natural or synthesized male calling song, and both males and females flew or walked into the trap. In North America, field crickets of the genus *Gryllus* have been acoustically trapped by Cade (1979, 1981) and Walker (1986). Sound trapping field crickets has contributed to studies of their migratory and mating behaviors (Campbell & Shipp 1979, Cade 1981, Walker 1987). It can also provide a ready source of live crickets for laboratory studies or for feeding animals: for three years, a trap broadcasting *G. rubens* song at Gainesville, Florida, caught hundreds of *G. rubens* most months and an annual average of 8,209 (Walker 1986).

A third group of insects successfully trapped acoustically are tachinid flies of the tribe Ormiini. These flies are parasitoids of crickets and katydids, and females find their hosts by homing on the hosts' calling songs. Cade (1975, 1981) trapped gravid females of *Euphasiopteryx ochracea* at broadcasts of the recorded song of *Gryllus integer*, and Mangold (1978) trapped it at the song of *Scapteriscus acletus*. In three trap-years Walker (1986, 1989) trapped 3,583 *E. ochracea* at synthesized *Gryllus rubens* song. A South American species of *Euphasiopteryx*, *E. depleta*, is important as a potential biological control agent for *Scapteriscus* mole crickets that became major pests when accidentally introduced into the southeastern United States (Fowler & Garcia 1987). Fowler (1988) devised sound traps to capture gravid *E. depleta* females for biological studies and for shipment to the United States.

Sound traps have been used for other insects with less success and/or on a more modest scale. For example, Webb et al. (1983) caught female Caribbean fruit flies (*Anastrepha suspensa*) using sound-baited traps within field-caged guava trees; Silveira-Guido & Fowler (1988) caught *Megacephala fulgida*, a tiger beetle predator of mole crickets, at mole cricket sound traps; and Walker (1979) and Zuk (1987) suspended gryllid males (*Anurogryllus arboreus* and *Gryllus veletis* and *G. pennsylvanicus*) over pitfalls to study what mates or enemies particular males attract.

Components of Sound Traps

The principal parts of a sound trap are a sound source, a controller, and a catching device.

Sound source

Sounds used to attract insects to sound traps are, thus far, natural sounds or electronic imitations of natural sounds. Natural calls of insects can be used directly (e.g., Campbell & Shipp 1974, Forrest 1983b); they can be captured by microphone, amplified, and broadcast in real time; or they can be recorded for later broadcast (e.g., Ulagaraj & Walker 1973, Cade 1979). The first method changes no feature of the natural call. The second method keeps the timing and quality of the sound natural while permitting it to be amplified and broadcast from one or more speakers. The third allows a selected natural sound (the recording) to be produced on a predetermined schedule at a predetermined intensity. The third method can be adapted to routine operation of sound traps, but automated playback of recorded sounds requires expensive equipment not easily adapted to field use.

Using sound synthesizers as sound sources greatly simplifies automatic sound trapping (Walker 1982, Campbell & Forest 1987). Except for speaker diaphragms, electronic sound synthesizers have no moving parts to wear or bind, and they can be built or programmed to produce precisely the sound that is wanted. Under field conditions they reliably produce the specified song for weeks or longer; those incorporating a digital microprocessor may retain their calibration indefinitely.

Synthesizers are either line operated (e.g., 110 volt AC) or battery operated (e.g,, 12 volt DC). Once lines are run to a trapping site, line power is economical and requires little routine maintenance. The virtues of battery power are that it can be used at any trapping site and is not disrupted by line power failures.

A bag made of 3 mil black polyethylene is an easy way to weatherproof a sound synthesizer (Fig. 1). The sound is attenuated 8 dB by the bag, but quality is not affected.

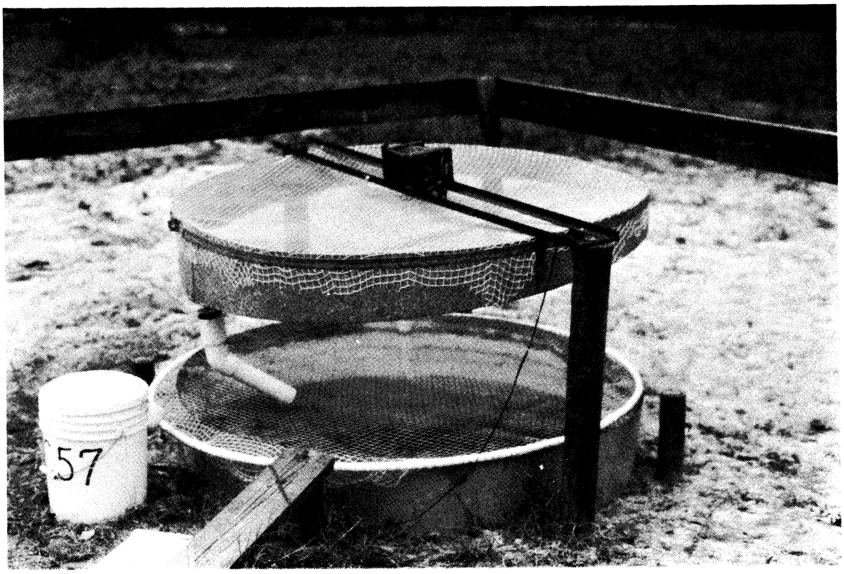

Fig. 1. Mole cricket sound trap. Sound synthesizer in black plastic bag produces calling song of *Scapteriscus* sp. Attracted mole crickets land on coarse net and crawl or fall into shallow, obliquely truncated, wirecloth-bottomed cylinder. Net prevents crickets from flying out as they work to low point of cylinder and fall into pipe. Outlet of pipe can be directed either into pool (as shown), where crickets swim until collected, or into bucket, where they find soil (for live collections), or preservative. Time clock (lower left) switches synthesizer on at sunset and off two hours later, when the flight period is over.

Controller

Unless a human operator is always available or the sound is to be broadcast continuously, routinely operated sound traps need a device that switches the sound on and off at appropriate times. Reliable, economical timer-controlled switches are commercially available for line-operated sound sources. For battery operated sound sources, commercial timers are difficult to find and expensive—e.g., the Paragon EC72D 12-volt DC timer costs ca. $170.

Catching devices

In some cases, it is important that the insects caught at a sound trap be kept healthy for later use. In other cases, dead specimens are all that are needed. Lethal traps may use an electrified grid, sticky material (e.g., Tack Trap©), or insecticides. Catching devices for live traps are sometimes difficult to devise. For mole crickets and field crickets, sheet-metal funnels will direct those that land within its diameter to a holding container (Fig. 2) (Walker 1982, 1986). For mole crickets, an obliquely truncated sheet metal cylinder with a wire mesh bottom works like a funnel but does not direct rain

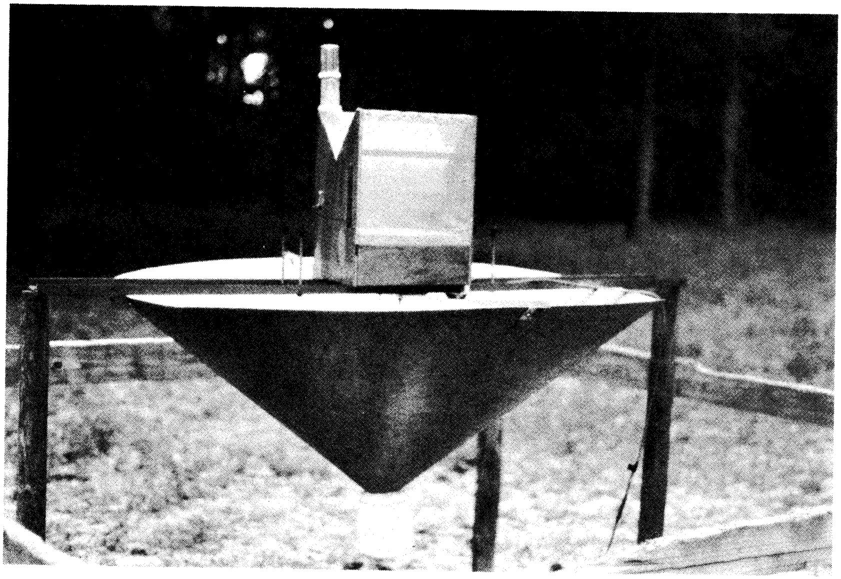

Fig. 2. Field cricket and fly sound trap. Sound synthesizer (concealed beneath screen cage) produces calling song of *Gryllus rubens*. Attracted field crickets that land in funnel slide into removable 2-liter plastic jar (which has a screen bottom to prevent flooding). Attracted flies (*Euphasiopteryx ochracea*) that land on top of cage run toward sound and pass into cage through 1-cm-wide slit at bottom of notch. They later fly upward and are trapped in removable collecting vial (on cage at upper left).

water into the holding container (Fig. 1). A cheaper, easier to transport device for mole crickets is a foldable child's wading pool (Fig. 1) (Walker 1982). Mole crickets landing on water are bouyed by their hydrofuge pile and swim or float for 12-24 hours until collected.

A serious problem with catching mole crickets that land at sound traps is that many alight meters from the sound source. Matheny et al. (1983) found that only 8% of *S. vicinus* and 36% of *S. acletus* landed within the 1.5-m-diameter funnel or pool of a standard mole cricket trap. Increasing the diameter of the catching area to 4.6 m increased the potential catch of the two species to 30% for *S. vicinus* and 75% for *S. acletus*.

The efficacy of catching devices for ormiine tachinids has also been a problem. Fowler (1988) and Walker (1989), who developed live traps for *Euphasiopteryx depleta* and *E. ochracea*, respectively, noted that attracted flies often did not find their way into the holding cage and thus escaped. However, the *E. ochracea* trap (Fig. 2) caught approximately as many flies as a concurrently operated sticky trap (Walker 1989).

Sound Level

Most acoustic traps have amplifiers and therefore can be operated at any of a wide range of sound levels. If the sound level matches that of the natural sound (e.g., a calling male), the number of insects attracted should approximate the number that would come to the natural sound. In most cases though, the goal of sound trapping is either to catch as many target insects as possible or to catch large samples. Sounds louder than natural, generally, perhaps invariably, attract more target insects than sounds of natural intensity. This is in keeping with Burk's (1988) contention that intensity indicates fitness and cannot be counterfeited. It is also in keeping with the physics of competing sound fields (Forrest, personal communication).

The exact effects of intensity on the performance of acoustic traps are poorly known. Cade (1979) found that taped *integer* calling songs attracted significantly more *E. ochracea* and *G. integer* females when amplified ca. 10 dB above the natural sound level. Ulagaraj & Walker (1975) reported that at sound pressure levels (SPL's) between 70 and 106 dB (re 20μPa, measured at 15 cm) catches of *S. acletus* approximately doubled with each 6 dB increase. Forrest (1980), using improved equipment and more replication, found that between 101 and 111 dB, catches of *S. acletus* averaged 5.7 times greater for the louder of two groups of traps differing in acoustic output by 6 dB. The 95% confidence limits for the 5.7 ratio were 5.2 and 6.3. Walker & Forrest (unpublished) ran further tests with *S. acletus*, increasing the range of sound levels tested to 128 dB. For traps differing by 12 dB, the louder traps caught 2.5 to 10.9 times as many *S. acletus* as the softer traps.

Discussion

Limitations to acoustic trapping

The most fundamental limitation to using acoustic traps is that few insect species are attracted to sound. Those that are attracted come to natural sounds or their imitations. Nothing presently suggests that long-range acoustical communication is as common as long-range chemical communication or that yet-to-be-discovered acoustical signals will prove remarkably attractive to many insect species (cf. UV light for light traps).

Not only are few species attracted to sound, but within a species, attraction is usually restricted to one or a few classes of individuals. For example, in *Euphasiopteryx* spp. the only flies that come to broadcasts of the host's calling song are gravid females. In this case it is evident that individuals attracted are those that, under normal circumstances, would benefit from coming to the sound. The attraction of male crickets to calling songs of males is harder to explain—e.g., 44% of sound-trapped *G. rubens* were males (Walker 1986). It may be a matter of males landing near calling males for the opportunity to intercept attracted females (Cade 1979) or of their using conspecific calls to locate habitat, with calling sites and potential mates. The latter accords with the finding of Matheny et al. (1983) that the sex ratio of sound-attracted *Scapteriscus* spp. becomes less female biased as landing distance from the sound source increases.

Yet another limitation to acoustic trapping is its high cost—for purchase, operation, and maintenance of sound synthesizers, controllers, and catching devices. Unlike chemical traps, sound traps that do not use live insects to produce the attractant require batteries or line current for power and an amplifier and speaker for propagation. Improved electronic technology may lower the costs of acoustic trapping, but sound traps will likely remain many times as expensive as chemical traps.

Uses of sound traps

Sound traps have already proved their usefulness for studying behavior and ecology, collecting specimens, and monitoring populations. For example, Forrest (1983b) used male-baited traps to study phonotaxis, song and flight periodicity, and mate choice in mole crickets. Mole crickets attracted to amplified synthetic calls have been used to test pesticides, chemical attractants, and feeding stimulants in the laboratory; to test and to rear biocontrol agents; and to study damage to grass cultivars (Walker 1984). By running sound trapping stations throughout peninsular Florida, Walker et al. (1983) revealed population trends, seasonal distribution, and life cycles. By trapping simultaneously in habitats suitable and unsuitable for mole crickets, Walker & Fritz (1983) estimated prevalence of interhabitat flights.

Sound traps are potentially important in establishing mole cricket biological control agents and in monitoring their spread. Mole crickets attracted to a sound trap can be automatically infected with an agent and released. Some will fly away the next evening (Ngo & Beck 1982), dispersing the agent. Sound traps can also be used to collect biological control agents for satellite releases and to collect samples of hosts for assay.

Crickets caught in sound traps could be used (or sold) for fish bait or animal food. Sound synthesizers, programmed to produce the most effective cricket call for the time and season, could be suspended over ponds to help feed fish.

Prospects are not good for using sound traps to control the attracted insects by directly reducing their populations. The attracted individuals may be impressively numerous but they are not likely to be a major portion of the local population, most of which may not be attracted. Indeed, the insects that are attracted may be chiefly migrating individuals that might not have stopped except for the supernormal stimulus of the trap's broadcast. Of those that do land, a small portion may be caught (Matheny et al. 1983)—though by poisoning the area around the trap or by placing the trap over a large fish-filled pond, those landing far away could be prevented from augmenting the local population. Sound traps are too expensive to use to blanket large areas—as has been done with chemical traps (e.g., >400,000 boll weevil traps were used in 1985: Dickerson 1986). For sound traps to be effective and competitive with other methods of control, an array of variables would have to coincide in favoring the method. That seems less likely to happen for sound than for chemical traps, and chemical traps have proved useful for control in few instances (Lanier 1989).

A final caveat: devices that attract and destroy large numbers of insects hold a fascination for the general public, and some farmers, out of proportion to the good they do—as witnessed by the popularity of UV-baited electric "bug zappers." Some entrepreneur may very well make and market sound traps to control mole crickets or some other insect pest. Even if the traps do not provide control, their catches may be impressive enough to ensure their commercial success.

Endnote

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