An acoustic trap to survey and capture two *Neoscapteriscus* species

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Invasive *Neoscapteriscus* (Orthoptera: Grillotalpidae) mole crickets damage turfgrasses and pastures throughout the southeastern USA (Hayslip 1943; Walker & Nickle 1981; Liskey 2000). The southern mole cricket, *Neoscapteriscus borellii* (Giglio-Tos) (Orthoptera: Grillotalpidae), and tawny mole cricket, *Neoscapteriscus vicinus* (Scudder) (Orthoptera: Grillotalpidae), were introduced inadvertently into southeastern Georgia before 1900, and thereafter spread rapidly throughout the southeastern US (Walker & Nickle 1981). These insects feed on plant roots and tunnel through the soil, uprooting and killing plants (Xu et al. 2012), which reduces forage for cattle, increases turfgrass sod production time, and reduces turfgrass quality and playability on golf courses (Frank & Walker 2006). Because mole crickets remain underground for much of their life cycle, the cause of initially observed damage may remain unknown until populations rise to destructive levels, as with many other subterranean insects (e.g., Mankin et al. 2007).

Neoscapteriscus borellii and *N. vicinus* attract mates using acoustic communication, and were among the earliest targets of insect acoustic trapping technology (Ulagaraj & Walker 1973; Walker 1996). During spring and fall mating seasons (Hayslip 1943; Walker & Nation 1982), males build carefully constructed, horn-shaped burrows in which they stridulate for several h after sunset (Ulagaraj 1976). The stridulations are amplified by resonances within the burrows (Bennet-Clark 1987, 1999), generating loud calls that attract conspecific, virgin, and mated flying females (Ulagaraj 1976; Forrest 1986). The females land, search for the burrow entrance, and mate with the calling male (Ulagaraj & Walker 1973; Ulagaraj 1976). Also, other males are attracted to the area around the burrow, possibly because the presence of calling males indicates suitable habitat for colonization (Ulagaraj 1975). By replicating the mating call and broadcasting it from a trapping device (Ulagaraj & Walker 1973; Ulagaraj 1975; Forrest 1980, 1983; Walker 1982), researchers can take advantage of the phonotactic behavior of both sexes to monitor local populations, alert turf managers to *Neoscapteriscus* presence, and test efficacy of control strategies (e.g., Parkman et al. 1993; Frank & Walker 2006; Kerr et al. 2014; Mhina et al. 2016; Aryal et al. 2019).

The first mole cricket traps were constructed in the 1970s with a battery-operated tape recorder as the sound source and a 1.2-m-diam sheet-metal funnel attached to a jar as the catching device (Ulagaraj 1975, 1976; Ulagaraj & Walker 1975). Walker (1982) and colleagues placed a synthesizer, amplifier, and power source with a switch to toggle between mole cricket species' mating calls into a battery-powered box that became the first-ever semi-automatic mole cricket trap. Walker (1996) and colleagues further advanced these traps by building the first microprocessor-based mole cricket trap, powered by a 12-volt battery, and furnished with a built-in photocell to autonomously time broadcasts. Development of such traps initially required electrical and audio engineering skills, and most mole cricket researchers contracted out their broadcast systems (e.g., Thompson & Brandenburg 2004).

Advances in audio and computer technology enabled Dillman et al. (2014) to construct an acoustic trap to survey *N. borellii* by combining a commercially available Arduino microcontroller platform (Mankin et al. 2012, 2016; Johnson et al. 2018) with an open-source 'wave shield' (Adafruit Inc., New York, New York, USA) that allows a nontechnical user to play recorded sounds from an SD memory card into audio output. Dillman et al. (2014) connected the audio output to an amplifier and a pair of motorcycle speakers (Pyle Audio, Brooklyn, New York, USA), powered with a 12-volt battery. Their initial collection device was an assembly of two 1.5-m diam wading pools constructed as in Thompson & Brandenburg (2004). One wading pool was filled to about 10 cm depth pure sand mixed with perlite to harbor captured mole crickets and limit desiccation, and the second pool was empty with 6 holes cut into it, and placed over top of the sand-filled pool, minimizing escape by captured mole crickets and predation from vertebrate predators (Thompson & Brandenburg 2004). This wading pool trap design enables retrieval of live specimens for use in experiments.

To conduct studies described here, we constructed a modified version of the Dillman et al. (2014) acoustic wading-pool trap, hereafter termed as the Borelli Vicinus Acoustic Pool trap, with 2 modifications. One modification was the use of an SD memory card that broadcast 4 s of separate recordings from both *N. borellii* and *N. vicinus* played in a continuous loop (Fig. 1), and the second was the addition of a 12-volt solar panel (model #41007; RDK Products, Buford, Georgia, USA) to recharge the 12-volt battery during daylight, eliminating the need for routine field recharges (Fig. 2A). We obtained recordings of each species' mating call from the Singing Insects of North America database (http://entnemdept.ufl.edu/Walker/buzz/index.htm). As in Dillman et al. (2014), the sound pressure level was set to 106 decibels at 15 cm from the speaker.

In 2017, we deployed 1 Borelli Vicinus Acoustic Pool trap at each of 7 pasture sites throughout north-central Florida (Fig. 2B). We collected mole crickets for 10 wk from 23 Apr to 6 Jul 2017. In 2018, we redeployed the same traps at 5 pasture locations (Fig. 2B). Mole crickets were collected for

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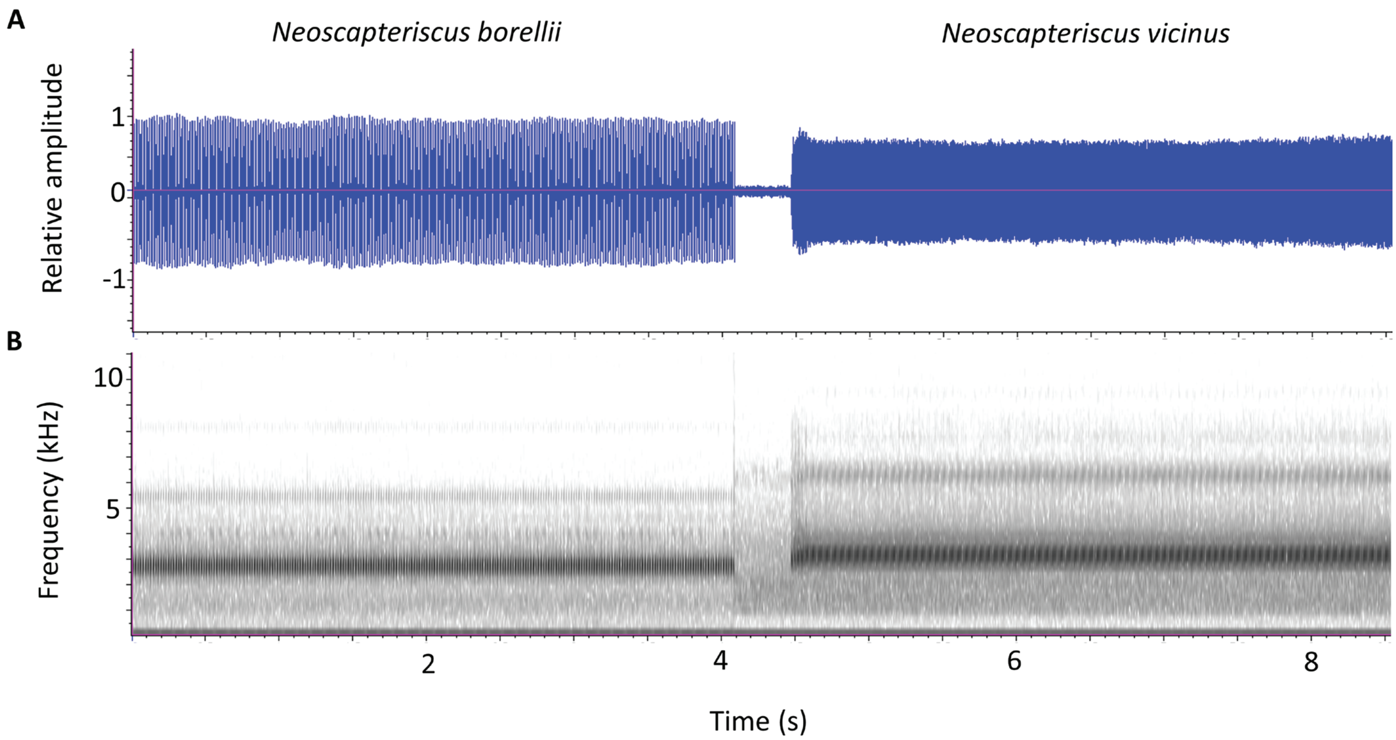

Fig. 1. (A) Oscillogram and (B) spectrogram of *Neoscapteriscus borellii* and *N. vicinus* species-specific mating calls broadcast from speakers in a continuous loop. Darker shading in spectrogram indicates greater energy at specified frequency and time.

8 wk from 7 Feb to 5 Apr 2018. Sites were at least 48 km apart in 2017 and 16 km apart in 2018, and spanned approximately 9,000 km^2. Each trap was placed in the middle of a bahiagrass (*Paspalum notatum* Flüggé; Poaceae) pasture away from any acoustic (e.g., anthropogenic noise sources) or structural (e.g., trees, buildings) interference. Mole crickets were collected from the traps once per wk, and immediately placed individually into clear plastic vials, labeled by site and date, and taken to the laboratory for identification. All collected mole crickets were identified to species.

In 2017 and 2018, the traps caught varying numbers of *N. borellii* and *N. vicinus* at each location (Fig. 2A, B). In sum, we collected 675 *N. borellii* and 13 *N. vicinus* in 2017, and 71 *N. borellii* and 438 *N. vicinus* in 2018. The bias towards *N. borellii* in 2017 and *N. vicinus* in 2018 was expected because the 2017 surveys were conducted after peak *N. vicinus* flight activity had occurred, and the 2018 surveys before *N. borellii* peak flight activity. By connecting a solar panel to each trap's battery, no batteries needed a recharge through the dura-

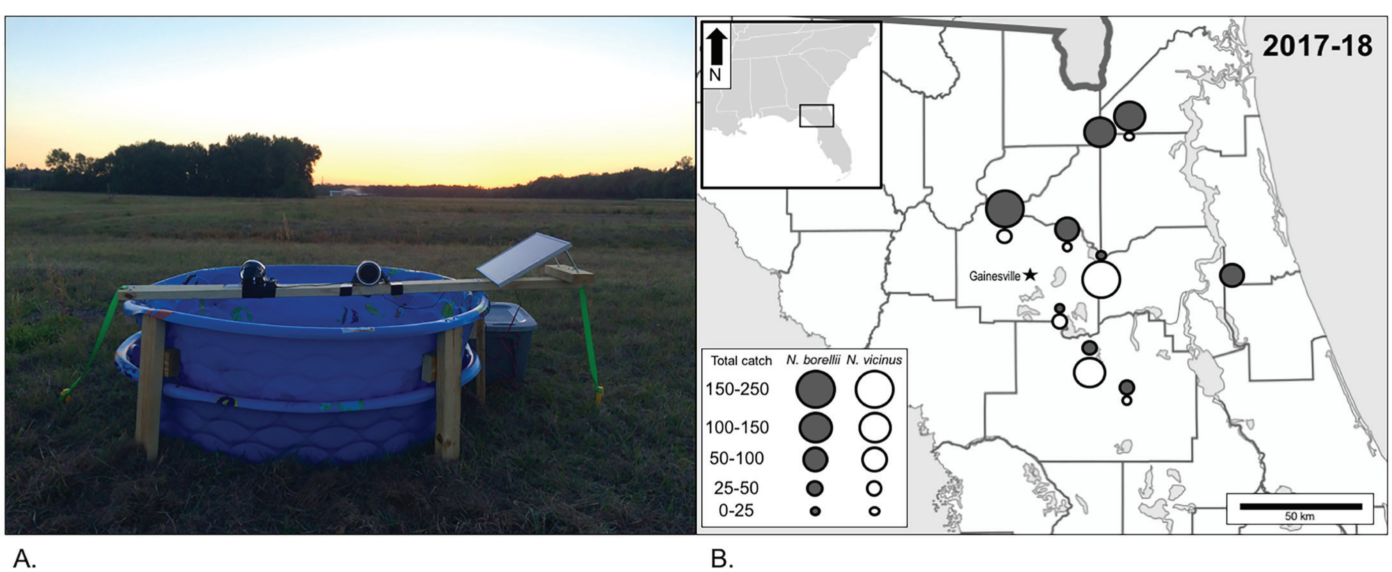

Fig. 2. (A) The Borelli Vicinus Acoustic Pool trap used to attract and capture *N. borellii* and *N. vicinus* mole crickets throughout the study. (B) Total *Neoscapteriscus* mole crickets captured in Borelli Vicinus Acoustic Pool traps from late spring (23 Apr to 6 Jul) 2017 and early spring (7 Feb to 5 Apr) 2018 in northern Florida, USA. Dark circles represent *N. borellii* and light circles represent *N. vicinus*. The size of each circle indicates the total individuals captured per site from 0 to 250, as illustrated in the figure legend. The same traps with the exact same settings were used in both yr.

tion of this study. As expected based on previous studies (Ulagaraj & Walker 1973), traps captured predominantly female mole crickets (> 85% of captured individuals). Nevertheless, several hundred individuals of both species were captured by Borelli Vicinus Acoustic Pool traps each year, indicating that our Borelli Vicinus Acoustic Pool traps, playing a continuous loop of 4-s intervals of the 2 species-specific mating calls (Fig. 1), successfully attracted and captured both invasive mole cricket species. Our current Borelli Vicinus Acoustic Pool trap design costs approximately $400 per trap for materials, a one-time $500 program license fee for use on multiple traps, trap assembly labor costs, and technical training or support, which is prohibitive for many. Therefore, future work should develop trap designs that cost a fraction of this price and require little technical knowledge or training, enabling land managers and researchers to employ these tools to monitor invasive pests (not as a pest control tool) on their respective properties.

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Summary

There is an extensive history of mole cricket integrated pest management (IPM) research in Florida, USA (Kerr et al. 2014; Mhina et al. 2016), much of which has incorporated acoustic trapping as a monitoring tool. The acoustic trap design described in this report provides a method for surveying 2 *Neoscapteriscus* mole cricket species relatively autonomously at low cost, which can facilitate future efforts to study the biology, ecology, and distribution of invasive mole crickets (e.g., Walker 1988). In a broader context, however, there remains considerable need to reduce the costs and simplify the technology of these and other traps based on inexpensive microcontroller platforms, not only for *Neoscapteriscus* species, but also for other pests that mate based on either acoustic or vibrational communication (Mankin 2012).

Key Words: mole cricket; forage; turfgrasses; survey

Sumario

Existe una extensa historia de investigaciones sobre el manejo integrado de plagas (MIP) del grillo topo en la Florida, EE. UU. (Kerr et al. 2014; Mhina et al. 2016), una gran parte de las cuales ha incorporado el atrapamiento acústico como herramienta de monitoreo. El diseño de la trampa acústica descrito en este informe proporciona un método para estudiar 2 especies de grillo topos del género *Neoscapteriscus* de forma relativamente autónoma a bajo costo, lo que puede facilitar los esfuerzos futuros para estudiar la biología, ecología y distribución de los grillo topos invasivos (por ejemplo, Walker 1988). Sin embargo, en un contexto más amplio, sigue existiendo una necesidad considerable de reducir los costos y simplificar la tecnología de estas y otras trampas basadas en plataformas económicas de microcontroladores, no solo para las especies de *Neoscapteriscus*, sino también para otras plagas que se aparean en base a la comunicación acústica o vibracional (Mankin 2012).

Palabras Clave: grillo topo; forraje; céspedes; sondeo

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