A field evaluation of a trap for invasive American bullfrogs

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Native to the eastern United States, American bullfrogs (*Rana catesbeiana* [*Lithobates catesbeianus*]) have been introduced in many countries throughout the world. There have been relatively few effective and efficient control methods developed to manage bullfrogs. Particularly in the Hawaiian Islands, Pacific coast of North America, and Japan, finding effective methods for controlling invasive bullfrogs is needed with special emphasis on low impacts for sensitive native species. We conducted a field study to examine the efficacy of a newly designed live trap for capturing invasive bullfrogs. We found that our trap was successful at capturing bullfrogs because we captured up to seven in a single trap overnight. Fishing lures, live crickets, and lights were used as attractants and all capture bullfrogs, however more research is needed for finding effective attractants. We captured one known non-target frog that was released. Our findings suggest that the multiple capture traps could effectively be used as part of an integrated pest management strategy for controlling invasive bullfrog populations.

Key words: American bullfrog, attractants, integrated pest management, invasive species, multiple capture trap, *Rana catesbeiana*

INTRODUCTION

ORIGINALLY native to eastern North America, American bullfrogs (*Rana catesbeiana* [*Lithobates catesbeianus*]), hereafter referred to as bullfrogs, have been introduced throughout western North America, Oceania (Pacific Ocean islands), Asia, Europe, the Caribbean, and South America (Staples and Cowie 2001; Witmer and Lewis 2001; Lever 2003; Govindarajulu 2004; Palen 2006). Most introductions occurred from1900 to 1940, primarily because bullfrogs served as a food source for humans, but also as released pets or biological control agents (Witmer and Lewis 2001; Lever 2003; Boersma et al. 2006; Kraus 2009). The ecological impacts of invasive bullfrogs are known to cause significant impairment to native species (Hayes and Jennings 1986; Kiesecker and Blaustein 1997; Kiesecker et al. 2001; Doubledee *et al.* 2003; Lever 2003). In places like the Hawaiian Islands, control of bullfrogs is becoming increasingly essential to assist the recovery of native species (Staples and Cowie 2001). However, in other locations, (e.g., Japanese Islands), little information is known about the impacts from bullfrogs, even though they have been established for over 50 years (Lever 2003).

Bullfrogs can inhabit most permanent water sources including canals, reservoirs, marshes, ponds, and lakes (Bury and Whelan 1984). There have been reports of bullfrogs travelling distances of 1–2.8 km, over land, to colonize new water sources (Willis et al. 1956; Miera 1999). In their native range, bullfrogs and other *Rana* species coexist through selective habitat preferences, where the bullfrogs primarily select the water margins and other species select deeper water or more inland locations (Stewart and Sandison 1972). However, in their introduced range, invasive bullfrogs may displace native amphibians from their preferred habitats (e.g., Moyle 1973; Hammerson 1982; Kats and Ferrer 2003), which can indirectly increase the native species' susceptibility to other predators (Kiesecker and Blaustein 1998).

The relatively large body size of bullfrogs gives them a competitive advantage over many native species (Bury and Whelan 1984; Kraus 2009). Invasive bullfrogs out-compete and depredate native species (Hecnar and M'Closky 1997; Díaz De Pascual and Guerrero 2008). Many studies have implicated invasive bullfrogs as being directly responsible for declines in native herpetofauna (Moyle 1973; Hammerson 1982; Schwalbe and Rosen 1988; Kupferberg 1997). Some examples of the native species that are consumed by bullfrogs include: Pacific treefrogs (*Hyla regilla*), red-legged frogs (*R. aurora*), leopard frogs (*R. pipiens*), yellow-legged frogs (*R.muscosa*), alligator lizards (*Elgaria multicarinatus*), western fence lizards (*Sceloporus occidentalis*), and Oregon *garter snakes (Thamnophis atratus hydrophilus*) among many others (Hammerson 1982; Crayon 1998; Adams 1999; Doubledee et al. 2003; Kats and Ferrer 2003; Govindarajulu 2004). Typically, bullfrogs will consume any fish, wildlife, or insects smaller than it is (Staples and Cowie 2001).

Bullfrogs may also impact native amphibian populations through other, less obvious means; such as carrying pathogens which adversely affect native frogs. Recent research has implicated invasive bullfrogs as reservoir hosts of the chytrid fungus, *Batrachochytrium dendrobatidis*, which if transmitted to some indigenous amphibians can be severely

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pathogenic (Hanselmann *et al.* 2004; Pearl and Green 2005; Garner *et al.* 2006). Additionally, juvenile and subadult bullfrogs have been observed initiating interspecific amplexus with native frogs, possibly resulting in reproductive interference with negative demographic consequences for native ranid populations (Pearl et al. 2005).

An immediate solution is needed to reduce or eradicate localized populations of invasive bullfrogs, especially those populations that serve as reservoirs for new infestations or expanding populations. However, bullfrogs are challenging to control because of their high mobility, generalized eating habits, and high reproductive capacity (Moyle 1973; Adams and Pearl 2007). Bullfrogs can live at extremely high densities, and when densities are reduced (e.g., after an unsuccessful eradication), their survival and successful reproductive rates increase (Altwegg 2002; Govindarajulu 2004). Hand-capturing, netting, spearing (gigging), shooting (Bury and Whelan 1984; Moler 1994), and electro-shocking (S. A. Orchard, BullfrogControl.com Inc., *personal communication*) are some of the methods that have been used to remove bullfrogs. In some cases, habitat manipulation has also been used (Adams and Pearly 2007). Many of these methods are labour and time intensive, and often do not reduce bullfrogs to desired levels (Miera 1999). Eggs and tadpoles typically are destroyed by draining ponds or chemical treatment (Moler 1994), however these methods can have undesired effects on native species, which are not well understood (e.g., Maret et al. 2006). Effective traps may provide a more non-intrusive way to reduce bullfrog populations, especially when compared to logistically challenging techniques such as hand-capture, draining ponds, or toxicant application.

A major benefit of using traps is the ability to capture targetted species over a variety of habitats (Baskin 2002), occasionally requiring relatively low labor intensity. Additionally, even if trapping is not effective for complete eradication of a pest species, it can be used as part of an Integrated Pest Management (IPM) strategy to remove individuals using a variety of methods (Schwarzkopf and Alford 2007; Witmer 2007). Particularly, multiple capture traps have been used worldwide to reduce populations of various invasive or damaging species (Manfred 1980; Reich and Tamarin 1984; Witmer et al. 2008). For example, multiple capture traps have been used to remove invasive cane toads (*Bufo marinus*) that are threatening native species and ecosystems in Australia (Lever 2003; Murray and Hose 2005; Kraus 2009). Surprisingly, multiple capture traps are one of only a few methods available for control of cane toads (Schwarzkopf and Alford 2006, 2007). Schwarzkopf and Alford (2007) predicted that highly effective trapping (i.e., removing 25–40% of the population [McCallum 2006]) could provide a valuable means of controlling toads.

There are currently no multiple capture traps that are commercially available for bullfrogs; and, to our knowledge, none have been tested for bullfrogs. Therefore, the goal of this study was to test the effectiveness of a multiple capture trap for capturing bullfrogs. We modified a multiple capture trap, originally designed for cane toads (FrogWatch, Darwin, Australia), to be used for bullfrogs. We tested these traps in ponds along the Rocky Mountain Front Range of Colorado, USA that contained bullfrogs resulting from introductions after the 1940s (Bury and Whelan 1984). Bullfrogs are considered non-native and invasive throughout the state of Colorado by the Colorado Division of Wildlife (CDOW 2010). Because there is little information available on trapping of bullfrogs, we used various types of attractants within the traps, and various placements of the traps along ponds. We also attempted to identify any non-target effects to native species.

METHODS

We conducted trials during September 2008 in small ponds near the cities of Windsor and Longmont, Colorado, and again during August 2009 in a small pond near the city of Pueblo, Colorado. We placed the traps completely or partially in ponds where invasive bullfrogs occurred. In all of the ponds, we tested two identical 69 cm × 69 cm × 25 cm traps constructed with 1.3cm × 1.3 cm wire mesh. Three sides of each trap had a one-way door (30.5 cm × 12.7 cm) comprised of clear plastic strips that hung from the top of the entry opening. We began by placing the traps on or near the water edge (<0.5 m) for the Windsor (n = 4 trap nights) and Longmont (n = 6 trap nights) ponds. During 2009, we modified the traps so they floated by attaching Styrofoam flotation devices to the underside of the traps (Fig. 1) for the Pueblo pond (n = 10 trap nights).

The traps were set in the evening shortly before dark, and were checked after daylight the next morning. Non-floating traps were placed along the pond shore. Floating traps were placed directly in the water, so that the entry doors were level with the surface of the water. Because those traps were placed in the water, the captured frogs could not desiccate, we left the traps in place during the daytime. Traps were re-located every evening so a new area was trapped every night. The traps were set at least 20 m apart so that they were not likely to influence bullfrogs near the other trap. Traps

Fig. 1. A multiple capture trap modified to float.

were always placed in locations where bullfrogs had been previously viewed or heard. Adult bullfrogs were sexed by comparing the diameter of the tympanum to the diameter of the eye on each individual (George 1938; Bury and Whelan 1984). All captured bullfrogs were removed from the ponds and euthanazed, and any non-target captures were released at the trapping site.

Because very little information was available regarding which attractants were effective for trapping bullfrogs, we tried three different attractants based on work done with other species and anecdotal evidence. For the Windsor and Longmont ponds, we used a light-emitting diode (LED) light (3 LED Headlight, Energizer, St Louis, Missouri). Light has been used as an attractant for trapping cane toads, because light attracts insects for the toads to eat, and possibly directly attracts toads (FrogWatch 2006). For the Pueblo pond, we randomly rotated combinations of attractants by trap and by trap-night (see Table 1), and recorded the amounts of bullfrogs captured for each attractant. Schwarzkopf and Alford (2007) suggested that acoustic attractants enhanced trapping success for cane toads; therefore the second attractant we tested was live crickets inside a porous plastic container wired inside the trap. Noise from the crickets was audible outside the traps. The third attractant we tested was brightly colored (red and yellow) fly-fishing lures (poppers, South Bend Sporting Goods Inc., Northbrook, Illinois) hung with monofilament line inside the trap. All hooks were removed from the lures prior to being placed in the traps. We also tested the LED light, or a 15cm yellow glow stick (Sunncon, Zhejiang, China) placed on the top of traps in the Pueblo pond. For the pueblo pond, we compared the number of bullfrogs captured by attractant with an analysis of variance (Proc GLM, SAS Institute, Cary, North Carolina, USA).

Because the pond located near Pueblo was isolated from any other water source that would allow bullfrogs to easily migrate, it served as an ideal location to identify if our trapping efforts had noticeable effects on the population. The pond was small (approximately 0.002 km^2), and was heavily infested with bullfrogs. Following the methodologies of Thompson et al. (1998), we conducted audio and visual survey counts to identify any changes in abundance of bullfrogs. We conducted the counts on the first night, before deploying the traps. During the following days we removed bullfrogs that were trapped, and during the nights we continued to conduct the counts. We conducted the audio counts by counting the total amount of bullfrog calls heard in a 10-minute period. We conducted the visual counts by recording the total number of bullfrogs observed using a spotlight during a single pass walking around the perimeter of the pond. Survey counts were conducted twice each night, starting at midnight. We used the largest audio and visual count, respectively, for each night as the nightly estimate. Bullfrogs were less

likely to be active when temperatures were cooler, and therefore would call less, so we recorded the ambient temperature each night at midnight.

Finally, on the last night of removal in the Pueblo pond, we initiated a basic IPM strategy by attempting to hand-net bullfrogs in two passes around the perimeter of the pond. All hand-netted bullfrogs were also removed from the pond. We conducted the final audio and visual survey counts one night after all methods of removal had ceased.

RESULTS

Cumulatively, we captured 1 bullfrog from the Windsor and Longmont ponds in 10 total trap nights. At the Pueblo pond, we captured 18 bullfrogs in 10 trap nights. Of the 19 bullfrogs we trapped, 15 (79%) were males and 4 (21%) were females. We captured 1 known non-target frog, a northern leopard frog (*Rana pipiens*), that was released unharmed. The traps were effective at capturing multiple bullfrogs in one night, with the highest number of captures being seven bullfrogs in one trap. We also found that bullfrogs were captured during the day and night, but mostly at night.

In the Pueblo pond, each type of attractant or combination of attractants was tested between 1 and 4 trap nights. All attractants captured bullfrogs, and the rate of captures did not differ among types ($F_{6,9}$ = 1.12, P = 0.384; Table 1). All attractants remained intact within the traps, even with bullfrogs present.

At the pueblo pond, the ambient night temperatures fluctuated between 16–23°C during our 6 nights of monitoring. We removed 13 additional bullfrogs with a hand-net on the fifth night. When we combined one night of hand-netting with five nights of trapping, the audio and visual counts showed some evidence of being reduced (Fig. 2).

Table 1. Attractant types and bullfrog captures in a 0.002 km² pond near Pueblo, Colorado, August 2009.

Attractant(s)	Trap nights	Bullfrogs captured per night Mean	Range
Fishing lures	3	3.6	1 – 7
Fishing lures + Lights + Crickets	2	1.5	0 – 4
Fishing lures + Lights	1	1.0	NA
Lights + Crickets	2	0	NA

DISCUSSION

We discovered that multiple capture traps can be easily placed near or in ponds to capture bullfrogs, and many bullfrogs can be captured in a single trap overnight. The three study sites showed varying degrees of success with the multiple capture traps. The low capture rates observed during 2008 may have occurred because traps were deployed late in the summer, when nights were cool and insects were not very abundant or active. In 2009, the temperatures were warmer. However, we also suspect that placing the traps on the shore may not be as effective as floating the traps in the water, because floating traps may serve as platforms for bullfrogs to exit the water. Additionally, placing the traps on flotation devices made the entire pond accessible to trapping, not just the shoreline. This is important because all

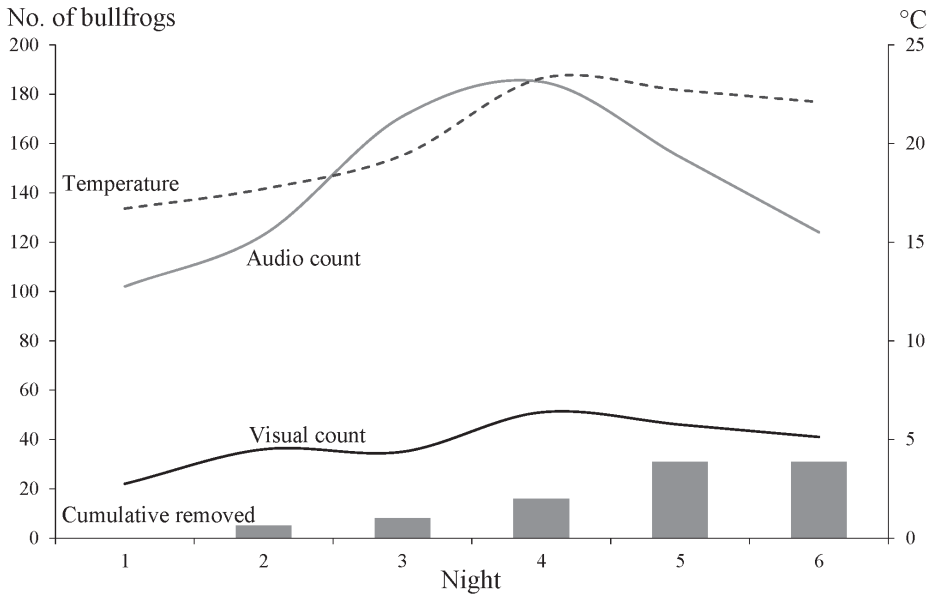

Fig. 2. Number of bullfrogs removed (with traps and hand-nets) and counted (during audio and visual surveys) in a 0.002 km² pond near Pueblo, Colorado, August 2009. The sixth night was used for conducting counts only.

individuals must be put at risk of being removed for any successful eradication (Parkes and Murphy 2003). Any areas left as refuges for bullfrogs and could serve as population sources, thereby sustaining the overall population and allowing dispersal into new areas.

We only observed 1 non-target capture during our study and it was easily released, but we acknowledge that other non-targets may have been captured and consumed by bullfrogs while in the traps. We also noted that the mesh size of the trap was likely large enough for some smaller non-targets to escape. More investigation is needed to determine if bullfrogs consume non-target species inside traps.

We captured nearly four times as many males than females during our trapping effort, which has also been shown to occur with cane toads in Australia (Schwarzkopf and Alford 2007). For cane toads, one likely hypothesis was that the males explored their habitats more than females, providing greater chances of encountering and entering a trap (Schwarzkopf and Alford 2002). We suspect the same may also be true for male bullfrogs. The home ranges of males are generally larger than females (Currie and Bellis 1969). During the breeding season a male will aggressively defend a territory ranging from 3–25 m of shoreline (Emlen 1968, Wiewandt 1969). This may suggest that trapping during breeding could yield higher bullfrog captures, especially for males. However, removing females is likely more critical for effectively reducing a population, because reports have shown that a female can deposit between 1 000–40 000 eggs in a mass, sometimes twice in one year (Bury and Whelan 1984).

Finding an effective attractant to lure bullfrogs into the traps is very important for increasing trap success. Observations of our traps in the field suggest that our lures were not very attractive. On multiple occasions, bullfrogs were observed lingering directly outside traps for an extended period, but did not enter them. We also noticed that whenever we captured females, we typically had at least 1 or more males captured. Of the 4 females we captured, 2 were engaged in amplexus with a male inside the trap when we approached. This may suggest that a female bullfrog intentionally placed, or captured, in a trap could attract multiple males. Similarly, Schwarzkopf and Alford (2007) found that using conspecific mating calls as acoustic attractants increased the capture success for cane toads for both sexes. We suggest that further research be conducted on finding more attractive lures for bullfrogs, perhaps using mating calls or a female bullfrog. Using a female bullfrog as an attractant may increase the capture success of male bullfrogs; because males are opportunistic when attempting to mate with females (Howard 1978).

We found some evidence to suggest that removing bullfrogs using a basic IMP strategy may have reduced the abundance of bullfrogs in a small, heavily infested pond. During the first two nights that we conducted audio and visual counts, the air temperature was cooler than the remaining nights, thus may have lowered bullfrog activity. Low temperatures may help explain why abundance counts were lower the first nights than the last. However, during the last night of the counts, the air temperature was high and the numbers for both abundance counts were reduced. We suspect the bullfrog abundance was being noticeably reduced in the pond, but we could not quantify the portion of population reduction. Because the pond was isolated we were not able to test a control pond; therefore our results could be related to other environmental factors that we could not identify. More research should investigate the effectiveness of using traps within an IPM strategy for removing bullfrogs.

IMPLICATIONS FOR MANAGEMENT

Based on the success we had with trapping bullfrogs in this field evaluation, we recommend that similar multiple capture traps be considered as part of an IPM strategy for removing invasive bullfrogs. Floating the traps is an effective way of trapping aquatic frogs. Another advantage of using this multiple capture trap design is the easy release of non-target captures. The occurrence of non-target captures should be further investigated especially at locations like Hawaii, where a variety of sensitive amphibian species are known to exist. Removing all or part of invasive bullfrog populations should help alleviate depredation, interspecific competition, and disease transmission for many native species, thereby decreasing threats to biodiversity.

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