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Improving Bullfrog Capture Methods in Areas Managed for Hawaii's Endangered Endemic Waterbirds

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ABSTRACT: American bullfrogs were introduced to Hawaii's wetlands from California in the late 1800s. As in other areas where American bullfrogs have been introduced, these voracious predators threaten Hawaii's native fauna. Of particular concern are Hawaii's federally endangered endemic waterbirds: the Hawaiian stilt, Hawaiian coot, Hawaiian gallinule, and Hawaiian duck. Wetland managers in Hawaii control bullfrogs for the benefit of these endangered waterbirds. The U.S. Fish and Wildlife Service manages several core wetlands on national wildlife refuges in Hawaii that are necessary for survival of the waterbirds. These refuges include bullfrog control as a management strategy. Unpublished studies on James Campbell National Wildlife Refuge have documented bullfrogs as a major predator of newly hatched endangered waterbird chicks. This refuge currently maintains a year-round bullfrog trapping program with increased effort in the spring during the peak of waterbird breeding. Existing trapping methods employ a simple fish-style funnel trap with red flagging used as an attractant. As part of an effort to improve efficacy of current bullfrog capture methods, we investigated the effectiveness of different attractants for the traps. In addition to the current attractant of red flagging, we tested light, bullfrog call acoustic recordings, and life-size bullfrog decoys. The results showed that most of the treatments were no more effective than the control (no attractant). If we can improve bullfrog trap yields, we expect greater chick survival for the endangered Hawaiian waterbirds.

KEY WORDS: *Anas wyvilliana*, bullfrog, endangered species, *Fulica alai*, *Gallinula galeata sandvicensis*, Hawaiian coot, Hawaiian duck, Hawaiian stilt, Hawaiian gallinule, *Himantopus mexicanus knudseni*, *Lithobates catesbeiana*, National Wildlife Refuges, *Rana catesbeiana*

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INTRODUCTION

The North American bullfrog [*Lithobates (Rana) catesbeiana*] is native to the central and eastern United States and southern Canada, but this species has been widely introduced beyond its native range (Bury and Whelan 1984, Adams and Pearl 2007). The introduction of bullfrogs to novel aquatic systems has resulted in devastating consequences for native fauna (Bury and Whelan 1984, Adams and Pearl 2007, Snow and Witmer 2010). Introduced bullfrogs have outcompeted native amphibians and negatively impacted almost every other cohabiting aquatic animal assemblage, which has led to their designation as one of the world's worst invasive species (Bury and Whelan 1984, Lowe et al. 2000, Adams and Pearl 2007, Louette et al. 2014).

Bullfrogs are believed to have arrived to the Hawaiian Islands from California in the late 1800s and early 1900s (Bryan 1932, Kishinami 2001). After introduction, they quickly spread to most of the main Hawaiian Islands (Hawaii). Bullfrogs in Hawaii are known to consume native fauna and threaten some of Hawaii's most endangered wetland biota (Viernes 1995, Kishinami 2001, USFWS 2011). Of particular concern are Hawaii's endangered endemic waterbirds the Hawaiian stilt (*Himantopus mexicanus knudseni*), Hawaiian coot (*Fulica alai*), Hawaiian gallinule (*Gallinula galeata sandvicensis*) and Hawaiian duck (*Anas wyvilliana*). Specifically, bullfrogs consume newly hatched chicks of these endangered species (Viernes 1995, Kishinami 2001, USFWS 2011), and

with total species populations of only several thousand, the loss of every individual has the potential to further threaten each species' existence.

The accepted wetland management strategy for the endangered Hawaiian waterbirds includes nonnative vertebrate predator control as a key component (USFWS 2011, Underwood et al. 2013). Wetland managers in Hawaii routinely target bullfrogs as part of these control efforts. In Hawaii, the U.S. Fish and Wildlife Service manages several of the most important wetlands needed to promote recovery of endangered waterbirds, as part of the National Wildlife Refuge System. At James Campbell National Wildlife Refuge (Refuge), Hawaii, staff have documented bullfrogs as a major predator of newly hatched chicks (unpubl. report). The Refuge staff conducts a year-round bullfrog trapping program with increased effort during the peak of endangered waterbird breeding in the spring.

Although a variety of control techniques are available for bullfrogs (Snow and Witmer 2011), the current Refuge control scheme relies on the use of a fish-style funnel trap with red flagging as an attractant. Each trap can capture multiple individuals during a single deployment. Though effective at bullfrog capture, in this study we explored the possibility of improving capture rates by switching the attractant. The findings of our study are applicable across Hawaii's wetlands and could apply across the landscape to which American bullfrogs have been introduced.

Figure 1. Location of James Campbell National Wildlife Refuge, with Ki'i Unit of the refuge highlighted, Island of Oahu, HI.

Figure 2. Fish-style funnel trap with flagging as attractant, used to capture American bullfrogs at James Campbell National Wildlife Refuge, HI.

MATERIALS AND METHODS

We conducted this study at James Campbell National Wildlife Refuge during November-December 2013 and November 2015-March 2016. The actively managed wetlands on the Refuge are situated within the Ki'i Unit (Figure 1), which is composed of ten wetland ponds (1.1-3.9 ha) and several canals found in close proximity to each other. Wetland ponds and canals are separated by a 2-3 m grass-covered berm. For our study, we selected six of the ten wetland ponds based upon their suitability for bullfrogs; suitability is determined primarily by water salinity. The highest densities of bullfrogs occur in the wetland ponds with the freshest water.

To capture bullfrogs, we used 15 fish-style funnel traps (Figure 2) measuring 1.2 m in length by 0.5 m in diameter, constructed of 2.54×2.54-cm wire mesh, with the interior funnels constructed of 0.64×0.64-cm wire mesh. We placed an attractant in the interior of the trap above or near

the waterline after trap positioning. The traps were placed <2 m from shore with the majority being <0.5 m from the water's edge. The traps rested directly on the pond substrate and were located in water with a maximum depth of 0.3 m and a minimum depth of 0.2 m. This water depth was necessary for the interior opening of the funnel to be ¼ to ¾ submerged in water. The ideal positioning is to have the interior funnel entrance half submerged in the surrounding water; however, due to difference in water depth and substrate, the aforementioned range was acceptable.

In order to randomly assign trapping locations, the shoreline of the each wetland pond was gridded with a 10×10-m square overlay. We chose a 10-m² grid because it corresponded with the maximum area of a male bullfrog territory, or zone of defense (Emlen 1968, Wiewandt 1969, Bury and Whelan 1984). Two wetland ponds were selected for each trapping session. We paired wetland ponds by both proximity and size to attain a universe of 60 and 100 potential trap locations. With 15 traps, this number of potential trap locations allowed us to achieve a 15-25% grid saturation rate. Considering the minimum water requirement for trap placement, prior to each trapping session we inspected the wetland ponds and removed from consideration grid cells that were dry or nearly dry.

From the pool of available grid cells in the chosen wetland ponds, we randomly selected 15 locations for traps. Each location was then randomly assigned one of the treatments (control, light, flagging, decoy bullfrog, or acoustic recording). We tested only two attractants and a control (no attractant) in each phase of the study. All trapping sessions during a phase tested the same two attractants. During each trapping session all attractants and the control had five replicates. Traps were continually deployed in the same location during each trapping session (four nights) and were checked each morning. This methodology mimics the current trapping procedure where traps are deployed in the same location for an entire work week. Captured bullfrogs were sexed by comparing the size of tympanum to the size of the eye (Bury and Whelan 1984) and then euthanized. All non-target captures were released at the trap site. After each trapping session of one work week, the traps were removed from the site. We selected a new set of random locations and treatment assignments in an alternate pair of wetland ponds for the next trapping session. We did not trap the same wetland ponds in consecutive weeks.

For attractants, we used 1 3/16-inch (3-cm) red flagging tape (Brady Corp., Milwaukee, WI). We purchased life-like decoy bullfrogs (Incredible Creatures American Bullfrog, Safari Ltd., Miami Lakes, FL) measuring 11.7×13.2×7.1 cm, which is the size of a small to medium adult bullfrog. We obtained bullfrog call acoustic recordings from CaliforniaHerps.com (2015). To play the acoustic recordings we purchased water resistant internal storage Mp3 players (STORMp3, ToiletTree Products Inc., Ramsey, NJ). We used two sources of light in each trap testing light as an attractant. The first was a LED solar floating pool light (Eveltek, Seenwell Technology Co. Ltd., China), and the second was a collapsible waterproof LED lantern (either Viking Nature Camping Lantern, Amazon.com; or

Luci Inflatable Solar Lantern. MPOWERD, New York, NY). To conserve battery life or allow for solar recharge, both the Mp3 player and the lights were turned off at dawn when the traps were checked and then turned back on at dusk.

In November-December 2013 we conducted a pilot study. Treatments included a control (no attractant), red-flagging and the decoy bullfrog. This pilot consisted of three trapping sessions of various lengths (two to five nights/session) within four wetland ponds. Due to the limited and irregular sampling effort during this phase, results are reported anecdotally, as we were not able to conduct statistical analyses. The results of the pilot study showed no discernable difference in the efficacy of red flagging, decoy bullfrogs, or the control. This led us to evaluate two new attractants in the next phase (November 2015-March 2016), light and bullfrog calls, which we thought might be more effective. We did not test red-flagging in this second phase, as its efficacy during our pilot study was similar to the control. The second phase consisted of nine equal length trapping sessions of four nights each within six wetland ponds. We evaluated the results of this phase in R Stats Version 3.2.1 (R Development Core Team 2015) using ANOVA, and a Tukey HSD (Honest Significant Differences) procedure to compare the effectiveness (frogs/night) of these two attractants with the control and each other. We also conducted the same statistical analyses to test the relationship between sex and attractant, and to evaluate how the length of time the trap was in the same location impacted catch effectiveness. We used the conventional value of $P < 0.05$ as a measure of significance.

RESULTS

During the pilot study we trapped a total of 55 trap-nights per treatment across three sessions. Capture rates were similar for the three attractant types (Figure 3). Catch per trap-night was 0.2 frogs/night for red flagging, 0.15 frogs/night for the decoy bullfrog, and 0.18 frogs/night in the control. As mentioned previously, the limited number of sessions and variability in session length made statistical evaluation inappropriate; however, there did not appear to be a difference in effectiveness between red-flagging or decoy bullfrogs and the control.

In the next phase we trapped a total of 180 trap-nights per treatment across nine trapping sessions. Catch rate varied from 0.45 frogs/night for the acoustic recordings, to 0.26 frogs/night for the control, and 0.29 frogs/night when light was the attractant (Figure 3). The best-performing attractant varied each trapping session, with acoustic recordings capturing the most frogs in six of nine weeks, and the light attractant performing best in two weeks. The ANOVA test found a significant difference among attractants in this phase ($P < 0.05$). The post-ANOVA pairwise comparison using Tukey HSD found the observed differences were only significant between the acoustic recording and the control ($P < 0.05$) and not significant for the other comparisons (light vs. control, $P < 0.14$; calls vs. light, $P < 0.88$). We found males were captured significantly more frequently in the traps with calls than in traps with other attractants ($P < 0.04$). Females did not have a similar pattern of response ($P < 0.34$). When we evaluated catch per day by attractant, the only pattern that emerged was a

Figure 3. Bullfrog captures per trap-night by treatment and phase. A) Pilot study results with N = 55 trap-nights per treatment. B) Second phase results with N = 180 trap-nights per treatment. *Catch rate significantly higher for calls when compared to the control.

declining frequency of capture in the call traps for each day they were deployed in the same location. However, the pattern was not significant ($P < 0.11$).

DISCUSSION AND CONCLUSIONS

We found that playing bullfrog calls was the most effective attractant. However, this attractant's effectiveness appears to be biased toward males and its success diminished the longer the trap was in the same location. This finding may not be all that surprising, given that we would expect males with territories in the vicinity of the trap to respond to the perceived intruder in rapid fashion. Although we did not measure the size of frogs, anecdotally we caught bigger male frogs in call traps on the first two nights of trapping compared with the following days. One limitation of our study is that we have not conducted our experiment during the bullfrog's spring breeding season. We might expect an even greater frog response, in particular from females, to calls during the breeding season. An attractant that can increase the capture of females is more important than one that attracts males, as many females can be bred by a single male.

Nonnative invasive predators have been identified as a key threat to endangered waterbird species (USFWS 2011). Our results suggest that we can improve current bullfrog control efforts by switching the attractant to bullfrog calls and possibly by moving those call traps more frequently than weekly in the wetland units. However, the

additional cost and time required to implement these changes may not warrant a departure from current methods. Both the Mp3 players and lights needed batteries replaced every two or three days and needed to be turned off and on daily to extend battery life. This extra effort added 50% more time to the control process. Nevertheless, the biggest expenditure of time occurs when setting traps in the wetland unit. If we moved traps and reset them every two nights, it would more than double the time required to control bullfrogs. Although changes to the current methods may result in the capture of more bullfrogs, we have no clear understanding about the threshold level of bullfrog control necessary to minimize impacts on waterbird recruitment. Pre- and post-trapping surveys on the Refuge have shown existing control methods can result in a decline of 50% or more in bullfrog abundance (unpubl. report). Even so, more research needs to be done to evaluate the effectiveness of the current control methods. We also do not understand the impact of current control methods on bullfrog population dynamics. We do not know if removing bullfrogs simply allows for quicker maturation or increased survival among the remaining bullfrogs. There is also uncertainty whether or not a more targeted approach toward large individuals via shooting, netting, gigging, or other means might have greater benefit for the native waterbirds, or if we should be focusing on other life stages like tadpoles in order to better control the population. Although this study has focused on improving the current methodology, we also need to evaluate alternate methods for controlling bullfrogs. Any evaluation of switching attractants or methods needs to consider the cost-to-benefit ratio as it relates to time spent in control versus positive impact to waterbirds.

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