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Do the Tracks Track? Evaluating the Effectiveness of Baited Ink-plates for Rat Monitoring in a Montane Rainforest

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ABSTRACT: Since human arrival to the Hawaiian Islands, non-native predators have decimated native flora and fauna. In particular, native forest bird populations have suffered due to rat (*Rattus* sp.) depredation. To protect native species, conservation practitioners have been removing rats and other rodents from ecologically sensitive areas. Identifying reliable strategies for assessing the effectiveness of these control efforts is critical, particularly given limited resources for conservation. A common method used for monitoring rodents is baited ink-plates within a tunnel (hereafter ink-plates). While this method is widely used, its effectiveness has yet to be evaluated in many ecosystems, including montane rainforests. To evaluate the effectiveness of monitoring rat presence with ink-plates, we focused on the Alakai Plateau on the island of Kauai, which is home to several of Hawaii's most critically endangered birds, and where over 300 Goodnature™A24 rat traps are currently in operation. The Alakai experiences approximately 11 m of annual precipitation, giving rise to areas of dense vegetation, which may affect how rats encounter and interact with ink-plates. We paired 116 Reconyx™ HyperFire cameras with individual ink-plates inside tracking tunnels in the summers of 2022 and 2023, at a site with an ungulate exclusion fence and at a site with no fencing, to monitor areas both with and without rat traps. Rats were detected on approximately twice as many cameras (34.5% presence) compared to ink-plates (16.4% presence). These results suggest that cameras could be a powerful tool for accurately assessing the efficacy of conservation interventions to mitigate the impact of invasive predators on Hawaii's native birds. Increased investments in camera technologies are worth consideration, particularly in the case of critically endangered species. Further research into the cost-effectiveness versus the information gained by the two methods could help further refine conservation strategies.

KEY WORDS: ink-plates, island conservation, rat monitoring, *Rattus* sp., tracking tunnels, trail cameras

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INTRODUCTION

Invasive mammals are destructive to the ecosystems in which they are introduced, both ecologically and economically, and ultimately cause irreparable damage both to biodiversity and financially (Doherty et al. 2016, Fantle-Lepczyk et al. 2022). Mammalian invaders are particularly detrimental to island ecosystems (Courchamp et al. 2003). Because many insular species evolved in the absence of mammalian and reptilian predators, they are often naïve to these non-native predators. As a result, invasive mammalian predators have contributed to the decline and extinction of numerous island species (Towns et al. 2006). To prevent the extinction of these island species and protect insular ecosystems, invasive mammal control, particularly rodent control, is often employed to mitigate the damage that they cause (Courchamp et al. 2003, Oppel et al. 2011, Duron et al. 2017). While controlling invasive mammals does not address all the issues faced by island species, it can provide immediate results and counteract continuing pressure from other threats, such as disease and habitat loss (Doherty et al. 2016).

Three species of invasive rat species are commonly found in island ecosystems − Norway rats (*Rattus norvegicus*), Pacific rats (*Rattus exulans*), and black rats (*Rattus rattus*) − and all have been shown to depredate native island species (Harper and Bunbury 2015). While several control methods exist, including poison distribution and snap traps, a relatively new method has been gaining popularity in island ecosystems, the Goodnature™ A24 automatic rat and stoat trap (A24). A24s are a CO_2-loaded bolt-action trap that self-resets (Peters et al. 2014, Carter and Peters 2018, Shiels et al. 2019). These traps are particularly attractive to predator control efforts because not only can they self-reset, they also only need the lure and CO_2 replaced every few months (Franklin 2014) and they do not employ toxicants. Compared to snap traps, A24s are more efficient when funding and personnel time is limited are low (Franklin 2014). A24s can be placed in a variety of landscapes and, by humanely killing rodents quicky, they are able to help protect not only the native birds, but the native insects and plants of Hawaii, many of which are endangered (Shiels et al. 2019).

The Kauai Forest Bird Recovery Project (KFBRP), a conservation organization on the island of Kauai in the Hawaiian Islands, has been utilizing these self-resetting traps as a conservation method for the native forest birds of the island of Kauai since 2015 (Crampton et al. 2022). To assess the effectiveness of the rodent trapping effort within the remaining forest bird habitat on the island, KFBRP has been utilizing baited ink-plates which are placed in plastic tunnels and put on the landscape in trapped (treatment) and non-trapped (control) areas. Preliminary ink-plate data have shown a decrease in rodent populations in the treated areas (Crampton et al. 2020). While this monitoring approach is the current method of measuring rat abundance, its accuracy as a measure of rodent population size has not been tested in a wet montane environment such as the Alakai Wilderness Preserve. While previous work in a California orchard showed that ink-plates sufficiently monitored rodent populations (Baldwin and Meinerz 2022), a New Zealand study found that trail cameras were better tools for rodent population estimates (Anton et al. 2018).

Given the differences in the effectiveness of ink-plates demonstrated by these studies, the efficacy of this rat monitoring method in the steep, wet, and channelized terrain of the Alakai Wilderness Preserve needs to be verified. This is of particular importance because this region is home to Kauai's last remaining native forest birds, which are under severe threat from rat depredation. To understand the effectiveness of ink-plates of monitoring rat populations in this type of environment, we paired trail cameras in conjunction with ink-plates in July of 2022 and 2023 to monitor how rats consistently rats are detected by ink-plates. We hypothesized that cameras would detect more rats than ink-plates based on previous studies in more similar environments (Anton et al. 2018).

METHODS

Study Area

This study took place on the Alakai Plateau located within the Alakai Wilderness Preserve. The study area consists of wet and mesic montane forest annually receiving approximately of 11 m of precipitation/year and consists of native vegetation (Giambelluca et al. 2013). This forest is dominated by ohia lehua (*Metrosideros polymorpha*) with other key tree and shrubs species in this forest including olapa (*Cheirodendron trigynum*), lapalapa (*C. platyphyllum*), ohia ha (*Syzygium sandwicensis),* kawau (*Ilex anomala),* ohelo (*Vaccinium calycinum*), and kanawao (*Broussaisia arguta*) (Hammond et al. 2015, Behnke et al. 2016, Crampton et al. 2017).

Within the eastern Alakai Wilderness Preserve, the State of Hawaii's Division of Forestry and Wildlife owns a large tract of land where native forest bird conservation efforts have consistently occurred: Fenced (84 ha) and Unfenced (64 ha). Starting in 2015 and 2018, respectively, the two sites have had delineated areas where rat trapping via A24s is occurring (treatment) and non-trapped areas in which only rodent presence/absence is monitored (control). The fenced study site was entirely contained in 2017 to exclude ungulates which included feral pigs (*Sus scrofa*), feral goats (*Capra hircus*), and black-tailed deer (*Odocoileus hemionus*). To date, removal efforts have been successful at removing the previously listed species. and all these species have been primarily successfully removed. Currently, 200 A24 traps are deployed in the treatment area of the fenced site. The unfenced study site currently contains 124 A24 traps and remains unfenced with feral ungulates roaming freely.

Sampling Design

Tracking Tunnels that house the ink-plates have been placed on the landscape since prior to the initial deployment of the A24 rat traps at both the fenced and unfenced sites. To monitor the effectiveness of the trapping, tunnels were also placed in control (monitoring only) plots where no traps were are located. The tunnels, which stay on the landscape year-round, were placed 100 meters apart from each other.

In July of 2022 and 2023, ink-plates baited with peanut butter were placed in the tunnel for a total of three trap nights and were retrieved after the third night of deployment. Photos were taken of the ink-plates and the presence of tracks were recorded as well as if they were rat or mice. For the duration of this study, we used motion activated Reconyx™ HyperFire 1 and HyperFire 2 trail cameras. All cameras were set to maximum sensitivity and to take bursts of three images without delay for 24 hours throughout the deployment. In total, 116 cameras were deployed, paired with a baited ink-plate and placed approximately 1 – 1.5 m away from the tunnel and approximately 26 cm above the ground, with the entirety of the tunnel in view (Figure 1). Camera station deployment was spatiotemporally randomized across all available tracking tunnel locations. Half the of the cameras were deployed in areas where trapping took place (treatment) and half were deployed in areas where no traps are deployed (control). In 2022, a total of 51 cameras were deployed, with 24 placed at the fenced site, evenly distributed between trapping areas and control areas (12 in each area for a total of 24 cameras). At the unfenced site, 27 cameras were deployed, with 13 deployed in the control area and 14 within the treatment area. In 2023, a total of 65 cameras were deployed, with 30 cameras within the fenced site (15 within the treatment area and 15 within the control area) and 35 cameras were deployed across the unfenced sites (17 within the treatment area and 18 within the control only areas).

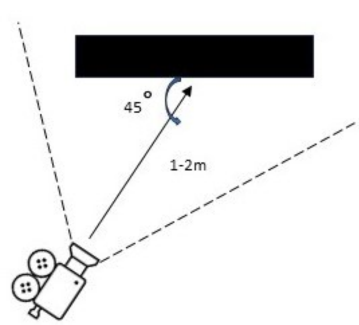

Figure 1. Diagram of trail camera placement when facing a track-tunnel housing an ink-plate. Cameras were pointed at a 45° angle and 1 to 2 m away as to attempt to capture rodents approaching each end of the tunnel from the other side that the ink-plate is contained in that the camera could potentially miss.

Analysis

To make the camera image data comparable to that of the ink-plates, which are only documented as presence/absence data, we treated the camera images similarly and only marked if a rat or mouse was present in at least one image during the study time. Camera images and ink-plates were reviewed separately from each other. We used a logistic regression model for each method (camera or ink-plate), with presence/absence (1/0) at each station as the response variable. For each method, we modeled presence/absence in relation to three variables: habitat (stream or plateau), treatment type (experimental or control), and site (fenced or unfenced). Analysis was preformed using R 4.3.1 (R Core Team 2023)

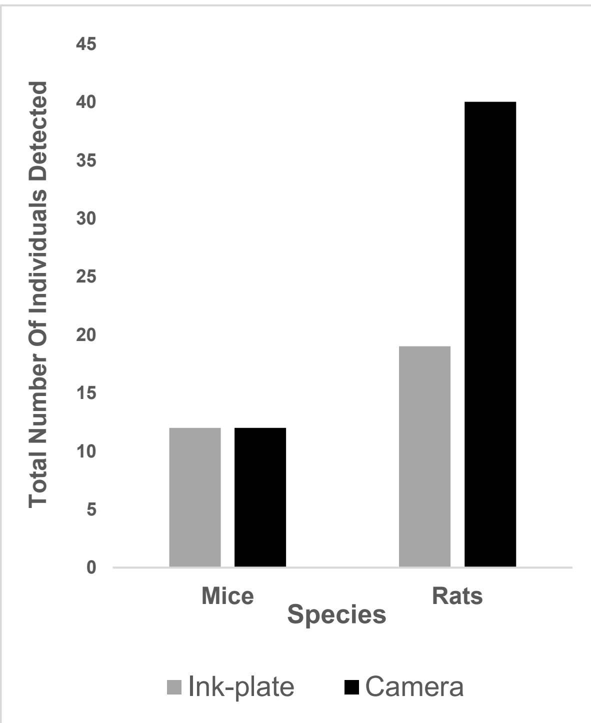

Figure 2. Raw counts of rodent presence on ink-plates and cameras at both sites across both years over three consecutive nights per year.

RESULTS

Rats

In total, rats were detected at 19 ink-plates and 40 cameras out of 116 survey stations, meaning rats were detected at 16.4% and 34.5% survey stations, respectively (Figure 2). The cameras detected 21 more sites with rats present than the ink-plates. There were no occurrences in which rats were only detected on the ink-plate and not the paired camera (Table 1). The differences between trail camera detection and ink-plate detection varied by site and treatment across both years (Table 1). Differences between treatments were stronger and clearer from the camera data than the ink-plate data. When the years were combined for analysis, rats in areas without rat traps were 3.028 times more likely (1.37 to 6.94; 95% C.L.) to be detected by cameras than rats in areas with rat traps ($p=0.007$). For ink-plates, rats in areas without rat traps were 2.51 times more likely (0.91 to 7.65; 95% C.L.) to be detected by ink-plates than rats in areas with rat traps ($p=0.09$). For both analyses, there was no differences between habitats ($p\geq0.87$) or site ($p\geq0.55$).

Mice

Mice were detected at 12 of the monitoring stations on both ink-plates and trail cameras (Figure 2). In some instances, mice were detected by trail cameras, but not the associated ink-plates, and in other instances were detected by ink-plates and not the associated trail cameras.

DISCUSSION

Trail cameras, in general, detected twice as many rats as the baited ink-plates, which supports our hypothesis that cameras would more reliably detect the presence of rats on the landscape. In all images evaluated, approximately half of the rats detected did not enter the tunnel, and thus were not detected by the ink-plates. In and of itself, this is not a fatal monitoring flaw, provided the proportions stay spatiotemporally consistent. However, in our study, the differences between the two monitoring methods varied widely during the two years across both treatment and control areas and between fenced and unfenced sites, complicating our inference of rat presence within these areas. For instance, cameras indicated that there were significantly fewer rats in areas with rat traps than areas without rat traps ($p=0.007$), while ink-plates also indicated fewer rats in trapped areas but did not support a significant difference ($p=0.09$). For mice, the two monitoring methods detected the species equally, with both methods missing mice equally. One clear advantage of cameras is the increased detail of data they collect. For instance, one camera pointed at a tracking tunnel containing an ink-plate documented the presence of two rats simultaneously. Additionally, the images collected would allow for identification of the rat species present. Future research directions will be to calculate rodent occupancy using both methods and compare the differences in results to further refine monitoring methods to increase the efficacy of rodent trapping on the landscape.

While cameras offer some clear advantages over ink-plates, there are some limiting factors as well. Conservation funds are finite (Bottrill et al. 2009, Waldron et al.

Table 1. Totals and percentages of rat (*Rattus* sp.) presence on ink-plates and on cameras at both the fenced and unfenced site as well as treatment type ("On" being areas with traps and for each site).

Location	Ink-plate	% Ink-plate	Camera	% Camera	Total Stations
Fenced	10	18.52%	20	37.04%	54
Control	7	25.93%	13	48.15%	27
Treatment	3	11.11%	7	25.93%	27
Unfenced	9	14.52%	20	32.26%	62
Control	6	19.35%	14	45.16%	31
Treatment	3	9.68%	6	19.35%	31
Grand Total	19	16.38%	40	34.48%	116

2013), and trail cameras are expensive, especially in wet or harsh climates where the most weatherproof devices, such as Reconyx™ cameras ($459.99 as a base cost at the time of this study), must be utilized. Using lithium batteries, as can be necessary with long deployments and harsh conditions, can further complicate matters due to shipping regulations and higher costs. Additionally, cameras are heavy for personnel to carry across the landscape, limiting the number that can be deployed at once. Ink-plates are significantly less expensive than trail cameras (approximately $3.00 each not including shipping and handling or the outer tracking tunnels which are approximately $7.00), as well as lighter in weight for people to carry. Both methods require people to travel the same distance, therefore requiring similar amounts of time for deployment and retrieval. Identification of the presence or absence of rodents on an ink plate can be done fairly quickly and requires less data processing time compared to going through camera images for the deployment depending on the number of incidental captures of non-target species such as birds as it is possible that rodents do not appear until the last image on the last day of deployment. Overall, we found that the quality and quantity of data collected by cameras is extensive compared to that of ink-plates, which provide results at a coarser scale, but individual projects must weigh this against the increased costs associated with cameras. In the end, the results of our study are similar to that of the New Zealand study, but different than those of the California citrus orchards (Anton et al. 2018, Baldwin and Meinerz 2022). This strongly supports the idea that one should evaluate their chosen monitoring methods within the system in which one is working, as so many environmental factors can influence rats (Cox et al. 2000, Goedert et al. 2020). In addition to these considerations, further research into the cost efficacy versus the information gained by the two methods could help further refine conservation methods.

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