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Evaluation of lethal control of introduced sugar gliders as a tool to relieve bird nest predation

Running Head: Culling an introduced bird predator

Abstract

Lethal control of invasive mammalian predators can be controversial and is rarely a ‘silver bullet’ for conservation problems. Evaluating the efficacy of lethal control is important for demonstrating the benefits to threatened species are real and detecting unexpected perverse outcomes. We implemented a pilot study to evaluate if lethal control of introduced sugar gliders *Petaurus breviceps* can reduce the rate of nest predation on Tasmanian hollow nesting birds including swift parrots (*Lathamus discolor*). Using a before-after-control-impact design, we implemented a lethal control treatment whereby we attempted to remove sugar gliders from three treatment sites. In each time period across sites we monitored quail eggs in nest boxes to record predation, and used cameras to detect sugar gliders. We caught nine sugar gliders over three treatment sites. The model best supported by the data indicated an effect of site × time period on both egg survival and the rate of glider detection on cameras. There was no support for an effect of treatment on our data. We also recorded predation of a real swift parrot nest by sugar gliders at a treatment site where we recorded no predation of quail eggs. Our pilot study shows that at small scales, intensive lethal control of gliders yields low capture rates and no discernible effect on the metrics we measured. We conclude that alternative approaches to controlling the impact of sugar gliders, such as habitat protection, are critical in this study system before lethal control is widely implemented as a management tool.

Key Words: common starling *Sturnus vulgaris,* conservation management, nest survival, predator control, sugar glider *Petaurus breviceps*, swift parrot *Lathamus discolor*

Introduction

Invasive predatory mammals are a major threat to global biodiversity (Woinarski et al., 2015, Medina et al., 2011, Szabo et al., 2012), and alien predators can have double the impact of native predators (Salo et al., 2007). A common approach used by land managers to relieve the negative impacts on threatened prey species from invasive mammals is lethal control (Doherty and Ritchie, 2017), and similar approaches are used in agricultural contexts as well (Van Eeden et al., 2018). However, a review of the evidence from lethal control programs (Doherty and Ritchie, 2017) identified four common perverse outcomes of lethal predator control: herbivore and mesopredator release, disrupted predator social systems, predator immigration and ethical concerns. Doherty and Ritchie (2017) recommend that adaptive, evidence-based approaches should be used in the implementation of lethal control of invasive predators so that the efficacy of interventions can be evaluated adequately. Global meta analysis have shown that the main determinant of management success is the efficiency of the approach used to manipulate predator populations (Salo et al., 2010).

Here we report the results of a pilot study in Tasmania, Australia, aimed at relieving predation on hollow nesting birds by sugar gliders *Petaurus breviceps* (Stojanovic et al., 2014). Sugar gliders are introduced to Tasmania (Campbell et al., 2015), and are a severe threat to nesting swift parrots *Lathamus discolor* (Heinsohn et al., 2015). There is intense conservation interest in relieving predation pressure on swift parrots because they are critically endangered (Heinsohn et al., 2015). Non-lethal techniques like predator exclusion devices on nest boxes (Stojanovic et al., 2019) offer protection to individual nests, but finding a way of protecting nests in natural tree hollows over larger spatial scales is crucial because only a fraction of parrots utilize nest boxes. Trials of predatory owl call broadcasts at night did not reduce sugar glider predation on real or artificial bird nests (Owens et al., 2020). These mixed results do not provide effective long-term, large-scale tools for protecting swift parrots from sugar gliders.

Recently, Natural Resource Management South implemented a pilot study to evaluate the efficacy of lethal control as an alternative approach to reducing predation on nesting birds. Using a BACI design, we aimed to identify whether lethal control of sugar gliders: (i) reduced predation on artificial nests,

(ii) reduced sugar glider detection rates on remote cameras, and (iii) is logistically feasible at the spatial scales necessary to protect swift parrots.

Methods

Study sites and treatment groups

The pilot study took place at six locations in Tasmania, Australia, where swift parrots and sugar gliders are known to be sympatric (Heinsohn et al., 2015). The control sites were at Buckland (lat: 42°31', long: 147°39'), Lake Leake (lat:42°1', long: 147°49') and the Meehan Range (lat: 42°49', long: 147°24'). The treatment sites were at Tooms Lake (lat:42°13', long: 147°46'), Rheban (42°36', long: 147°54') and Southport Lagoon (lat: 43°29', long: 146°55'). All sites were dominated by dry woodland, and understory composition ranged from grassy to shrubby.

The treatment involved two capture techniques: (i) active trapping using Mawbey traps, and (ii) passive trapping using nest boxes fitted with doors operable by a person on the ground. A veterinarian euthanized trapped sugar gliders by using lethal injection. The location of both trap types was haphazard within swift parrot nesting habitat, and all sites had at least one natural swift parrot nest hollow within the array of nest boxes and traps. Our study involved a 'before' period (14 nights duration) when all sites were established and 20 nest boxes, 10 Mawbey traps (deactivated) and five camera traps baited with universal mammal bait were deployed. The 'after' period at treatment sites involved three trapping sessions of four nights duration each. Due to logistic constraints, we deployed personnel at only one site in a given week, so there was an interval of two weeks between trapping sessions at a given site. After the completion of the nine week 'after' period, we ceased trapping at sites for three months. We then implemented a 'long after' period, comprising a further two days of monitoring at each treatment site, with an interval of 21 days between egg deployment and follow up monitoring.

We assessed the impact of our treatment in two ways. At both treatment and control sites we deployed one quail egg in each of the 20 nest boxes at the start of each time period. At the end of each time period we checked whether quail eggs had survived the interval. We monitored glider occurrence at the sites using cameras, and tallied the total number of nights in each time period at all sites that we detected sugar gliders.

We spaced nest boxes and cameras ~30m apart within a given site to make monitoring feasible. This reflects the natural distribution of natural nests of swift parrots, but it is likely that the same individual sugar gliders preyed on multiple nests at the site level, and so we include site as a fixed effect in our analysis below. However, we assumed that predation events at a given nest box over successive time periods are independent of one another. Sugar gliders are the main predator of bird nests in the nest boxes we used (Stojanovic et al., 2019), but we also recorded high occupancy of nest boxes by common starlings *Sturnus vulgaris* at Lake Leake and Buckland. Common starlings compete with swift parrot for nests and destroy their eggs (D.S. unpublished data). We included data from nest boxes where common starlings destroyed the quail eggs because sugar glider removal may result in increased common starling abundance via relaxed predation pressure at artificially abundant nesting sites, creating the potential for a perverse outcome for parrots.

Analysis

We compared competing models using Akaike's Information Criterion, but corrected for small sample sizes (AICc), and we considered that models within 2 ΔAICc had equivalent support (Burnham and Anderson, 2002). All analyses were undertaken in R (R Core Team, 2017). We used predation of quail eggs as a response variable, and fitted generalized linear models site ID, treatment, time period, site ID × time period and treatment × time period as fixed effects. We used a binomial error distribution, and to account for differences in the duration of time periods between some sites we included the number of nights duration of each period as an offset term in the models. We never observed predation of quail eggs at Southport, so we excluded this site from analysis. We also used the number of nights sugar gliders were detected on cameras as a response variable in generalized linear models and included the same fixed effects as above. We used a Poisson error distribution and again included an offset term to account for the duration of each time period. We recorded no sugar gliders in the first two time periods at Buckland, so we excluded this site from analysis.

Results

Nine sugar gliders were captured during the implementation of the trapping treatment at Rheban (n= 3), Tooms Lake (n = 5) and Southport (n = 1).

The model best supported by the data for quail egg survival included the interaction between site and time (Table 1). Modeled estimates of predation probability are presented with confidence intervals in Figure 1. The very wide overlapping confidence limits indicate that there was low confidence in modeled estimates at some sites, and high between-site variation in predation rates over the study. The low support for the treatment × time period model (ΔAICc >2; Table 1) allows us to reject the sugar glider lethal control treatment as a potential explanation for the rate of predation on quail eggs. Instead, the model best supported by the data indicated that site level factors were the best predictor of quail egg survival. For example, high predation rates at Buckland and Lake Leake were largely attributable to common starling occupancy of nest boxes. Removal of common starling nests did not reduce predation of quail eggs because in the interval between nest box checks, common starlings were able to rebuild their nests and replace their clutches (as well as remove quail eggs from boxes). One treatment site (Southport) had no predation on quail eggs, but a real swift parrot nest within the study site failed due to sugar glider predation in the midst of the trapping effort. The other treatment sites had relatively comparable predation rates to controls, driven by sugar gliders throughout the trapping period, with a possible increase in the period long after trapping (but certainty was low given the wide confidence intervals).

The best model for the detection of sugar gliders on cameras also included the interaction between site and time (Table 2). Modeled estimates of the rate of sugar glider detection are presented with

95% confidence limits in Figure 2. The low support for the treatment × time period model (ΔAICc >2; Table 2) allows us to reject the sugar glider lethal control treatment as a potential explanation for the rate of sugar glider detection on cameras. Instead, the model best supported by the data indicates that site level factors were the best predictor of quail egg survival over time. At Southport, sugar gliders were detected more frequently on cameras before and long after the treatment was implemented. There was also a small increase in the rate of sugar glider detections by cameras at Tooms Lake in the long after period. At all other sites, rates of detection were comparable.

Discussion

This pilot study shows that site level variation, not the lethal glider control treatment, best explains variation in our quail egg and camera data. Our trapping effort totaled 36 nights, but yielded only nine sugar gliders in total, distributed between the three sites. Given these low capture rates, it is unsurprising that we found no support for the explanatory power of treatment group. Indeed, a real swift parrot nest failed due to sugar glider predation at Southport, indicating that there is a need to rethink the utility of lethal control as a management approach in this study system. The low capture rates we encountered were in spite of intensive trapping effort with limited conservation resources. Whether greater trapping effort, targeted site selection or some other adaptation of our method could improve the efficacy of lethal control remains uncertain, but seems unlikely based on our results, especially in an open system like our study sites.

There remain fundamental gaps in knowledge of the ecology of Tasmanian sugar gliders that hinder effective planning for lethal control. Although it is known that the species is widespread in disturbed forests (Allen et al., 2018), there is no information on Tasmanian sugar glider home range size, group size, immigration or behavioural plasticity in the habitats where swift parrots breed. These knowledge gaps are crucial for effective management. Although the scope of our results are limited by small scale and sample size, our pilot study is evidence that reduction of predation on bird nests by gliders is unlikely to be achievable with the approach we trialed. Future studies should evaluate how forest configuration (connectedness to other forest patches) might influence local extinction/recolonization dynamics of sugar gliders (assuming higher capture rates are achievable) and the scale at which trapping needs to occur to affect local densities. Furthermore, the risks identified by Doherty and Ritchie (2017), i.e. herbivore and mesopredator release, disrupted predator social systems, predator immigration and ethical concerns, remain unresolved for our study system. For example, the quail egg predation by common starlings we report highlights that mesopredator release is a possibility because sugar gliders prey on common starlings and potentially suppress their occupancy of nest sites (D.S. unpublished data). Unless common starlings are actively managed concurrently with sugar gliders, any benefits of culling the latter species may be nullified by overabundance of the former. Furthermore, at Tooms Lake (where we trapped the largest number of gliders) we recorded higher rates of quail egg predation and detection of sugar gliders on cameras in the period long after trapping. Whether this is attributable to disruption of the sugar glider social system or immigration is unknown, but has important implications for future lethal control efforts. The major gaps in knowledge of this study system pose non-trivial risks to the effective management of the predation risk to swift parrots using the intensive interventionist approaches we trialed. Earlier work suggests that areas with greater local cover of mature, hollow bearing habitat are at relatively lower risk of predation (Stojanovic et al., 2014). In light of our study, protecting this habitat may be more cost effective over the long term than intensive lethal control at small to medium scales.

However sometimes targeted suppression of problematic species can be beneficial in open systems (Crates et al., 2018, Crates et al., 2020), and the results of intervention should be interpreted in context of the effort invested in control/ removal. In our case, we argue that the relative costs of direct interventions like lethal control should be weighed against more general interventions like protection of key breeding sites against ongoing deforestation (Webb et al., 2019). Furthermore, we show that culling gliders may yield no benefit to swift parrots if common starlings are present in an area and exert strong competition for nesting sites. Finally but importantly, there are major unresolved issues surrounding the social license of lethal control of sugar gliders. Given our results, further trials of lethal control for sugar gliders must carefully consider the risks to social license if potential benefits are either difficult to demonstrate or non-existent.

Given the ethical and welfare implications of lethal control, we argue that better evidence is needed to support the implementation of culling as a management tool for sugar gliders in Tasmanian forests. Culling wildlife is an important management strategy for managing conservation problems in situ, but requires careful evaluation of outcomes to be justifiable (Salo et al., 2010). Our pilot study is evidence of the value of trialing management techniques to evaluate whether they can achieve conservation goals. Our results are in line with those of other studies that suggest that lethal control does not always have the desired impact if the methods are inefficient or affect a too small fraction of the predator population (Salo et al., 2010, Kämmerle et al., 2019, Cobden et al., 2020). To be effective, integration of multiple management actions targeting different aspects of a conservation problem simultaneously may be necessary (Doherty and Ritchie, 2017).

Conflicts of Interest

The authors declare no conflicts of interest

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TABLES

Table 1. Ranked model list by AICc for the survival of quail eggs.

Model	df	AICc	ΔAICc	Weights
site × time period	15	415.90	0	1
treatment × time period	6	438.23	22.33	0
treatment	2	454.15	38.25	0
site	5	459.64	43.73	0
null	1	459.71	43.80	0

Table 2. Ranked model list by AICc for the frequency of detection of sugar gliders on cameras.

Model	df	AICc	ΔAICc	Weights
site × time period	18	378.12	0	1
treatment × time period	6	461.19	83.07	0
site	5	503.92	125.81	0
treatment	2	572.14	194.03	0
null	1	581.76	203.64	0

FIGURES

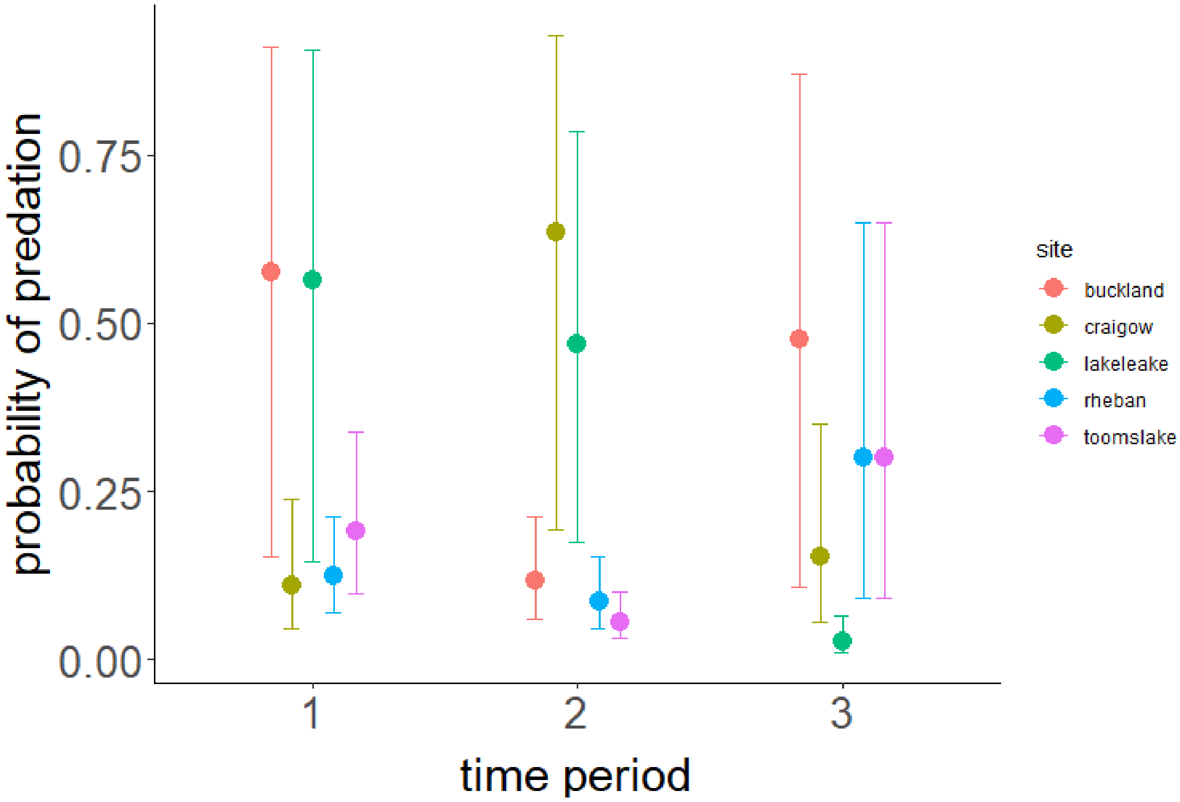

Figure 1. Modeled estimates (with 95% confidence limits) of the probability that a quail egg would not survive each time period. Treatment sites were Tooms Lake and Rheban, the others were controls. Time period corresponds to 1 – before, 2 – after, and 3 – long after implementation of the treatment.

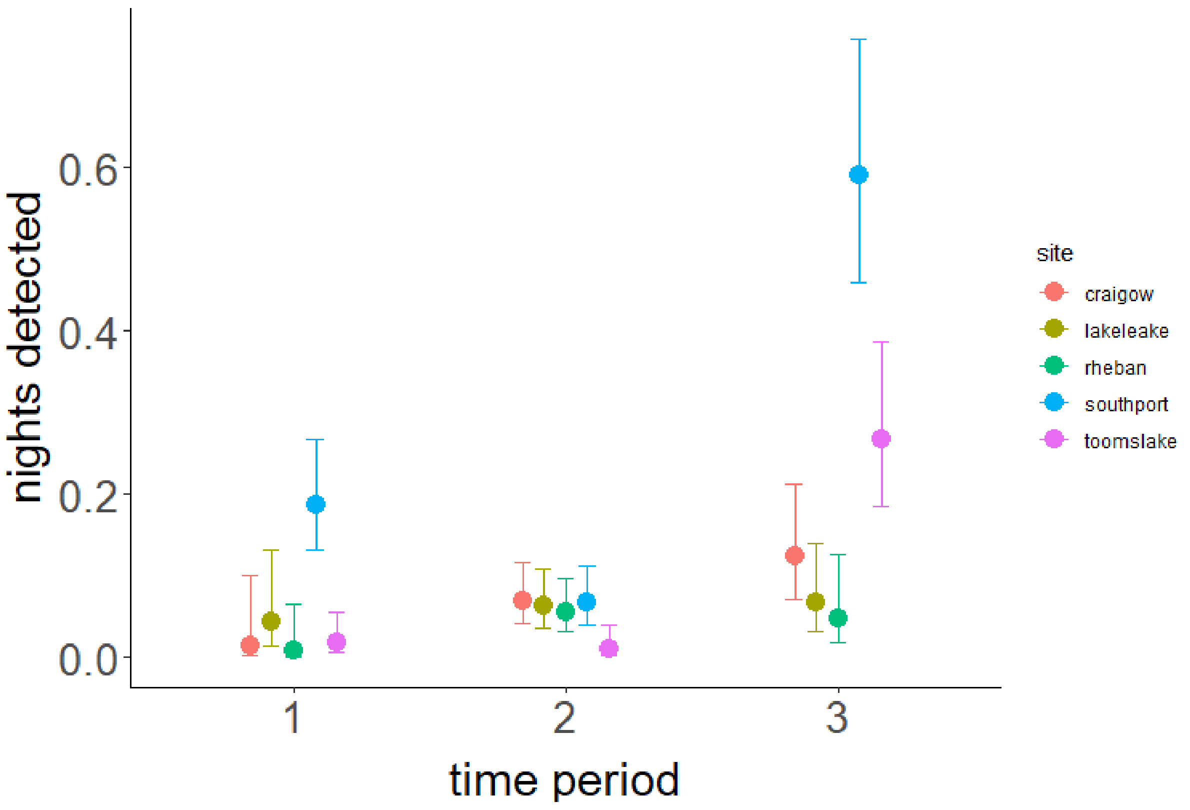

Figure 2. Modeled estimates (with 95% confidence limits) of the rate at which sugar gliders were detected on cameras. Treatment sites were Tooms Lake and Rheban and Southport, the others were controls. Time period corresponds to 1 – before, 2 – after, and 3 – long after implementation of the treatment.