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SHORT COMMUNICATION

Invasive rats consuming mountain flax nectar – resource competitors and possible pollinators?

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Abstract: The long history of human-mediated species introductions has resulted in a multitude of novel interactions around the globe. Many of these interactions have been to the detriment of native species. In New Zealand, the ship rat (*Rattus rattus*) is considered culpable for the rapid declines in the populations of numerous bird species. While seed masts have been implicated in rat population booms, alternative food resources, such as floral nectar, may play an underappreciated role in rat-bird interactions. Here, we present video footage and nectar volume data that indicate likely resource competition between rats and birds for floral nectar. Additionally, this footage indicates possible pollination services by rats. These findings suggest that attention should be paid to nectar as a limited resource that may bolster rat populations, as well as attract rats for pollination services.

Keywords: mountain flax, nectar, pollination, resource competition, ship rat

Introduction

The long history of human-mediated global species introductions shows a multitude of novel interactions. Arguably, many of these interactions have been to the detriment of the indigenous flora and fauna. Gregarious vertebrates, such as rats and mice, introduced to oceanic islands across the world have resulted in species' range restrictions, dramatic population declines, and extinctions of native species (Priddel et al. 2003; Towns et al. 2006; Hoare et al. 2007; Jones et al. 2008).

The ship rat (*Rattus rattus*), one of the most destructive of such invaders (Dowding & Murphy 2001; Global Invasive Species Database 2021), was introduced inadvertently to Aotearoa New Zealand in the early 19th century with the arrival of sealers and whalers. Ship rats spread across the country in the latter half of the 19th century (Atkinson 1973). In New Zealand, the ship rat is considered culpable for the rapid declines in the populations of numerous bird species (Atkinson 1973; Diamond & Veitch 1981). While extensive efforts have been made to eradicate populations of invasive mammalian predators, these measures are often counteracted by cyclic masting events (Harper 2005; Elliott & Suggate 2007). In particular, rimu (*Dacrydium cupressinum*) and beech (*Nothofagus* spp.) trees mass produce seeds every 2–6 years, which recruit invasive mammalian predator populations to explosive levels, leading to a significant depletion of seed resources and increased predation on birds (King 1997; Dilks et al. 2003; Harper 2005; Elliott & Suggate 2007).

Predator populations should decrease following depletion of the mast-seed resource, yet switching to alternative resources may contribute to sustaining their population size. Specifically, there is limited evidence of invasive rats consuming native flowers (Baker & Allen 1978; Campbell 1978; Jaca et al. 2019) and nectar (Pattemore & Wilcove 2012). Nectar is a calorific resource, which could help supplement omnivorous predators' diets during lean times. While floral nectar often refills following removal (Baker & Baker 1983), it is not unlimited. In the extreme case when rats consume the flowers, the nectar is removed from the resource pool. In New Zealand, some flowering plants have evolved to provide copious volumes of nectar to attract birds in exchange for essential pollination services (Craig & Stewart 1988; Castro & Robertson 1997). Through nectar consumption, rats may disrupt this evolutionary relationship (Traveset & Richardson 2006), and further decimate bird populations through competition for resources. Additionally, they may also provide pollination services (Pattemore & Wilcove 2012). However, as rats are primarily nocturnal, a clear picture of their impacts as resource competitors and pollinators remains hidden.

Methods

As part of a larger study, we used seven camera traps (Reconyx XR6) to monitor vertebrate visitation to mountain flax (wharariki *Phormium cookianum*) in a small, restored wetland area that borders a residential neighborhood in Lincoln, New Zealand (43.646778 S, 172.490108 E). This

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site had limited woody riparian vegetation and was primarily inhabited by wetland plants, such as sedges and mountain flax. The camera traps were mounted on posts approximately one meter away and level with the mountain flax inflorescences. Each camera was positioned to record visitation to two–three mountain flax inflorescences. The camera traps were programmed to be motion activated and either take bursts of photos or record short videos. These cameras were deployed continuously from 17 January to 25 January 2019. These cameras were capable of recording both diurnal visitation and nocturnal visitation, through use of dedicated dual lenses for daytime images and nighttime images with infrared illumination.

To characterize mountain flax nectar as a resource, we selected and tagged 78 unopened flowers across five plants and enclosed these flowers in fine mesh bags on 22 January 2019. These flowers were split across three treatment groups: bagged (control), experimental removal, and open visited. The next morning, when the flowers had opened, we used a pipette to extract all of the nectar from the 35 flowers in the experimental removal group and measured the nectar volume. These measurements provided the baseline nectar volume from new flowers. These flowers were again enclosed in the mesh bags. At this time, we also removed the mesh bags from the 14 flowers in the open visited group, to make these flowers accessible to floral visitors. The following morning, we used a pipette to extract and measure all of the nectar from all of the flowers in these three treatment groups (bagged: 39; experimental removal: 28; open visited: 14). Note that the experimental removal group has fewer flowers than expected, as seven broke off during the process of extracting nectar and re-bagging. We used a Kruskal-Wallis test to compare nectar volume across the groups and a Dunn test with a Bonferroni correction for pairwise comparisons between the groups (Kassambara 2021). These analyses were done in R v.3.6.3 (R Core Team 2020).

Results

Over the nine-day period, we photographed and video recorded an individual ship rat (or individuals) climbing across mountain flax inflorescences and appearing to feed repeatedly on mountain flax nectar between the hours of 23:00–04:00 across six different nights (Fig. 1; Appendix S1 in Supplementary Materials). In the photos and videos only one rat at a time was present. We also recorded silvereyes (*Zosterops lateralis*) visiting mountain flax flowers during the day, but did not detect visitation by starlings (*Sturnus vulgaris*) or bell birds (*Anthornis melanura*), which have previously been described as common visitors to flax and are present in this region (Gibb 2000; Webber et al. 2012). Additionally, upon in-person inspection of the flowers and stalks during daylight, bite marks were not present, but puncture holes indicative of nectar robbing by silvereyes and/or bumblebees were present on 3 of the 14 (21.4%) open visited flowers.

We found that new mountain flax flowers produced 111 ± 13.34 μL (mean ± SE, range 0–330 μL). Nectar volume differed across new flowers and the treatment groups (Fig. 2; Kruskal-Wallis $X^2(3) = 59.1$, $p < 0.001$, $n = 116$). Across all the groups, nectar volume was highest in the new flowers ($p < 0.004$). As expected, bagged flowers had significantly more nectar than did flowers in the experimental removal and open visited groups ($p < 0.012$). There were no statistically significant differences in nectar volume between flowers from which we removed nectar and those that were open to visitation ($p = 1$). Additionally, nectar volume for these two groups was very low (experimental removal: 6.1 ± 3.08 μL; open visited 10.4 ± 7.49 μL).

Discussion

The interactions captured here combined with the nectar volume data suggest that rats feed on mountain flax. Whether or not rats visit frequently enough to compete with birds for nectar, and if rats can function as effective pollinators of mountain flax, are intriguing questions that require more intensive study. Rats consume a wide variety of plant materials, including flowers (Campbell 1978; Jaca et al. 2019) and nectar (Pattemore & Wilcove 2012), and are often recognised by the destruction they leave in their wake. However, across all recorded observations the rat(s) appeared to consume the nectar and move across the inflorescences without gnawing or breaking off the flowers or the stalks, which is consistent with previous observations of rat visitation to native New Zealand plants (Pattemore & Wilcove 2012). Specifically, we observed movements near the rat's jaw that were consistent with the action of drinking the nectar and contact occurred between the rat's face and the stamens and pistil which extend above the petals (Fig. 1; Appendix S1). The observation of ship rat visitation is important for two reasons: (1) the removal of nectar by rats coupled with our nectar volume data suggest that rats use mountain flax nectar as a resource and that this resource is limited, and (2) rat visitation may result in pollination of these flowers.

Flax (*Phormium* spp.) produce a large volume of nectar that forms a key resource for native birds such as tūī (*Prosthemadera novaeseelandiae*) and bellbird (*Anthornis melanura*), and

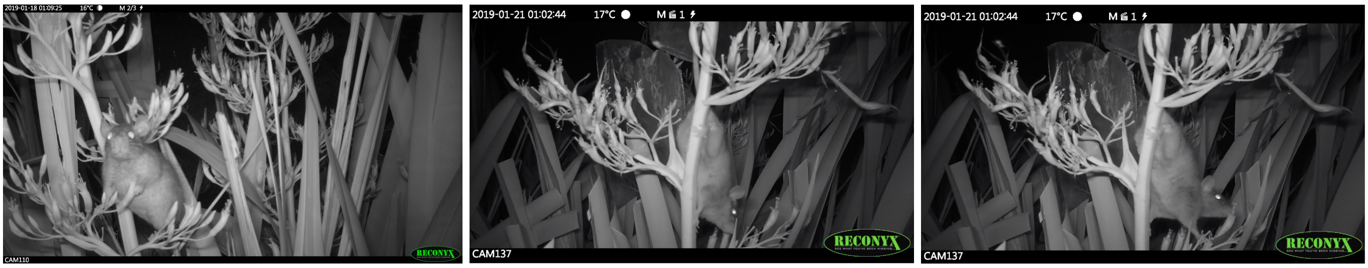

Figure 1. Photos from across multiple nights and camera traps, show a ship rat climbing across and appearing to feed from a mountain flax flower and reaching across to another open flower. During the feeding and when it reaches the other flower, the rat appears to contact the stamens and pistil, which extend above the petals and sepals.

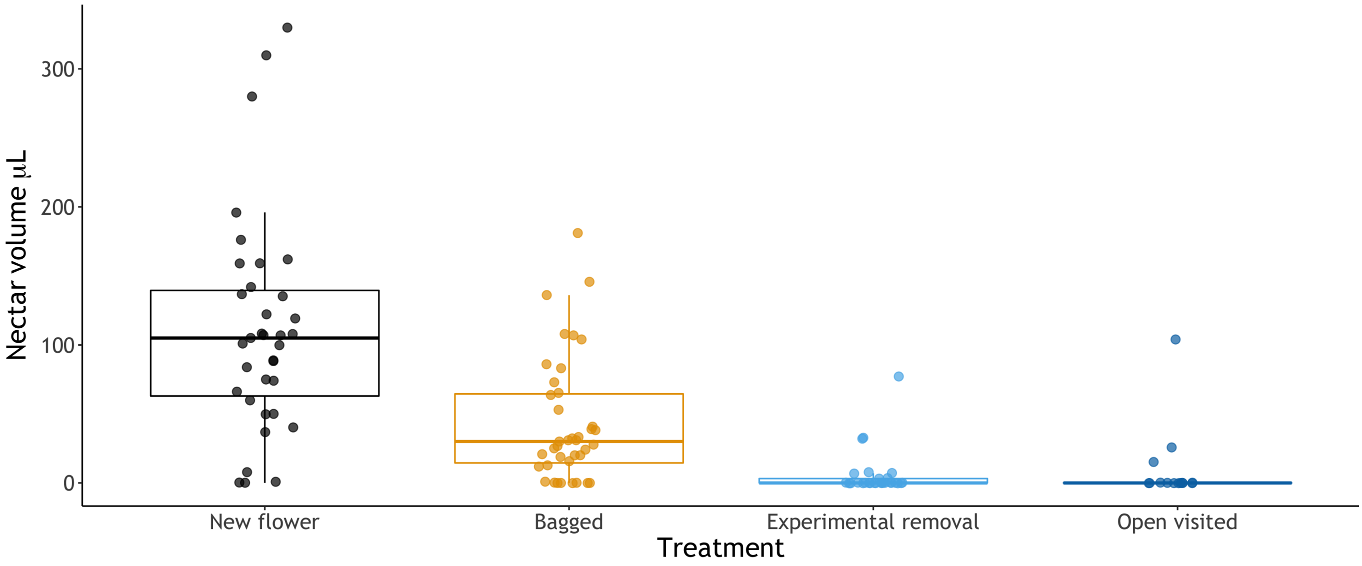

Figure 2. Nectar volumes (µL) recorded from newly opened flowers and flowers in the bagged, experimental removal, and open visited treatment groups after a 24-hour period.

self-introduced silvereye (*Zosterops lateralis*) (Craig & Stewart 1988; Webber et al. 2012). Our findings show that nectar removal (both experimentally and naturally) generally results in low replenishment of nectar. This contrasts with many other plant species that have high replenishment rates (Baker & Baker 1983; Castellanos et al. 2002). Due to these low replenishment rates, murine nocturnal nectar consumption may result in resource competition with diurnal avian visitors. With masting events inducing murine population booms, dietary inclusion of nectar resources—as observed here—may contribute to sustaining the high population sizes, as well as deplete critical resources for avian populations. This indirect competition for resources may further exacerbate myriad documented detriments rats exert on birds.

However, plants may benefit from this interaction with rats. Our observations revealed that the ship rat may serve as a novel pollinator to mountain flax. Avian species visiting flax are easily identified due to the bright orange-yellow pollen that adheres to their plumage (Thorogood et al. 2007). It is likely that this pollen also sticks to the fur of the rat visitors, and is vectored to other flowers as the rats feed. While previous work has documented a decrease in reproductive fitness in the absence of bird-mediated pollination (Craig & Stewart 1988), it is possible that rat visitation may compensate for this loss. Indeed, compensatory pollination by ship rats has been reported for other floral species such as *Metrosideros excelsa* and *Knightia excelsa* in New Zealand (Pattemore & Wilcove 2012). As such, the visitation and movement of ship rats among flax flowers may promote flax pollination. This may be especially true at sites like ours where native avian pollinators, such as tūī and bellbird are not present, and the self-introduced silvereye can be common nectar robbers of bird-specialised flowers (Anderson et al. 2011; Pattemore & Anderson 2013). Yet, at sites where avian pollinators are present, it remains unknown if rat pollination disrupts this co-evolved mutualism.

This newly documented dietary expansion of ship rats to mountain flax nectar deserves urgent attention, specifically to understand (1) if nocturnal murine nectar consumption results in resource competition with avian consumers, and (2) whether murine visitation enhances cross-pollination. These two questions highlight that a possible negative indirect interaction (resource competition) may result in a positive direct interaction (pollination).

Nocturnal consumption by rats may deplete the limited nectar resource on which the nectar-feeding birds rely. Studies tracking the amount of floral nectar removed during the night compared to the amount removed during the day would help determine whether rat consumption reduces nectar availability for diurnal birds; this could be accomplished with a reciprocal dusk and dawn bagging experiment. Also, quantification of the sugar concentration of the nectar would provide insight on the caloric value of mountain flax nectar to birds and rats. Further, whether rats enhance the reproductive success of flax can be ascertained through experimental manipulation of floral access, coupled with an assessment of seed-set (Larson & Barrett 2000; Pattemore & Wilcove 2012). Additionally, as previous work on flax identified outcrossing to be important for flax reproduction (Howell & Jesson 2013), it will also be key to capture rats to determine if they vector out-crossed pollen. With these combined experiments at multiple locations, we can begin to assess the net impacts of murine consumption of flax floral nectar on the ecosystem.

Our observation of rat visitation to flowers is timely, as February–March of 2019 was considered a “mega mast” for beech and rimu trees, along with tussock grasslands in New Zealand (Sage 2019). With this influx of resources, rodent populations were predicted to reach plague proportions (Sage 2019). It stands to reason that as seed resources dwindle, rats may increasingly consume nectar, which merits consideration of potential resource competition with nectivorous birds. However, with increased floral visitation, rats may increasingly perform pollination services. As rats have a near global distribution (Aplin et al. 2003) it is likely their roles as resource competitors and pollinators may be widespread, yet currently underappreciated due to their nocturnal nature.

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Author contributions

MLD and MKD conceptualised the research, MLD undertook the fieldwork and data analysis and wrote the original draft, and both authors contributed to review and editing of the manuscript.

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Supplementary material

Additional supporting information may be found in the supplementary material file for this article:

Appendix S1. Video of a ship rat climbing across mountain flax inflorescences and appearing to feed on nectar.

The New Zealand Journal of Ecology provides supporting information supplied by the authors where this may assist readers. Such materials are peer-reviewed and copy-edited but any issues relating to this information (other than missing files) should be addressed to the authors.