NEW ZEALAND JOURNAL OF ECOLOGY

RESEARCH

Intake of sugar water by kākā in Orokonui Eco-sanctuary

Anna Aichele[1], Philip Seddon[1] and Yolanda van Heezik[1]*

[1]Department of Zoology, University of Otago, P.O. Box 56, Dunedin, New Zealand.
Author for correspondence (Email: yolanda.vanheezik@otago.ac.nz)

Published online: 8 December 2020

Abstract: Supplementary food is provided to native birds in eco-sanctuaries throughout New Zealand to discourage their movement outside the sanctuary, to enhance reproductive success, and to promote visitor encounters with wildlife. We recorded the frequency of visits by South Island kākā (*Nestor meridionalis meridionalis)* to four feeders in Orokonui eco-sanctuary to quantify sugar water consumption as a contribution to daily energy requirements. During 11 days of observations that took place between May and July 2018, thirty-one kākā visited the feeders (16 juveniles, 8 sub-adults, 8 adults; 55% females); we obtained complete records of all visits from 20 birds. The amount of time spent drinking at the feeders did not vary between sexes, age groups, or feeders. Mean daily kilojoules consumed (4.01 kJ ± 3.30 SD) was only 0.76% ± 0.62% of daily energy requirements. Provision of sugar water therefore encourages kākā to regularly visit the feeders, providing good viewing opportunities for the public, but does not appear to form a major component of the birds' diet.

Keywords: *Nestor meridionalis meridionalis*, parrot, provisioning, supplementary feeding

Introduction

Supplementary feeding of wildlife is used to support high densities of game animals, to attract wildlife away from specific areas, to attract birds into backyards and to support them when resources may be limited, and to enhance tourist experience by promoting encounters with wildlife (Murray et al. 2016). Populations of threatened species are food-supplemented if it is felt that the availability of natural food is limiting population persistence (Armstrong & Perrott 2000; López-Bao et al. 2010). For example, Egyptian vultures (*Neophron percnopterus*) are supplemented with food in Spain, at the so-called "vulture restaurants" to improve breeding success and increase population numbers (Cortés-Avizanda et al. 2016). In New Zealand, supplementary feeding has been used to increase body mass and breeding activity in kākāpō (*Strigops habroptilus*) (Powlesland & Lloyd 1994; Clout et al. 2002), while reproductive success of reintroduced populations of stitchbird or hihi (*Notiomystis cincta*) has been improved through supplementary feeding (Ewen et al. 2015; Doerr et al. 2017).

Supplementary feeding can cause unanticipated consequences, including winter range expansion (Greig et al. 2017), altered behaviour (i.e. loss of fear of human presence; Knight & Anderson 1990; Steyaert et al. 2014), decreased migration tendency (Plummer et al. 2015), reduced dispersal of juveniles, skewed sex ratios leading to depressed productivity (Clout et al. 2002; Margalida et al. 2010), increased nest predation (Cortés-Avizanda et al. 2016), and increased disease transmission (Galbraith et al. 2017; Brown & Hall 2018; Lawson et al. 2018). Feeder-dependence has also been suggested as a potential negative impact of food provisioning (Robb et al. 2008).

Predator-free fenced eco-sanctuaries are a strategy to protect mainland populations of vulnerable native species in New Zealand. Supplementary feeding of some species has been used as a way to encourage vulnerable species to remain inside the sanctuary (Lieury et al. 2015), and also to focus their movements on particular sites to provide visitors with better viewing opportunities. An example is the supplementary feeding of South Island kākā (*Nestor meridionalis meridionalis*) in Orokonui Ecosanctuary, Dunedin. Kākā, reintroduced to the Orokonui eco-sanctuary first in 2008, and other birds are supplemented with food to discourage movements outside the limits of the eco-sanctuary and to improve visitor experience. Kākā have a varied diet of leaves, fruit, berries, sap, insects, pollen, and nectar (Moorhouse 1997). They do not regularly breed, because their reproductive cycle is linked to food availability (Moorhouse 1997; Wilson et al. 1998; Moorhouse et al. 2002; Powlesland et al. 2009).

Kākā are supplemented with two different types of food in Orokonui; pellets and bottles of sugar water are provided at four locations. This research was focused on the sugar water feeders: the aim was to determine which kākā visited the feeders, the frequency of visits by individual kākā, and the amount of sugar water consumed, in order to determine the extent to which sugar water contributed to kākā daily energy requirements.

DOI: https://dx.doi.org/10.20417/nzjecol.45.9

Methods

Study site and data collection

The study was based at Orokonui Ecosanctuary (45°46′S 176°36′E) in the South Island of New Zealand. This wildlife sanctuary is a 307-hectare fenced, mammalian pest-free protected area (pests reduced to undetectable levels except for small numbers of mice since 2012), covered with coastal forest, mainly comprised of kānuka (*Kunzea ericoides*) and broadleaved trees, with a small number of old canopy trees such as miro (*Prumnopitys ferruginea*) and rimu (*Dacrydium cupressinum*). The kākā population is estimated to be around 40 colour-banded individuals, based on annual counts made at the four feeders at dusk on four occasions, with teams at each feeder communicating with other teams when unbanded kākā were present to ensure no double-counting of these individuals (E. Smith, pers. comm.).

Banding of kākā has taken place in the sanctuary since 2008 when the first six birds were released, and every year since. Most young (~90%) are banded every year except for one or two that evade capture. Almost all adult kākā that visit the feeders are banded (~95%), and when capture sessions are carried out to catch juveniles it is uncommon that an unbanded adult is caught. Most adult kākā in the sanctuary appear to be resident as they are frequently observed, whereas juveniles tend to disperse out of the sanctuary (E. Smith, pers. comm.).

Within the sanctuary there are four wooden feeding platforms, about 1.5 m high and located at least 20 m apart, where solid food (Harrison's High Potency Coarse Pellets) and sugar water is provided. Feeding has taken place since 2008. No more than two sugar water bottles are provided at each of the four feeding stations, the first at about 10 am. The bottles are not topped up. Each platform has a rain cover: the solid food is contained within a metal feeder that has an opening mechanism designed specifically for kākā, and the sugar water is provided in two one-litre bottles with a metallic head. It is not possible to record how much solid food is consumed as the heads of the kākā are out of sight when they are using the feeder. Sugar water was mixed by adding 240 g of white industrial sugar (sucrose) to 2 L of tap water. The bottles are removed from the feeders every day irrespective of whether they are empty, and they are replaced by full bottles. Two sets of bottles are used and they are cleaned and disinfected daily. Feeding platforms are cleaned every day as well to prevent disease.

Four trail cameras (Bushnell Essential E2) were installed during winter 2018 (May and July), one at each feeder, and the activity of kākā was video-recorded during the day. Due to technical issues we configured the cameras to record video in one-minute time periods, separated by a 2 s interval. Video and the trigger and movement sensors were set to record as soon as a bird arrived on the platform. The cameras were in place for a total of 81 days. Under low light conditions the cameras switched to black and white mode, meaning that identification of birds from colour bands was impossible.

Identification of kākā visiting feeding platforms

From the video footage, we could identify kākā with bands that visited the feeders. We defined arrival time as the moment when a bird touched the platform with its feet and leaving time when the feet lost contact with the platform. Kākā without bands could not be identified and videos of these individuals as well as those where the band could not be read were discarded. Thirty-one individual kākā were identified during this study.

Feeding

Feeding behaviour was recorded only from those records in which the complete sequence of actions, from arrival to departure from the platform, was captured; i.e. a clear time when the bird began to drink, clear breathing interruptions, and a clear time when drinking finished. Arrival and departure times were used to calculate the average time spent on each platform. The beginning of drinking was defined as when a bird touched the metallic head of a sugar water bottle with its beak or tongue, and the end of drinking was when a bird stepped aside, moving both feet (more than 3 steps) or flew away. Kākā do not drink continuously; small pauses are made for breathing (breathing intervals).

We calculated duration of drinking by recording start and end times. We recorded the frequency of breathing intervals, with the duration of breathing intervals calculated from 45 observations of different individuals on platform 2.

Since it was not possible to measure directly the amount of sugar water consumed by kākā at the feeding platforms without repeatedly frightening birds away, we obtained measurements that allowed us to relate time spent drinking to the amount of sugar water consumed by measuring the drinking time, the amount of sugar water consumed, and breathing interruptions (frequency and duration), in a controlled aviary environment on three juvenile kākā of unknown sex. In the aviary we provided kākā with sugar water feeders containing known volumes of water and concentration of sugar. An observer recorded the exact time of drinking and the number of breaths taken. As soon as the birds stopped drinking, we measured the volume remaining. A total of 18 separate observations of drinking were obtained.

Data analysis

We determined the influence of the independent variables (age and sex of kākā), on the dependent variables (time spent on platform, drinking time) applying a linear mixed model using the package lmer4 for R (LMM, R Core Team 2016), with birds and feeders as random factors. Using banding information, three age groups were created after Moorhouse and Greene (1995): juveniles (under one year old), sub-adults (between 1 and 4 years) and adults (over 4 years). The dependent variables were transformed to satisfy assumptions of normality. Results from the analysis of deviance table are presented as they provided the most meaningful p-values for individual comparisons for each of the fixed effects in the mixed models.

On 11 days we were able to record all birds visiting and drinking from the feeders. All but three of the feeding sequences recorded were shorter than one minute, and these longer sequences were excluded from the analysis because they did not satisfy the three criteria for a clear sequence.We calculated the maximum likely consumption of sugar as a proportion of the daily winter energetic requirements, using the mean energy requirement of adult kākā calculated by multiplying the estimated costs of different activities, such as flight, foraging etc, based on observed time budgets, and also by a combination of allometric equations estimated for existence metabolism and time budget data for the cost of flying (528 kJ ± 5 kJ day^{-1}; Beggs & Wilson 1987, 1991).

To estimate maximum consumption, we used the average value for breathing duration when calculating the corrected value of total time spent drinking. Using the data from the aviary observations, we regressed 'total time spent drinking minus breathing time' against 'Volume consumed' (R^2 = 0.287; F = 5.235, p = 0.04), after removing one outlier, and used the equation describing the upper confidence interval of this linear relationship; i.e. Volume consumed = 7.182 ± 0.416 ml s^{-1} (time spent drinking minus breathing time). We then calculated the amount of sugar consumed by each bird, summed over the 11 days when all birds visiting the feeders were recorded, and converted this value to kilojoules. Finally, we calculated the average kilojoules consumed per day for each bird, expressed as a percentage of the daily requirement reported by Beggs and Wilson (1987).

Results

Characteristics of kākā visiting the platform

A total of 31 individual kākā, plus an unknown number of unmarked birds, visited the feeding platforms: 16 juveniles (less than one year old), eight sub-adults (1–4 years old) and seven adult birds (over 4 years old). All but four (two females and two males) of the 16 juvenile kākā hatched or reintroduced during 2017 into Orokonui visited the feeders, as well as eight sub-adults (three males and five females) and seven adults (two males and five females). Just over half (55%) of the kākā visiting the feeders were females, 42% were males and the remainder were of unknown sex.

Time spent on the platform

The LMM was significant only for age: comparisons of the three age groups indicated a non-significant tendency for juveniles to spend more time on the platform than sub-adults and adults (X^2 = 4.9087, df = 2, n = 39, p = 0.086). The longest mean time spent on the platform was 4.33 ± 0.31 s (mean ± SE), which was by a juvenile kākā. Sub-adult birds, irrespective of sex, spent less time on the feeding platforms (mean = 1.86 ± 0.41 s) than juvenile and adult kākā. Too few data points were available for adults. Sex did not influence time on the platform: females and males, irrespective of age, spent mean times of 2.29 ± 0.33 s and 2.1 ± 0.24 s, respectively.

Feeding on sugar water

A total of 77 individual drinking events by kākā free-living in the sanctuary were analysed. The mean duration of breathing intervals was 0.6 ± 1.53 s. The LMM found no significant differences in sex, age, or feeder for the sanctuary birds, and the individual comparisons of these variables were also non-significant (sex: X^2 = 2.358, df = 1, p = 0.125; age: X^2 = 2.253, df = 2; p = 0.324; Fig. 1). The longest mean drinking time recorded at any of the feeders was for adult females (10.91 ± 0.25 s). Males and juveniles had similar mean drinking times of 1.8 ± 0.16 and 2.17 ± 0.24 s, respectively. There were no consistent trends regarding time spent drinking on different feeding platforms, other than that only a very small amount of time was spent drinking at feeder one. Adult females as well as sub-adults of both sexes spent very little time drinking at

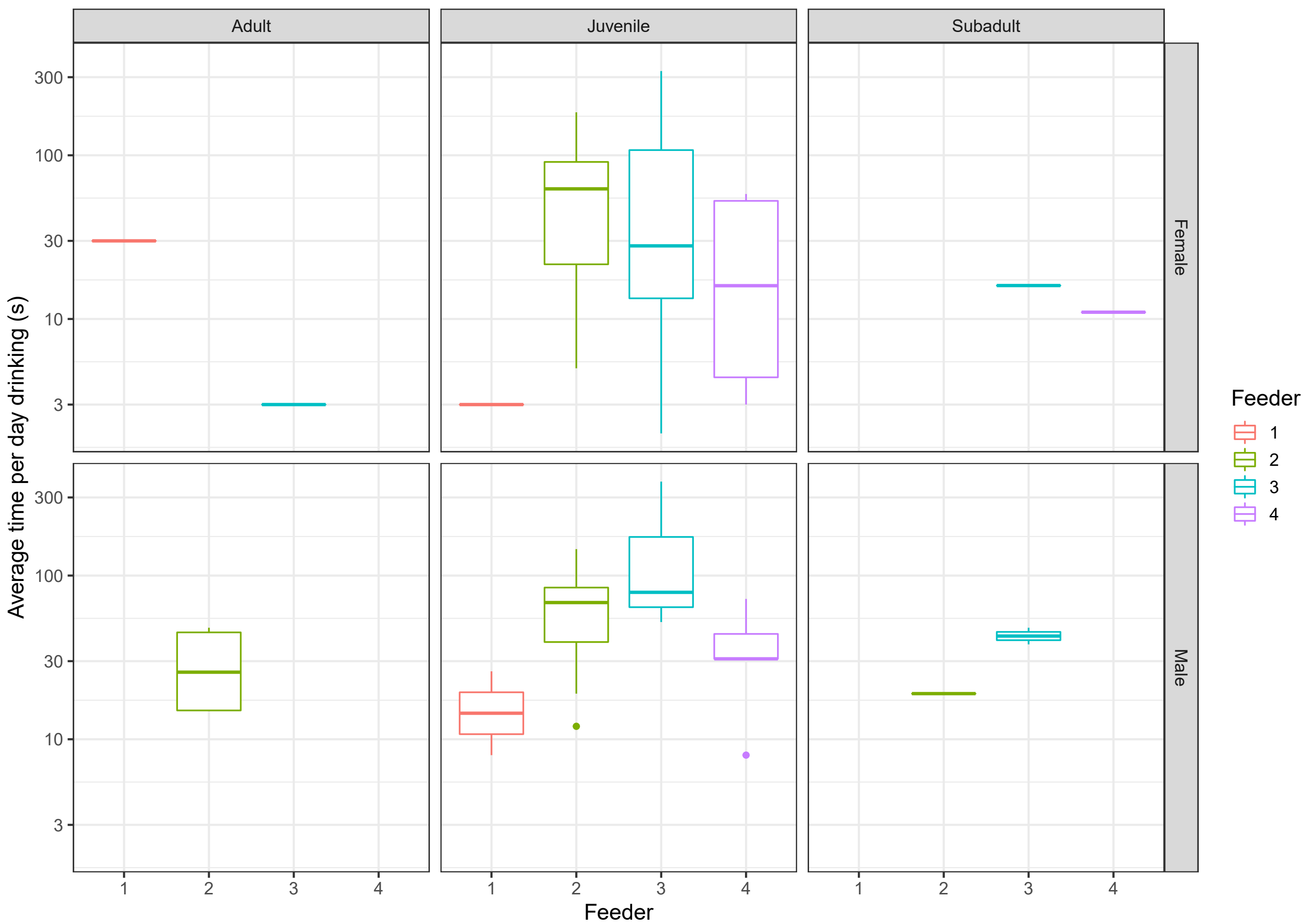

Figure 1. Daily average time spent drinking by kākā of different ages and sex, and on different feeding platforms

the feeders.

There were 20 individuals that were recorded feeding on sugar water during the 11 days on which all individuals feeding on all platforms were recorded. The mean estimated daily consumption of kilojoules per bird was 4.01 kJ ± 3.30 (SD), with values ranging between 1.28 kJ and 14.44 kJ. When expressed as a proportion of each individual's energy requirements per day, the mean value was 0.76 ± 0.62% (SD); values ranged from 0.24 to 2.74%.

Discussion

Given the estimated population of kākā in Orokonui is about 40 banded birds, 60% of banded kākā and an unknown number of unidentified birds visited a feeding platform during the duration of this study. We found no evidence that supplementary feeding of sugar water leads to nutritional problems or dependency on sugar water because individual birds spent very little time drinking sugar water and the energy consumed was a very small proportion of their daily energetic requirements. Even after calculating the maximum possible volume of sugar water consumed (by using the upper confidence interval of the regression equation), the mean proportion of the daily energy requirements met by the sugar water was still less than 1%. The highest values were found in juveniles, but this only represented about 2.7% of a bird's daily energy requirements. Kākā in Orokonui obtained the majority of their daily energy by foraging on other food sources and did not show a dependence on sugar water. In their study of a wild population of kākā, Wilson et al. (1998) found 83% of breeding age kākā wearing radio transmitters regularly visited the supplementary feeding sites, but the food provided was not sufficient to induce breeding if an important natural food source, in this case beech seed, was absent, indicating that supplementary feeding did not have a major impact on the birds.

While neither age nor sex affected the time individual kākā spent on feeding platforms and the time they spent drinking, there was a non-significant trend for juveniles to spend slightly more time on the platforms. Moreover, > 51% of the 31 identified kākā using the feeders were juveniles, and the four individuals that consumed the most sugar water were also juveniles. The feeders may be an easy food source to access when juveniles are learning how to find food for themselves. In a study using supplementary feeding to investigate whether shortages of high energy food cause the poor breeding performance of kākā in Nelson Lakes, only juveniles visited feeding stations (O'Donnell & Rasch 1991). This study took place just after the breeding season, when juveniles were newly independent (Powlesland et al. 2009), and their time at the feeders could represent explorative behaviour typical of juvenile kākā (Loepelt et al. 2016). In our study the sample size of adults and sub-adults was low, possibly because they spend time outside of the eco-sanctuary during winter, or because they are uninterested in visiting the feeders. Even though sap and nectar are important food sources in the diet of kākā (O'Donnell & Dilks 1989; Beggs & Wilson 1991; Moorhouse 1997), and sugar water has a similar energetic value to nectar (Nicolson & Fleming 2003), availability of food in and around the eco-sanctuary must have been sufficiently good that kākā did not rely on sugar water.

Supplementary feeding is carried out for a variety of reasons, and can lead to a number of potentially negative consequences, such as increased wildlife stress, increased rates of aggression at feeding sites, malnutrition (low quality food can compromise body condition and immune function), density-dependent decreases in productivity, disruptions in normal activities, habituation resulting in loss of fear for humans leading to aggressive behaviours, and increased risk of pathogen transmission when aggregations of birds at feeders increase the contact rates between hosts (Newsome & Rodger 2008; Becker et al. 2015; Cortés-Avizanda et al. 2016; Murray et al. 2016). Feeding for conservation purposes mostly have positive wildlife health benefits, but also some unintended consequences, such as reduced emigration from areas with feeding sites, in the case of vulture restaurants (Lieury et al. 2015). However, when what Newsome and Rodger (2008) term "structured feeding" occurs, where specific feeding areas are used with controls over feeding activity and an associated educational programme is in place, advantages are visitor satisfaction and the promotion of awareness and goodwill towards wildlife through education and interpretation. Food provisioning at Orokonui Ecosanctuary is designed to both enhance visitor experience, and also to encourage kākā to remain within the safety of the ecosanctuary. While it is carefully controlled with rigorous cleaning procedures, ongoing monitoring should test for the incidence of pathogens in the feeders and the birds visiting the feeders, as well as behavioral changes that could be detrimental to the population growth of this endangered species.

In conclusion, the supplementary feeding programme for kākā is successful in encouraging these birds to regularly visit the feeders inside the sanctuary but does not appear to create dependency on sugar water. However, the contribution of the solid food to kākā total energy intake is not known and is difficult to measure. Supplementary food is certainly effective at providing opportunities for visitors to see this threatened parrot species, as well as other native birds that regularly visit feeding stations, facilitating environmental education. Given the dominance of juveniles at the feeders at the time of year sampled, further research is necessary to ensure a better understanding of seasonal variations in supplementary food intake.

Author contributions

AA, PS and YvH conceptualised the research, AA collected the data, carried out the analyses and produced a first draft, YvH contributed to the writing and revisions, PS commented on drafts.

Acknowledgements

We wish to acknowledge the support of the staff at Orokonui Ecosanctuary, in particular helpful advice and technical support from Elton Smith, and thank Jacqueline Beggs and an anonymous reviewer for their constructive comments.

References

Armstrong DP, Perrott JK 2000. An experiment testing whether condition and survival are limited by food supply in a reintroduced hihi population. Conservation Biology 14(4): 1171–1181.

Beggs JR, Wilson PR 1987. Energetics of South Island kākā (*Nestor meridionalis meridionalis*) feeding on the larvae of kanuka longhorn beetles (*Ochrocydus huttoni*). New Zealand Journal of Ecology 10: 143–147.

Beggs JR, Wilson PR 1991. The kākā *Nestor meridionalis*, a New Zealand parrot endangered by introduced wasps and mammals. Biological Conservation 56: 23–38.

Brown LM, Hall RJ 2018. Consequences of resource supplementation for disease risk in a partially migratory population. Philosophical Transactions of the Royal Society B: Biological Sciences 373(1745): 20170095.

Clout MN, Elliott GP, Robertson BC 2002. Effects of supplementary feeding on the offspring sex ratio of kākāpo: a dilemma for the conservation of a polygynous parrot. Biological Conservation 107: 13–18.

Cortés-Avizanda A, Blanco G, DeVault TL, Markandya A, Virani MZ, Brandt J, Donázar JA 2016. Supplementary feeding and endangered avian scavengers: benefits, caveats, and controversies. Frontiers in Ecology and the Environment 14(4): 191–199.

Doerr LR, Richardson KM, Ewen JG, Armstrong DP 2017. Effect of supplementary feeding on reproductive success of hihi (stitchbird, *Notiomystis cincta*) at a mature forest reintroduction site. New Zealand Journal of Ecology 41: 34–40.

Ewen JG, Walker L, Canessa S, Groombridge JJ 2015. Improving supplementary feeding in species conservation. Conservation Biology 29(2): 341–349.

Galbraith JA, Stanley MC, Jones DN, Beggs JR 2017. Experimental feeding regime influences urban bird disease dynamics. Journal of Avian Biology 48(5): 700–713.

Greig EI, Wood EM, Bonter DN 2017. Winter range expansion of a hummingbird is associated with urbanization and supplementary feeding. Proceedings of the Royal Society B: Biological Sciences 284(1852): 20170256.

Knight RL, Anderson DP 1990. Effects of supplemental feeding on an avian scavenging guild. Wildlife Society Bulletin (1973-2006) 18(4): 388–394.

Lawson B, Robinson RA, Toms MP, Risely K, MacDonald S, Cunningham AA. 2018. Health hazards to wild birds and risk factors associated with anthropogenic food provisioning. Philosophical Transactions of the Royal Society B: Biological Sciences 373(1745): 20170091.

Lieury N, Gallardo M, Ponchon C, Besnard A, Millon A 2015. Relative contribution of local demography and immigration in the recovery of a geographically-isolated population of the endangered Egyptian vulture. Biological Conservation 191: 349–356.

Loepelt J, Shaw RC, Burns KC 2016. Can you teach an old parrot new tricks? Cognitive development in wild kākā (*Nestor meridionalis*). Proceedings of the Royal Society B 283(1832): 20153056.

López-Bao, JV, Rodríguez A. Palomares F. 2010. Abundance of wild prey modulates consumption of supplementary food in the Iberian lynx. Biological Conservation 143(5): 1245–1249.

Margalida A, Donazar JA, Carrete M, Sánchez-Zapata JA 2010. Sanitary versus environmental policies: fitting together two pieces of the puzzle of European vulture conservation. Journal of Applied Ecology 47(4): 931–935.

Moorhouse RJ 1997. The diet of the North Island kākā (*Nestor meridionalis septentrionalis*) on Kapiti Island. New Zealand Journal of Ecology 21(2): 141–152.

Moorhouse RJ, Greene TC 1995. Identification of fledgling and juvenile kākā (*Nestor meridionalis*). Notornis 42: 187–196.

Moorhouse R, Greene T, Dilks P, Powlesland R, Moran L, Taylor G, Jones A, Knegtmans, J, Wills D, Pryde M, Fraser I, August A, August C 2002. Control of introduced mammalian predators improves kākā (*Nestor meridionalis*) breeding success: reversing the decline of a threatened New Zealand parrot. Biological Conservation 110: 33–44.

Murray MH, Becker DJ, Hall RJ, Hernandez SM. 2016. Wildlife health and supplemental feeding: a review and management recommendations. Biological Conservation 204: 163–174.

Newsome D, Rodger K 2008. To feed or not to feed: A contentious issue in wildlife tourism. In: Lunney D, Munn A, Meikle W eds. Too close for comfort: contentious issues in human-wildlife encounters. Mosman, Royal Zoological Society of New South Wales. Pp. 255–270.

Nicolson SW, Fleming PA 2003. Nectar as food for birds: the physiological consequences of drinking dilute sugar solutions. Plant Systematics and Evolution 238(1-4): 139–153.

O'Donnell CFJ, Dilks PJ 1989, Sap-feeding by the kākā (*Nestor meridionalis*) in South Westland, New Zealand. Notornis 36: 65–71.

O'Donnell, CFJ, Rasch G 1991. Conservation of kākā in New Zealand. A review of status, threats, priorities for research and implications for management. Science & Research Internal Report No. 101. Wellington Department of Conservation. 13 p.

Plummer E, Siriwardena GM, Conway GJ, Risel, K, Toms MP 2015. Is supplementary feeding in gardens a driver of evolutionary change in a migratory bird species? Global Change Biology 21(12): 4353–4363.

Powlesland RG, Lloyd BD 1994, Use of supplementary feeding to induce breeding in free-living kākāpo *Strigops habroptilus* in New Zealand. Biological Conservation 69: 97–106.

Powlesland RG, Greene TC, Dilks PJ, Moorhouse RJ, Moran LR, Taylor G, Jones A, Wills DE, August AC 2009. Breeding biology of the New Zealand kākā (*Nestor meridionalis*), (Psittacidae, Nestorinae). Notornis 56: 11–33.

R Core Team 2016. R: A Language and Environment for Statistical Computing. Vienna, Austria. Retrieved from https://www.R-project.org/.

Robb GN, McDonald RA, Chamberlain DE, Bearhop S 2008. Food for thought: supplementary feeding as a driver of ecological change in avian populations. Frontiers in Ecology and the Environment 6(9): 476–484.

Steyaert SM, Kindberg J, Jerina K, Krofel M, Stergar M, Swenson JE, Zedrosser A 2014. Behavioral correlates of supplementary feeding of wildlife: Can general conclusions be drawn? Basic and Applied Ecology 15(8): 669–676.

Received: 16 April 2019; accepted: 1 October 2020
Handling editor: Colin O'Donnell