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SHORT NOTE

Red-crowned parakeet (kākāriki, *Cyanoramphus novaezelandiae*) mortality inside and outside a fenced sanctuary in Wellington City, New Zealand

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Red-crowned parakeet (kākāriki, *Cyanoramphus novaezelandiae*) were translocated to Zealandia Te Māra a Tāne, a 225 ha fenced sanctuary, from Kāpiti Island in 2010–2011 (55 in 2010, 52 in 2011). At that time, kākāriki had not been successfully translocated to the mainland, with failed translocations in Mt Bruce Scenic Reserve (1968) and the Waitakere Ranges (1977–1985) (Miskelly & Powlesland 2013). Translocation to Zealandia presented several challenges, as the sanctuary is bordered by contiguous forest and suburban areas. Individuals leaving the sanctuary must contend with both introduced predators and novel conditions presented by urbanisation, such as the presence of buildings/windows, cars, exotic avian competitors, and fragmented habitat (Marzluff & Ewing 2001; van Heezik *et al*. 2010; Ausprey & Rodewald 2013; Machtans *et al*. 2013). Kākāriki are known to be vulnerable to introduced mammalian predators due to their habits of feeding on the ground and nesting in single entry cavities, resulting in them being primarily confined to offshore islands (Pratt *et al*. 1987; O'Donnell 1996; Greene 1998, 2003; Higgins 1999; Ortiz-Catedral & Brunton 2009). Furthermore, predation by introduced predators, specifically cats (*Felis catus*), was cited as a potential cause of at least one of the failed translocations (MacMillan 1990).

The population established well in the sanctuary, and the translocation is now considered a success (Miskelly & Powlesland 2013); nevertheless, kākāriki establishment outside of the sanctuary is less certain. Studies of mortality can be used to evaluate risks to wild populations and indicate areas of conservation concern (Silva-Rodríguez *et al*. 2010; Scheelings 2015; Gonzalez-Astudillo *et al*. 2017). To better understand the threats the birds are facing in Wellington, we examined mortality records of kākāriki compiled by Zealandia staff.

After translocation, Zealandia staff kept records of any birds found dead inside or outside the sanctuary, noting the band combination if present, the sex and age class (adult/juvenile) of the bird, and the cause of death if known. If the body was found in good condition and the cause of death was not known, birds were sent off for necropsy. For the purposes of this study, we focused only on juvenile

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and adult birds, removing records of nestlings that failed to fledge as we had no comparative data from birds hatched outside the sanctuary, and nestlings were almost never sent for necropsy. We also compared the number of mortality records to the number of fledglings produced from Zealandia artificial nest boxes each season (as birds at Zealandia typically begin breeding in August or September, we denoted August as the start of the season). Because the number of nest boxes varied slightly between seasons, we divided the total number of fledglings by the number of nest boxes monitored to control for monitoring effort.

From 2010–2016, Zealandia staff recorded 39 deceased kākāriki; 85% of the birds died outside the sanctuary (n = 33) while 15% (n = 6) were within Zealandia. The majority (n = 27, or 73% of those whose age was known) were juveniles, mostly juvenile males (n = 16, or 57% of all birds whose age and sex were known). Only six females were found in total, two of which were juvenile, and there were records for six adult males. Half (n = 5) of the adult records were of birds transferred from Kāpiti that were killed within a few weeks or months after translocation. 54% of the total records (n = 21) and 59% (n = 16) of records for juveniles occurred between January and April. Of birds outside the sanctuary whose cause of death was known, 65% (n = 15) were killed by predators, mostly by cats (n = 9), and one record each for a mustelid (Mustelidae), dog (*Canis familiaris*), and avian predator, as well as three unknown predator kills. The next most common cause of death was collision into a window (26%; n = 6) followed by being hit by a car (9%; n = 2) (Table 1).

Overall, predation was the most common cause of death for kākāriki. Some predation by native avian predators, i.e. ruru (*Ninox novaeseelandiae*), kārearea (*Falco novaeseelandiae*), and kāhu (*Circus approximans*), would be expected even in a protected population. However, mammalian predators, specifically cats, were most frequently reported, likely because of the high number of roaming domestic cats in the suburban areas and reserves that surround Zealandia (Woolley & Hartley 2019); New Zealand has the highest recorded rate of cat ownership in the developed world (Mackay 2011). Some of the birds retrieved in this study were feeding on the ground in small, confined garden lawns surrounded by good cover when they were pounced upon (M. Booth *pers. comm.*); the tendency of kākāriki to feed on the ground may put them at extra risk from cats. However, people may also have been more likely to find birds killed by cats, as cats either bring their kills to their owners or because cat kills are often close to houses, and so more likely to be discovered (though it should be noted that despite this, cat kills are often underestimated; Loyd *et al*. 2013). Mustelids, on the other hand, often cache their prey, making bodies difficult to find (Cuthbert 2003). Other mammalian predators may therefore still represent a threat to kākāriki population establishment outside Zealandia, particularly to females when they are incubating or brooding young nestlings, as they cannot escape from their nest cavity.

Most of the mortality records were of juvenile males. Kākāriki exhibit male-biased dispersal, where juvenile males tend to disperse greater distances than females post-fledging (Irwin *et al*. 2021). The skew in the records may therefore be from juvenile males dispersing from the sanctuary in greater numbers. Accordingly, most of the records took place between January and April, at a time when many juveniles are dispersing. Previous research on other bird species has noted greater juvenile mortality (specifically due to window-strikes) potentially related to longer post-fledging dispersal movements (Hager & Craig 2014). In addition, summer and autumn are when many plants are flowering or fruiting (Irwin 2017). Kākāriki can be very selective for particular food sources, e.g. the fruits of certain trees like tōtara (*Podocarpus totara)* (Bellingham 1987; Irwin *et al*. 2021), and may therefore be more likely to leave the sanctuary and move around more when those ephemeral sources are available outside the fence.

As the number of kākāriki fledglings produced in Zealandia increased, particularly over 2014–2016, so did the number of mortality records, presumably because of the higher numbers of dispersing juveniles (Fig. 1A, B). The greater number of mortality records in the first few years after translocation was likely a result of post-release dispersal, as most of the records were of founder (Kāpiti) birds. In addition, while the number of fledglings increased substantially in 2013/14, there was not a corresponding increase in mortality records. Given that most of the mortality records across all years were of juveniles outside Zealandia, this pattern could be due to fewer juveniles dispersing out of the sanctuary during this period. Juvenile retention into the population within Zealandia was still relatively high in 2013/14 (26% in 2013/14 versus 3% in 2014/15; Gray 2016).

As most of the recorded deaths were outside the sanctuary and related to anthropogenic threats, it is unlikely that the Zealandia population itself will crash. However, dispersal outside the sanctuary has the potential to result in source/sink dynamics between Zealandia and surrounding areas, as birds dispersing outside of the sanctuary likely have a much higher risk of mortality. Previous research radio-tracking juvenile kākāriki at Zealandia found that approximately one-third of juveniles that dispersed outside the sanctuary were killed by

Table 1. Recorded deaths of red-crowned parakeet (kākāriki, *Cyanoramphus novaezelandiae*) in Wellington. Five of the birds (highlighted in grey) had transmitters attached as part of a radio-tracking study on juvenile dispersal, which led to their discovery. Birds whose origin is a question mark were unbanded. Data were compiled by Zealandia staff from 2010–2016.

Sex	Juvenile/ Adult	Origin	Date of death	Likely cause of death (if known)	Location of death (inside/outside sanctuary)
M	Adult	Kāpiti	July 2010	Cat kill	Outside
F	Adult	Kāpiti	September 2010	-	Outside
M	Adult	Kāpiti	October 2010	Car-run over	Outside
M	Adult	Kāpiti	October 2010	Window strike	Outside
F	Adult	Kāpiti	September 2011	Mustelid kill	Outside
M	Adult	Kāpiti	February 2012	Cat kill	Outside
?	?	?	March 2012	Cat kill	Outside
?	Juvenile	?	April 2012	Window strike	Outside
M	Juvenile	Zealandia	June 2012	Crop impaction-overeating	Inside
M	Adult	Zealandia	October 2012	Window strike	Outside
F	Adult	Zealandia	February 2013	-	Inside
M	Juvenile	Zealandia	December 2013	Window strike	Outside
?	Juvenile	?	January 2014	Window strike	Outside
M	Juvenile	Zealandia	February 2014	Cat kill	Outside
?	Juvenile	Zealandia	March 2014	Unknown predator kill	Outside
M	Juvenile	Zealandia	September 2014	-	Outside
F	Juvenile	Zealandia	November 2014	Flew into fence?	Inside
?	Juvenile	Zealandia	November 2014	-	Outside
M	Juvenile	Zealandia	January 2015	-	Outside
?	Juvenile	?	January 2015	Cat kill	Outside
M	Adult	Zealandia	February 2015	-	Outside
M	Juvenile	Zealandia	February 2015	-	Outside
?	Juvenile	?	February 2015	Cat kill	Outside
M	Juvenile	Zealandia	February 2015	Starvation	Inside
M	Juvenile	Zealandia	April 2015	Unknown predator kill	Outside
M	Juvenile	Zealandia	April 2015	Cat kill	Outside
F	Adult	Zealandia	August 2015	-	Outside
M	Juvenile	Zealandia	January 2016	Cat kill	Outside
?	Juvenile	Zealandia	March 2016	-	Inside
F	Juvenile	Zealandia	April 2016	Window strike	Outside
M	Juvenile	Zealandia	April 2016	-	Outside
?	?	?	April 2016	-	Outside
?	Juvenile	Zealandia	April 2016	Car-run over	Outside
M	Juvenile	Zealandia	May 2016	Cat kill	Outside
?	Juvenile	Zealandia	May 2016	Avian predator kill	Outside
M	Juvenile	Zealandia	June 2016	Unknown predator kill	Outside
M	Juvenile	?	June 2016	-	Outside
M	Juvenile	Zealandia	June 2016	Dog kill	Outside
M	Juvenile	Zealandia	August 2016	-	Inside

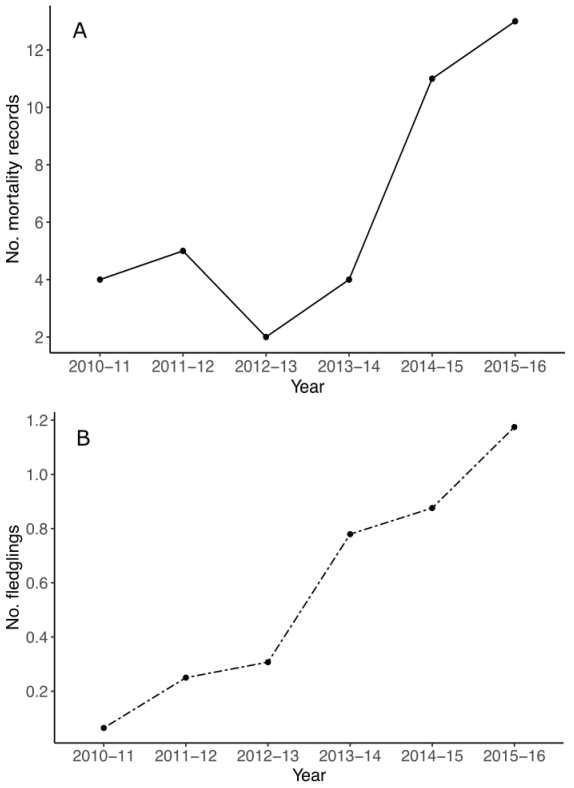

Figure 1. A. Number of red-crowned parakeet (kākāriki, *Cyanoramphus novaezelandiae*) mortality records and, B. the average number of chicks fledged from artificial nest boxes monitored at Zealandia from 2010–2016. To account for monitoring effort, the number of fledglings was divided by the number of nest boxes monitored each season.

predators within a few months (Irwin *et al*. 2021). These threats may therefore pose a risk to kākāriki population establishment outside the sanctuary, and more research should be done to assess the survival of birds outside Zealandia.

In conclusion, predation and other factors related to urbanisation (window strikes, cars) present a threat to kākāriki dispersing outside Zealandia. However, it should be noted that most dead birds both inside and outside the sanctuary are assumed to be never found, and there may have been biases in those that were recorded; for example, juveniles or males may be easier to locate than adult females, which could be more likely to die on the nest. Birds may also have been more likely to be found in areas (neighbourhoods, Zealandia tracks) frequented by people; this might have biased the data towards birds that were killed by dangers in those areas (cats, windows). Therefore, further investigation is required to examine the survival and threats to life stages not as well captured by this dataset, particularly birds breeding or hatched outside the sanctuary.

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