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Emblematic forest dwellers reintroduced into cities: resource selection by translocated juvenile kaka

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Abstract

Urbanization and exotic species are major threats to the conservation of forest-dependent wildlife species. Some emblematic species, indicators of habitat quality for the conservation of other species, might successfully be reintroduced within cities when habitat restoration and pest management programs are combined. We studied the landscape resource selection of juvenile kaka *Nestor meridionalis* tracked with Global Positioning System (GPS) units and released into the predator-free reserve of Zealandia in Wellington city, New Zealand. Kaka moved beyond the predator exclusion fence into urban suburbs. The home range size and areas of high use estimated using local convex hull (*a*-LoCoH) ranged from 20 to 240 ha and 2 to 21 ha, respectively. Using resource selection functions and model selection we found that native forest patches and urban areas close to the reserve were selected by kaka to establish their home ranges. At a lower scale of selection (i.e., selection of habitats within home ranges), kaka selected the same habitat, but not necessarily those close to the reserve. Native forest patches throughout the city can facilitate the dispersal of individuals, while the reserve provides protection and opportunities for supplementary feeding. Urban areas might have been selected due to the placement of feeders in private backyards. Survival of forest-dwelling species in cities requires careful urban planning and management to provide the necessary habitat patches, refugia, and food sources.

Key words: forest-dwellers, GPS, kaka, New Zealand, reintroductions, resource selection, urbanization, Wellington.

Habitat loss and fragmentation are major threats to the conservation of biodiversity worldwide. Urbanization, in particular, results in permanent destruction and modification of habitat at local and global scales (Marzluff 2001; McKinney 2008). Urbanization creates a matrix of disconnected natural patches inhospitable for many wildlife species (McKinney 2002). Among the wildlife species most affected by urbanization are forest dwellers or forest-dependent species (Gillies et al. 2010). The survival and persistence of forest-dependent species in urban environments is related, among other reasons, to the ability of individuals to move within and between forest patches of specific composition and configuration (Hanski 1998; Gillies et al. 2010).

Another major cause of biodiversity loss is biological invasions (Vitousek et al. 1997; IUCN 2001). Introduced animal species can become an agent of change and a threat to native biological diversity via predation or competition with native species (Courchamp et al. 2003). Urban areas can provide an appropriate environment for introduced generalist species able to adapt to the opportunities provided by anthropogenic resources and to become a threat to native wildlife (Cleargeau et al. 2004; Vanak and Gompper 2010).

The long-term conservation of native forest wildlife species, such as forest-dwelling birds, within modified urban environments (Jokimäki et al. 2014) might depend on: 1) the successful implementation of suitable urban design and urban planning to promote connectivity between green spaces and natural areas within a matrix of built-up areas (e.g. ecological networks, Ignatieva et al. 2011); 2) the conservation of natural forest patches; and 3) the management of exotic species. Urban planning and the conservation of natural forest patches can provide habitats to sustain wildlife populations and functional connectivity among patches to ensure movement and flow of individuals and genes between populations (Beier and Noss 1998). Management strategies for exotic species in urban areas should seek to minimize the impact caused by direct predation and by competition for resources within restored or remnant natural habitats. Ultimately, the suitability and success of these combined wildlife management strategies can be assessed in terms of ecosystem health through surrogate or focal animal species (Caro and Fagan 2002). The presence and health of these species can provide an indication of ecosystem condition (Weaver 1995). Moreover, the conservation of ecosystems to protect indicator species might also protect many co-occuring species. Thus, indicator species can also act as umbrella species (Roberge and Angelstam 2004).

One such forest dwelling species considered an indicator of ecosystem health is the charismatic New Zealand (NZ) kaka *Nestor meridionalis* (Leech et al. 2008, Figure 1). The kaka is an endemic arboreal parrot that inhabits lowland native forests where it occupies mid to high canopy, make its nests in hollow trees and feed from invertebrates and plant fruits, berries, nectar, sap, flowers, and buds (Heather and Robertson 2005). Kaka used to be abundant in native forests (Wilson et al. 1998). However, the species is susceptible to habitat destruction and degradation, and to direct predation and competition by introduced mammals (O'Donnell and Rasch 1991; Moorhouse et al. 2003; Greene et al. 2004). New Zealand's indigenous forests have been reduced by human exploitation from 82% to only 23% of the land area (Ewers et al. 2006), and as for many other native birds in NZ, the introduction of mammalian predators caused a dramatic decline in kaka populations (Beggs and Wilson 1991; Wilson et al. 1998; King 2005; Leech et al. 2008). Consequently, the species is classified as endangered (IUCN Red List 2015, www.iucnredlist.org, retrieved 12-3-15). Kaka can fulfill the role of indicator species to identify habitat quality in NZ, as well as being a flagship species to attract public support (Andelman and Fagan 2000; Leech et al. 2008). Specific management and conservation strategies for kaka will also be relevant for the conservation status and health of NZ lowland forest ecosystems (Leech et al. 2008).

As for other parrot species, such as the rainbow lorikeet *Trichoglossus haematodus*, musk lorikeet *Glossopsitta concinna,* and red-rumped parrots *Psephotus haematonotus* that have successfully colonized city parklands in Australia (Lill 2009), the kaka has recently been reintroduced to sites in or near the NZ capital, Wellington city (Miskelly et al. 2005; Kerry and Linklater 2013). Recent management objectives for the city identify a need to improve functional connectivity for wildlife species, and recognize the importance of understanding animal movements within patches to guide management strategies (Wellington City Council 2013). The success of the re-establishment of a kaka population and expansion also depends on the control of introduced mammalian predators. The main introduced predators of kaka (and other native birds) are stoats *Mustela erminea*, which kill adults (in particular females incubating eggs), brush-tailed possums *Trichosurus Vulpecula*, which rob nests and compete for high-energy foods and nest-sites, and rats (*Rattus* sp.), which prey on eggs and nestlings (Moorhouse et al. 2003; Heather and Robertson 2005). Pest control programs based on poisoning, trapping, and artificial physical barriers (e.g., to protect kaka nest cavities) have been applied to mitigate the impact caused by introduced mammals (Dilks et al. 2003; Greene and Jones 2003; Moorhouse et al. 2003; Veltman and Westbrook 2011).

Figure 1. The emblematic New Zealand kaka *Nestor meridionalis,* an endangered native forest-dependant parrot reintroduced into Wellington city. Photo: Keith Payne.

In Wellington city, the Karori Wildlife Sanctuary (now known as Zealandia) is a predator-free fenced area containing abundant native forest and connected to a green-belt surrounding the city (King 2005). The expectation was that species such as the kaka can find the necessary resources for breeding and feeding within the sanctuary, which is considered a population base supporting expansion of kaka along the city green-belt and green spaces toward other native habitat patches within the urban matrix. Kaka were first reintroduced into Zealandia in 2002 and more than 300 individuals have been banded there since then (www.visitzealandia.com, retrieved 12-3-2015). The current kaka population in Wellington is estimated to be between 180 and 250 birds (Karori Sanctuary Trust[1], 2013, Wellington, New Zealand, Unpublished data, unpublished data). Supplementary food in artificial feeders is provided year-round for kaka in the sanctuary (Kerry and Linklater 2013). However, reintroduced individuals are free to move over the exclusion fence and into city suburbs. The frequent presence of kaka in inner suburbs has been reported in previous research on sap feeding behavior (Kerry and Linklater 2013).

The successful reintroduction and conservation of kaka in cities faces two challenges: 1) the conservation and management of habitats to enable the movement and settlement of individual birds and,

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[1] Karori Sanctuary Trust 2013. Wellington, New Zealand. Unpublished data.

2) the reduction of introduced predator populations to minimum levels. Hence, the persistence of kaka in NZ cities requires an understanding of the space use of dispersing individuals as a prerequisite for the establishment and persistence of subpopulations (Levey et al. 2005). Although the reintroduction of kaka in Wellington took place more than a decade ago, no research has identified the patterns of space use of this indicator species within the city. Using GPS-tracking devices we studied the spatial ecology of released NZ kaka as an example of indicator and flagship species requiring a combined management strategy of habitat conservation and pest control. We quantified landscape resource selection by juvenile kaka in the urban environment of Wellington. This is, to our knowledge, the first study to track kaka using light-weight GPS devices. Considering the forest-dependent character of the species and the protection and artificial feeding opportunities provided by the wildlife sanctuary, we predicted that reintroduced kaka mostly selected patches within or in the proximity to native forest. Because of this supplementary food and the predator protection found in the wildlife sanctuary, we also predicted that most excursions into the cities' inner suburbs are originated from the wildlife sanctuary where kaka concentrate their space use (i.e., areas of high use).

Materials and methods

Study area

Our study area was placed in Wellington City, the administrative capital of NZ. The city lies in the south of NZ North Island (41°17'S) and is included within the larger urban area of the Wellington region, which comprises Wellington City, and 3 adjacent cities. The Wellington region has an urban population of 471,315 residents, whereas Wellington city has 190,956 residents (Wellington 2013 census, www.stats.govt.nz/Census.aspx, retrieved 12-3-2015), Wellington City combines flat areas adjacent to the harbor with surrounding hills. Overall, the Wellington region has an average green space (including tree lined streets, parks, gardens, community gardens, and cemeteries) ratio of 207 m^2 per person (Neate 2013). Regrowth native forests and bush remnants remain within the urban area in a network of reserves maintained by the Wellington City Council and local volunteers, in conjunction with pest management plans (Wellington City Council 2004). Relevant native forest tree species are podocarps such as tōtara *Podocarpus totara*, rimu *Dacrydium cupressinum*, kahikatea *Dacrycarpus dacrydioides*, miro *Prumnopitys ferruginea,* and mataī *Prumnopitys taxifolia*.

Zealandia is ~2 km from downtown Wellington, on the western boundaries of the urbanized area. This reserve is a 225-ha tract of native forest encompassing a former water catchment area for the city. It was developed by the Karori Wildlife Sanctuary Trust as a mainland island to preserve the habitat free from introduced predators and other mammals by means of a predator-proof fence that was erected in 1999 (King 2005). The sanctuary carries out varied programs on the conservation and restoration of native forest and wildlife, including invertebrates, reptiles, and birds (www.visitzealandia.com, retrieved 12-3-2015).

Bird tracking

We deployed harness-mounted GPS/GSM tracking devices (hereafter tracking units) on 9 juvenile North Island kaka *Nestor meridionalis septentrionalis* at Zealandia in April 2012. We deployed the tracking units on members of the same cohort from the 2011/2012 breeding season, and all units were removed by early September 2012. Tracking units were developed by the Department of Physics at the University of Otago and consisted of carbon fiber enclosures to house a GPS/GSM receiver, braided stainless steel antenna, and a VHF transmitter externally attached. We used eight harness-mounted battery powered tracking units and one experimental solar-powered version. The weight of the units including the harness was 20.5 and 22 g, respectively. We programmed GPS devices to collect locations every 7 hours for the battery-powered units and every 2 hours for the solar-powered unit. Preliminary stationary tests showed root mean square (RMS) location error of ± 4.7 m under clear-sky-view environment, ± 7.6 m in residential areas, ± 12.1 m in open forest and ± 15.5 m in dense forest/bush. Fix success rate in stationary tests was 100% in all the open environments, but in dense forest/bush this decreased to 95%. Tests of moving devices indicated a maximum error of 5 m from the actual location.

We captured kaka at 2 feeders inside the sanctuary, and incidentally at a residential address beyond the fence, by transforming into a cage the feeding posts normally used for supplementary feeding. Supplementary food consisted of sugar-water, commercially-prepared parrot pellets and nectivore mix (Kerry and Linklater 2013). As the Zealandia kaka have experienced only minimal handling, they readily entered cages. After capture, we transferred birds to a room in the sanctuary buildings for visual inspection, deployment of tracking units, and tagging for individual identification. We held all birds overnight and inspected them in the morning to ensure a correct fit of tracking units before release.

We retrieved the tracking units using the same capture procedure; the birds were more wary of the cage even 4 months after their initial tagging experience. After data retrieval, we did not apply any filter to remove expected inaccurate locations based, for example, on the dilution of precision values (DOP, e.g., horizontal dilution of precision (HDOP)) or unrealistic animal movements (Björneras et al. 2010; Recio et al. 2013, 2014; Adams et al. 2014). This was because the former filter has been shown to remove both accurate and inaccurate positions (Recio et al. 2011), whereas for the latter the 7-hour interval between locations did not reveal any step length or turning angle that could not plausibly be executed by kaka during that time period. Hence, we considered all the locations to be suitable for the resource selection analyses at the spatial scale considered.

Home range estimations

We estimated individual kaka home ranges using the non-parametric kernel method based on an adaptive Local Nearest-neighbor Convex Hull (*a*-LoCoH), suitable for large location datasets such as those collected using GPS devices and able to identify hard boundaries of the home range (Getz et al. 2007). The *a*-LoCoH considers the most suitable *a* value as being the longest distance between any 2 points in the sample. We calculated this distance for each individual kaka and used this as the *a* value (Getz et al. 2007). The LoCoH method estimates discrete hulls or isopleths representing utilization distributions (UD) within the home range (Getz et al. 2007), wherein smaller hulls are constructed around high-use areas, that is, the most intensively used sectors where the animal preferentially establishes activities (Bingham and Noon 1997). We calculated the 100%, 95%, and 50% isopleths (UD_{100}, UD_{95}, UD_{50}), the last as a representation of high-use areas. Identification of high-use areas indicates site fidelity related to specific behaviors such as feeding, breeding, or resting (Börger et al. 2008)

Resource selection analyses

We carried out resource selection analysis using resource selection functions (RSF) (Boyce et al. 2002). This method compares any landscape characteristic at sites of animal presence (i.e., GPS locations) with the available features in the environment represented by random locations. Random locations were selected over the study area to identify where animals select to establish their home ranges, or over the home range to identify the selection of resources within each individual home range. These analytical designs have been described by Johnson (1980) as second- and third-order selection, respectively, and similarly by Manly et al. (2002) as design II and design III. For the design II approach, we drew 4 random locations over the study area per GPS location for individual animals. For the design III approach, we used a one-to-one actual-to-random location over the home range (UD_{100}) for each individual animal. We considered these numbers of locations were suitable to represent the availability of landscapes at, the study area scale (design II) and the home range area (design III), respectively.

We estimated RSFs at a population level to predict where the kaka chose to establish their home ranges (design II), and to identify areas of greatest use within the home range (design III). To estimate RSFs we incorporated used and available locations as the response variable in logistic regressions within a generalized linear mixed model (GLMM) framework. GLMM accounts for differences in sample size (i.e., number of GPS locations) between individuals, data autocorrelation, and accommodates the hierarchical structure of the data (i.e., observations within individuals) (Gillies et al. 2006; Hebblewhite et al. 2008; Recio et al. 2013). Response variables were extracted from a digital landcover map available from Land Information New Zealand (LINZ) as the Euclidean distance (in metres) of each location (GPS and random) to the edge of the following landcover categories: native forest, exotic forest, exotic shrub, grassland, urban, urban park, and the reserve. A distance of 0 to a specific landcover category implied the kaka was within that landcover type. All the spatial operations were carried out using ArcGIS 10.1 (ESRI, Redlands, USA). Statistical analyses were carried out in R software (R Core Team 2013). We used model selection using the Akaike Information Criterion (AIC) (Burnham and Anderson 2002). We proposed 12 a priori models representing hypotheses explaining kaka resource selection, and also included global and null models as references. We used Spearman's pairwise correlation coefficients to test for collinearity between explanatory variables ($|r| > 0.5$, cutoff value, Hosmer and Lemeshow 2000). Non-correlated variables were included in model formulation to avoid multicollenearity and we did not include interaction terms because no relevant biological interaction was suspected. We considered model averaging only for the resulting models with $\Delta AIC \leq 2$ (Burnham and Anderson 2002). Coefficients (β_n) were incorporated in the particular log-linear function suitable for used/available designs that relates the relative probability of use (w) and predictors ($x_1, x_2 \ldots x_n$): $w(x) = exp(\beta_1 x_1 + \beta_2 x_2 + \ldots \beta_n x_n)$ (see Boyce et al. 2002).

We assessed the predictive ability of each population model in design II and III using *K*-fold cross-validation (10-fold, Boyce et al. 2002; Wiens et al. 2008). For this procedure, we randomly divided the sample of kaka locations into 10 subsets or folds, and then we recalculated the coefficients of the best model using 9 folds withholding 1 out for validation. This procedure was repeated 10 times. We then tested the predictive capability of each calculated model by confirming that each withheld value corresponded to a high predicted value using a Spearman-rank correlation statistic.

Results

Bird tracking

Two out of the nine tracking units deployed failed prematurely. One failed due to an internal mechanical issue that was most likely an assembly error, and the other (the only solar powered tag), due to water intrusion. Tracking unit lifetimes ranged from 46 to 68 days, with a mean of 52 days (Table 1). The total number of kaka locations collected by the 7 tracking units was 713, ranging from 61 to 195 locations per unit (mean ± $SE = 101.86 \pm 17.05$). Fix success rates ranged from 37.4% to 83.7%, with a mean of 55.5% (Table 1). Percentage of bird weight gained after tagging ranged from −5% to 3.5%, with a loss of weight in 5 of the 9 kakas tracked. However, all the birds were healthy at the time of tag recovery and lighter birds had gained weight while heavier birds had lost weight.

Home range estimations

Home range estimates varied between individuals (Figure 2). Home range size (UD_{100}) ranged between 20 and 240 ha (mean ± $SE = 102.1 \pm 29.5$ ha). High-use area size ranged between 2 and 21 ha (mean ± $SE = 8.8 \pm 2.6$ ha) (Table 1). We found no correlation between the number of GPS locations per animal and home range size ($|r| = 0.21$, $p = 0.64$).

Resource selection analyses

Results of design II RSF analyses revealed that where young reintroduced kaka choose to establish their home ranges in Wellington city was best defined by proximity to native forest ($\beta_{\text{distance to native forest}} = -0.0075$, SE = 0.0009), preferably inside and areas surrounding the Zealandia reserve ($\beta_{\text{distance to reserve}} = -0.0026$, $SE = 0.0001$) and urban areas ($\beta_{\text{distance to urban areas}} = -0.0037$, $SE = 0.0002$; Figure 3). There was little to no support for the alternative models tested (Table 2). Results of design III RSF analyses revealed that kaka selected areas within the home range that were close to native forest ($\beta_{\text{distance to native forest}} = -0.0081$, $SE = 0.1067$) and urban areas ($\beta_{\text{distance to urban areas}} = -0.0011$, $SE = 0.0003$), but not specifically inside the reserve ($\beta_{\text{distance to reserve}} = 0.0005$, $SE = 0.0001$; Table 2). The validity of the predictive capability of design II and III population models was adequate, with a mean Spearman's rank correlation coefficient of 0.96 ($P < 0.001$) for design II, and 0.81 ($P = 0.004$) for design III.

Discussion

Tracking the movements of juvenile kaka through the urban matrix of Wellington city using GPS devices allowed us to quantify the landscape selection of the species in a fragmented urban landscape, where a predator-free reserve offers food and refuge for individual birds. Analyses of landscape and space use confirmed our prediction that native forest is selected as the main habitat; however, urban areas were also selected as a landscape resource thus influencing the space use of kaka in Wellington city. Although we recognize the small sample size and short sampling period, these were the main habitats the tracked kaka selected for establishment of a home range (design II analyses). Our models revealed similar results for resources selected exclusively within each home range (design III analyses), with native forest and urban patches also the most selected habitats. However, the proximity of the reserve was not a major driver for the selection of habitats within the home range of kaka at the population level and therefore this finding does not support our

Table 1. Individual home range estimates for kaka tracked in Wellington city and performance figures for tracking units deployed on kaka

	LoCoH Isopleth (UD) area (ha)			GPS unit performance		
ID individual	100% (UD_{100})	95% (UD_{95})	50% (UD_{50})	Number of locations	Fix success rate(%)	Unit lifetime(days)
K02	113	67	15	69	43.1	46
K03	145	82	7	114	63.0	52
K04	240	125	21	88	49.2	53
K06	33	13	5	61	37.4	49
K07	20	11	2	81	48.8	49
K08	41	23	3	105	63.6	48
K09	123	66	9	195	83.7	68
Mean ± SE	102.1 ± 29.5	55.2 ± 15.8	8.8 ± 2.6	101.8 ± 17.0	55.5	52

Values represent the different sizes of the utilization distributions or isopleth revealed using local convex hull estimators (LoCoH), specifically *a*-LoCoH.

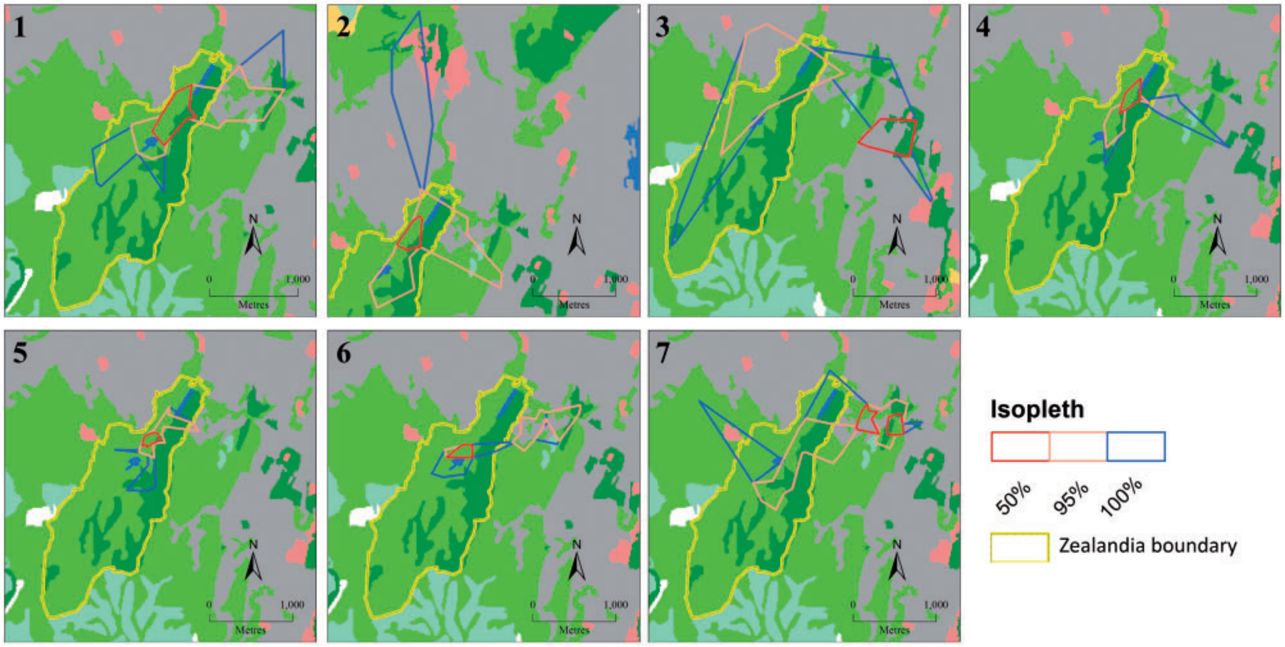

Figure 2. Representation of adaptative local nearest-neighbor Convex Hull (*a*-LoCoH) estimations for kaka *Nestor meridionalis*. Utilization distributions were calculated as the 100%, 95%, and 50% isopleths (UD_{100}, UD_{95}, UD_{50}, respectively), the latter represents high-use areas. Because smaller isopleths are contained within larger isopleths, smaller isopleths are drawn over larger ones whenever their boundaries coincide.

second prediction. In fact, not all of the tracked individuals established areas of high use in their home ranges within the reserve.

Results showing a positive selection for areas near urban environments can be a consequence of the use of small forest patches embedded within urban habitats, but might also relate to the observed provision of food in private backyards (K. Payne pers. Obs) or sap feeding from native and exotic trees commonly carried out by young kaka (Kerry and Linklater 2013). Artificial feeding of kaka could facilitate the successful establishment of reintroduced individuals out of the sanctuary by influencing dispersal and homing behavior. However, to settle in urban areas might have detrimental consequences for kaka due to predation pressure that might result in poor adult and nest survival (see the ecological trap-hypothesis, Battin 2004). Further research with tracked adults is required to understand whether the urban area selected by our tracked juveniles can in fact be suitable for nesting and the raising of fledglings, and to evaluate the bias and impact caused by artificial feeders outside the reserve in kaka space use and population dynamics.

Our results indicated the importance of patches of native forests as the main habitat used by the kaka within a mosaic of different habitat patches. This result highlights the importance of the creation or conservation of native forest habitats within cities such as Wellington, as well as the establishment of managed areas of native forest (i.e., predator-free refuges or areas with predator control programs to reduce predator pressure to minimal levels). In the Zealandia reserve, kaka have daily access to supplementary food, which can be a major determinant for the long-term patterns of space use in the kaka population by focusing high-use areas within the reserve. Long-term research is needed to assess the importance and impact of these feeders for the restoring population of kaka in Wellington.

Light-weight GPS/GSM units showed an acceptable performance for the objective of this research. Two of the units deployed failed, but due only to mechanical assembly errors and not electronic failures; we consider this is promising technique for further research. The fix rate success for kaka was lower than that obtained for other forest dwelling species, such as the wild turkey *Meleagris gallapavo*

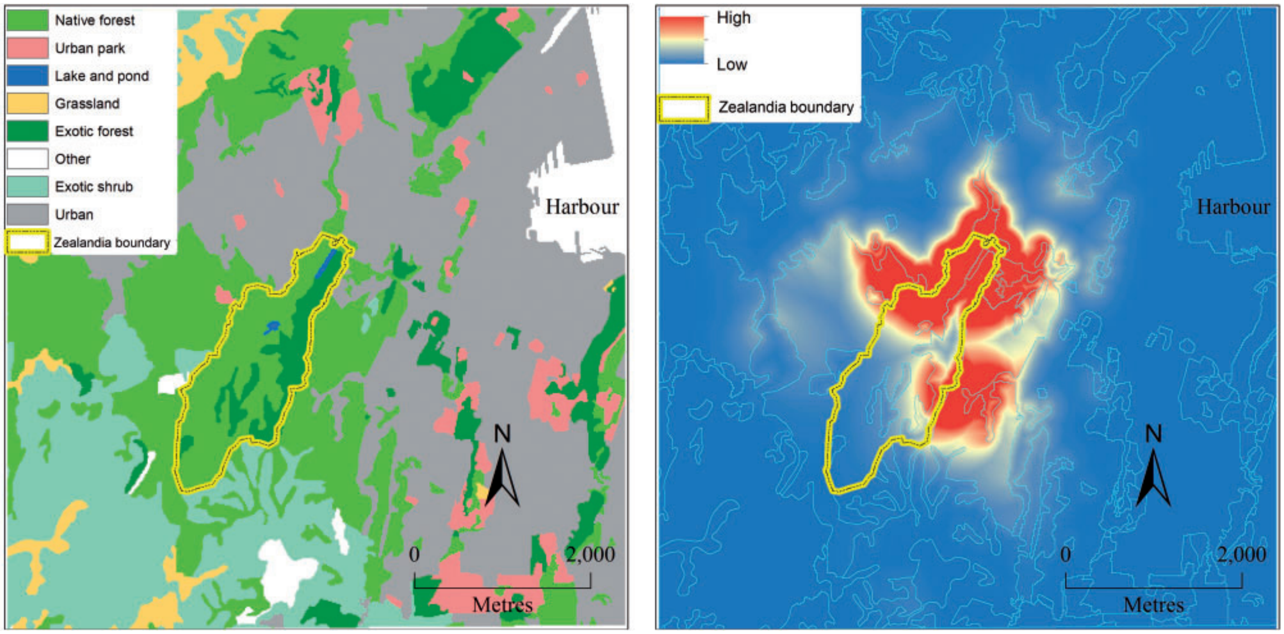

Figure 3. Digital map of the study area (left) and the prediction of the areas of highest use (right) calculated using resource selection functions (RSF) under a design II approach (used vs. available resources within the study area).

Table 2. Mixed-effects logistic regression models describing resource selection by kaka in Wellington at a population level

Analysis type	Rank	Model	AIC	ΔAIC	w
Design II	1	dinfore + durban + dzeeala	1767	0	1
	2	dinfore + durbanp + dzeeala	1932	165	1.4815E-36
	3	dgrassl	1976	209	4.1326E-46
	4	dzeeala + durbanp	2027	260	3.4811E-57
	5	dinfore + dzeeala	2178	411	5.6556E-90
	6	dzeeala	2242	475	7.1620E-104
	7	dinfore + dexfore	2395	628	4.2800E-137
	8	dinfore + durban	2760	993	2.3590E-216
	9	dinfore + durbanp	2921	1154	2.5820E-251
	10	dinfore	2974	1207	8.0030E-263
	11	durban	3415	1648	0
	12	dexshru	3525	1758	0
Design III	1	dinfore + durban + dzeeala	1902	0	0.9460
	2	dinfore + durbanp + dzeeala	1908	6	0.0470
	3	dinfore + durban	1912	10	0.0063
	4	dinfore + dzeeala	1917	15	0.0005
	5	dinfore	1943	41	0
	6	dinfore + dexfore	1944	42	0
	7	dinfore + durbanp	1952	50	0
	8	dgrassl	1959	57	0
	9	dzeeala + durbanp	1959	57	0
	10	durban	1960	58	0
	11	dzeeala	1971	69	0
	12	dexshrub	1976	74	0

Variable names are: *dinfore* distance to native forest, *dexfore* distance to exotic forest, *dexshru* distance to exotic shrub, *dgrassl* distance to grassland, *durban* distance to urban, *durbanp* distance to urban park, and the *dzeeala* distance to the reserve. Models were ranked using Akaike's Information Criterion (AIC); K = number of parameters in each model; ΔAIC = change in AIC, and w = Akaike weights.

in North America (Guthrie et al. 2011), but higher than the 43.3% obtained for feral pigeons *Columba livia* in urban environments (Rose et al. 2006). The size and the behavioral characteristics of animals can partly explain the reduction in fix success rates in comparison with the rates obtained in stationary tests, for larger animals, or for animals using open-sky environments (Recio et al. 2011). Kaka often use cavities where the satellite signal is blocked, nevertheless, a sufficient number of locations was obtained for kaka resource selection analyses.

In conclusion, this research provides detailed spatial information on how a reintroduced native forest-dwelling bird selects landscape patches within an urban environment with high alien predator pressure. Native forest patches are critical for individual kaka and despite landscape fragmentation, urban environments can support the conservation of native species. Understanding of the behavior of urban species and the ecology of their communities at varied scales is required for a better urban planning (Clergeau et al. 2001; Jokimäki et al. 2011). This planning should ensure the presence and quality of green patches of native forests to support reintroduction and survival for umbrella species within cities. These species may range from emblematic NZ birds such as the tui *Prosthemadera novaeseelandiae* or the kaka, to unique "hidden" species of invertebrates such as peripatus in Dunedin (NZ) (Barret 2013). Careful planning and ongoing management of urban landscapes is necessary to ensure cities become more liveable spaces for both humans and native wildlife species.

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