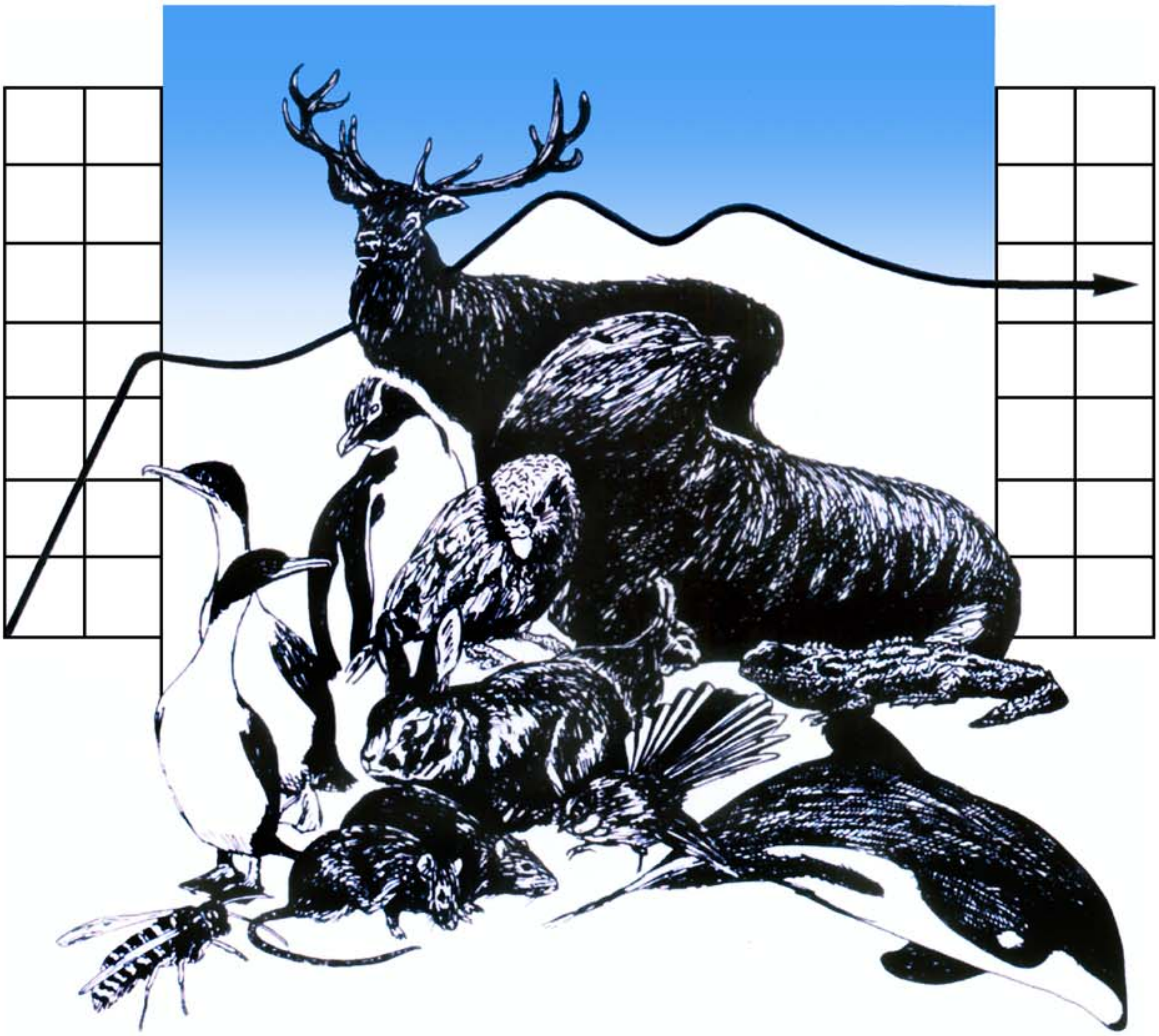
UNIVERSITY of OTAGO

Te Whare Wānanga o Otāgo

NEW ZEALAND

DEPARTMENT OF ZOOLOGY



WILDLIFE MANAGEMENT

A pilot study: Using distance sampling to estimate the abundance of kaka (*Nestor meridionalis septentrionalis*) in the Mt Bruce Reserve

Susi Preston

Submitted for partial fulfilment of the Postgraduate Diploma of Wildlife Management, University of Otago

University of Otago

Year 2008

University of Otago
Department of Zoology
P.O. Box 56, Dunedin
New Zealand

WLM Report Number: 215

Practice of Wildlife Management (WILM 403)

A pilot study: Using distance sampling to estimate the abundance of kaka (*Nestor meridionalis septentrionalis*) in the Mt Bruce Reserve

Submitted for partial fulfilment of the Postgraduate Diploma of Wildlife Management, University of Otago

Susi Preston

February 2007

Contents

Executive Summary

The kaka (*Nestor meridionalis)* is a threatened parrot endemic to New Zealand. After being locally extinct for 50 years, north island kaka (*Nestor meridionalis septentrionalis)* were successfully re-introduced into the Mt Bruce Reserve. Now, ten years after their reintroduction an efficient, cost effective and reliable tool is needed to monitor kaka abundance to ensure management techniques are being effective.

Distance sampling is successfully used to monitor kaka populations in other regions including the Waipapa Ecological Area in the Waikato. Distance sampling involves recording the distance to bird contacts and theoretically allows the estimation of actual bird densities, not just an index of abundance. Distance sampling allows accurate, unbiased estimates of density to be made with minimal assumptions provided the assumptions are met. Key assumptions include; birds on the line or point are detected with certainty, that distances are recorded accurately and without bias, and that birds are detected at their initial location. The aim of this pilot study was to assess the effectiveness of using distance sampling to monitor kaka abundance in the Mt Bruce Reserve.

The survey involved ten minute point counts. Four transect routes were set up within the Reserve and each route was replicated three times. There were between ten and 13 point count stations on each route, marked with blue tape. At each station the distance to any kaka seen was measured using measuring tape and the distance to any kaka heard was estimated. All kaka flying over the station were excluded from analysis. Data analysis was done using the program DISTANCE version 5.0. The data was truncated at 90 meters and grouped into five intervals. The estimator chosen to compute the density estimate was the negative exponential key function with the cosine series expansion.

The abundance estimate derived from distance sampling was 82 kaka with a density estimate of 0.09 kaka per hectare. Narrow confidence intervals suggested that the estimates were relatively precise and reliable. However, there is a problem with the possible violation of distance sampling assumptions, particularly the accurate measurement of radial distances. The requirement of between 80-100 detections to ensure a reliable estimate is the biggest weakness of distance sampling as it is time consuming in areas with low density

kaka such as Mt Bruce. Despite these problems distance sampling is the best tool available to effectively monitor the Mt Bruce kaka population.

Introduction

Kaka populations in New Zealand

The kaka (*Nestor meridionalis)* is a threatened forest-dwelling parrot endemic to New Zealand (Beggs and Wilson, 1991). It was once widespread and abundant in native forest throughout New Zealand (Buller, 1888) but its distribution and numbers have dramatically declined since late last century (Bull *et al.*, 1985). Habitat destruction, predation of nesting females and eggs by stoats (*Mustela erminea*) and possums (*Trichosurus vulpecula*) coupled with competition for food by introduced predators including wasps (*Vespula germanea* and *V. vulgaris*) and possums are major causes of this decline (Beggs and Wilson, 1991; Wilson *et al.*, 1998; Moorhouse *et al.*, 2003). Kaka are now relatively uncommon and found in only a fraction of their former range (Bull *et al.*, 1985; Moorhouse and Greene, 1998; Heather and Robertson, 2005).

There are two subspecies of kaka, the North Island kaka (*N. meridionalis septentrionalis*) and South Island kaka (*N. m. meridionalis*) (Berry, 1998). This report focuses on North Island kaka. Large and secure populations of North Island kaka exist on some offshore islands including Kapiti and Great Barrier Island (Heather and Robertson, 2005). Localised populations are also present in large forest tracks on the mainland of the North Island with the largest and most stable flocks present at Pureora and Whirinaki forests (Berry, 1998).

Kaka at Mt Bruce Reserve

Kaka were locally extinct from Mt Bruce Reserve for almost 50 years (Holland and Collen, 2000). They were successfully reintroduced into the Reserve in 1996 through the release of nine juvenile kaka and the subsequent release of a further five juvenile kaka in 1997 (Berry, 1998). The release site was the National Wildlife Centre (NWC) which is situated on the north-western boundary of the Reserve (Berry, 1998). Three feed stations were permanently set up at the kaka release site to provide the kaka with supplementary food after the release (Berry, 1998). The feed stations have been stocked on a daily basis at 3pm since the 4th June 1996 (Berry, 1998). The supplementary food provided to the kaka is based on the captive kaka diet at the NWC and includes walnuts, dates, cheese, apple, pear, sunflower seeds and jam-water (jam blended in water). The number of kaka using the feed stations varies, including as few as four and a maximum of 30 kaka on any given day. The kaka population at Mt Bruce is now self sustaining, as kaka are forming pairs and breeding; choosing to use both artificial predator proof nest boxes as well as natural nest sites.

An accurate understanding of the status of kaka populations is fundamental for effective conservation and management of the species (Moorhouse and Greene, 1998). Hence it is essential that the Mount Bruce kaka population is monitored regularly and accurately to ensure that the status of the population and the effectiveness of management techniques, including supplementary feeding and pest control, are correctly measured. Thus it is vital that the monitoring technique used is as exact and robust as possible. However, a precise assessment of kaka abundance is difficult due to the comparative rarity of kaka, as well as their long distance movements and extreme changes in diurnal and seasonal conspicuousness (Beggs and Wilson, 1991; Moorhouse and Greene, 1998).

Distance Sampling

Distance sampling has been recommended as the best method to estimate kaka abundance (Greene *et al.*, 2004). This is because traditional survey methods (such as five-minute counts) are particularly sensitive to aforementioned variations in kaka populations and hence, provide only crude indices of kaka abundance (Moorhouse and Greene, 1998). Additionally, low cost, simple to use indices only detect large changes in initially abundant populations (Wunderle, 1998; Greene, 2003). Furthermore, parrots, including kaka are particularly elusive birds and counts made within forests under the canopy, are likely to miss many birds (Wunderle, 1994). Thus, methods producing absolute estimates of density and abundance that account for probability of detection are more appropriate to produce population trends of kaka (Greene, 2003).

Distance sampling involves recording the distance to bird contacts and theoretically allows the estimation of actual bird densities, not just an index of abundance (Bibby *et al*, 1998; Dunn *et al.*, 2006). It provides an unbiased means of assessing population size by modelling the detectability of objects (in this case kaka) with increasing distance from a defined line or point (Buckland *et al.*, 1993; Greene and Moorhouse, 2004). The key parameter required in the estimation of density in distance sampling, is the detection function (g(y)) which describes the detectability of objects at given distances (y) from the line (Hounsome *et al.,* 2005). Thus, the rate of decline in numbers detected as a function of distance, can be used to estimate detection probabilities, and hence density, at each distance (Dunn *et al.*, 2006). A significant advantage of distance sampling is that the theory allows for the fact that many objects go undetected and that there is a decreasing probability of detecting a bird with increasing distance from the point or line (Buckland *et al.*, 1993). Also, an important benefit of distance sampling is that the methods have been designed to produce reliable estimates of abundance, regardless of varying conspicuousness (Buckland *et al.*, 1993). This is particularly useful for elusive birds such as kaka.

Distance sampling allows accurate, unbiased estimates of density to be made with only mild assumptions (Moorhouse and Greene, 1998), provided the assumptions are met (Buckland *et al.*, 1993). Key assumptions include; birds on the line or point are detected with certainty, that distances are recorded accurately and without bias, and that birds are detected at their initial location (Barraclough, 2000).

Results of a three year pilot study of kaka and kereru using distance sampling in Waipapa Ecological Area indicated that it is a robust, relatively simple monitoring tool which provides relatively unbiased measure of kaka density and abundance over temporal and spatial scales (Greene *et al.*, 2004). It has since been adopted by the Waikato Conservancy to monitor the kaka populations in their region (Greene *et al.*, 2004).

The aim of this study was to conduct a pilot survey to determine the effectiveness of distance sampling (using the point count technique) in measuring the abundance and density of kaka in the Mt Bruce Reserve.

Study site

Mount Bruce Reserve is located to the east of the Tararua Ranges in the Wairarapa region of the North Island, between Eketahuna and Masterton (fig. 2). The north-western boundary of the reserve where the NWC is situated adjoins State Highway 2 (fig. 1). The Reserve is 942ha, reaches an elevation of 710m and contains podocarp-broadleaf forest. Mount Bruce

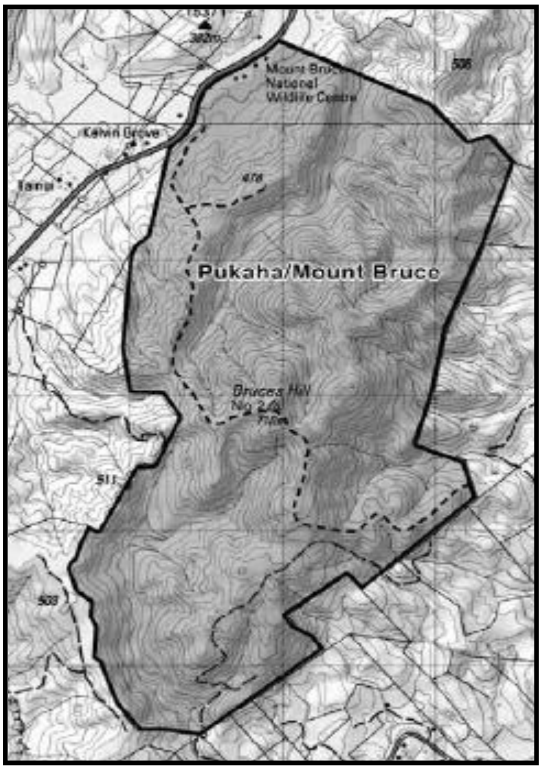
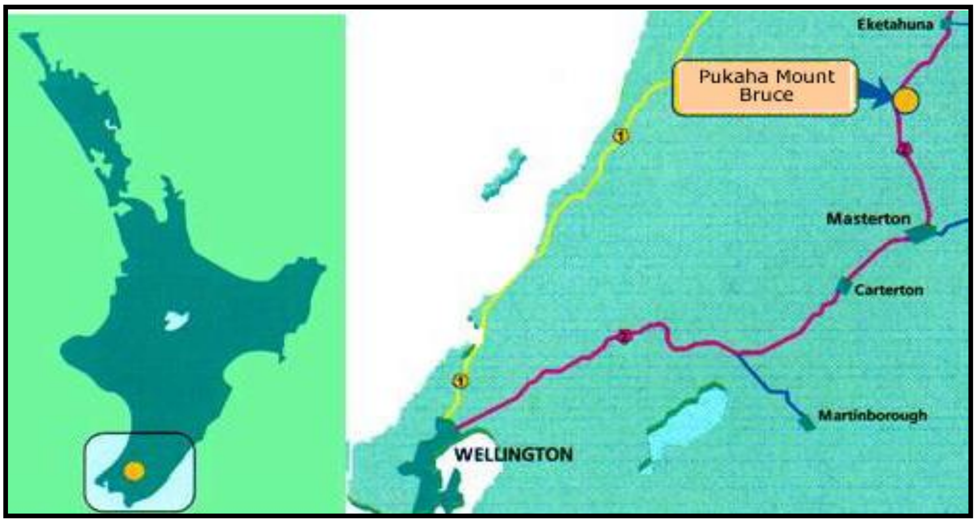


Figure 1: Mt Bruce Reserve and the location of the visitors centre. (Image: DOC fact sheet)

Reserve is the last remaining substantial remnant of an extensive podocarp forest known as the ‘Forty mile bush’ (Berry, 1998). The Reserve is now surrounded by farmland used for sheep and dairy farming.

The forest has been degraded through fires, fencing problems and stock trespass (Berry, 1998). Noxious mammals, particularly goats (*Capra hircus*), brush-tailed possums, stoats and rats (*Rattus rattus, R. norvegicus*) are present and also greatly contribute to the forest degradation (Berry, 1998). Other introduced mammals present within the Reserve include ferrets (*Mustela furo*), weasels (*Mustela nivalis*), and feral cats (*Felis catus*). The pest control within the Reserve consists of 190km of trap lines (T. Studholm, pers. comm) marked with coloured tape aimed at primarily controlling rat numbers, however trapping and secondary poisoning of mustelids and is common (T. Studholm, pers. comm). The system involves bait stations holding racumin bait, which contains the pesticide coumatetralyl, situated every 100m and traps (fenn and DOC 250’s) situated every 200m. Goat culls also take place periodically by the Department of Conservation and possum numbers are controlled through the Manawatu/Wanganui Regional Council who carry out 1080 pellet drops periodically within the Reserve.

Many possible food sources exist for kaka within the Mount Bruce Reserve. These include sap, invertebrates, fruits, flowers and seeds all produced from numerous tree species including rimu (*Dacrydium cupressinum*), rewarewa (*Knightia excelsa*) and red beech (*Northofagus fusca*) (Berry, 1998). Predator proof artificial nest boxes have been set up in the reserve, near the national wildlife centre. Kaka in the reserve use both the artificial and natural nest sites (R. Berry, pers. comm.). It is estimated that the reserve has the ability to support up to 600 kaka (R. Vander lee, pers. comm.)



Methods

Fieldwork

Fieldwork took place in the months of November and early December 2007 between half an hour after sunrise (at the earliest) and 12pm. While parrots are most active between sunrise and 11am (Wunderle, 1994), the survey period was extended to 12pm to enable more coverage of the reserve. No surveys were carried out in heavy rain or strong winds as both impair kaka detectability (Bibby *et al.*, 1998).

Four transect routes were set up throughout the Reserve along the bait station tracks (appendi e safety of the ob placed to ensure that an accurate representation of the reserve was covered and that the majority of habitats, vegetation and topographical features were represented. Between ten and 13 point count stations were placed along each transect route, 500m apart (Greene *et al.*, 2004). This distance reduced the chance of double counting between points, but still allowed maximum coverage of the reserve (Bibby *et al.*, 1998). Point counts were chosen over line transects because of the semi- cryptic behaviour of kaka and the density and terrain of the forest (Buckland *et al.*, 1993). One transect route was surveyed a day and all routes were covered three times during the study period. Thus, a total of 138 points were surveyed. The central points of census stations were marked with tape to ensure the exact measurement to the bird from the point and that the same point was used in the replications.

Figure 2: The location of Mt Bruce Reserve in the Wairarapa region, between Materton and Eketahuna. (Image: Mt Bruce website).

The observer approached each point with caution to avoid flushing the kaka. If this occurred, the distance from this point to the census station point was measured. Once at the census station, the observer allowed a two minute period to elapse to prepare for the count and allow the birds to settle (Bibby *et al.*, 1998). Ten minutes was used to detect all kaka observed or heard, out to maximum radius of 100m. A ten-minute count period was chosen as it allows maximum detection of cryptic birds while minimising error due to double counting or observer fatigue (Casagrande and Beissinger, 1997; Bibby *et al.*, 1998). During this time, the horizontal distances to each bird (or cluster of birds) was measured to the nearest meter using a tape measure. Laser range finders were avoided due to the density of the forest. The distance from the census point to the site of the first detected call was estimated for kaka heard during the ten-minute period. Kaka flying into or over the census plot were ignored to avoid over- estimating density. Kaka flying out of the census plot were recorded from their first point of origin. At the commencement of each count, the immediate area surrounding the point was checked for birds present but undetected during the count period and to ensure that no kaka near or on the point were missed.

Data analysis

Data was analysed using the program DISTANCE version 5.0 release two (Thomas *et al.*, 2006). This software estimates the detection probability as a function of distance by fitting six possible probability functions to the data (Buckland *et al.*, 1993). Kaka detections were treated as clusters, and densities were estimated using mean cluster size. After initial examination and analysis, the data was grouped into five intervals and truncated at 90m to eliminate outliers which provide little information about density and are often difficult to model (Buckland *et al.*, 1993). All key functions and series expansions were considered for density estimation and the program was run to select the optimal detection function. The selection of models for the detection function was based on a combination of Akaike's information criterion, overall variance estimates, goodness of fit statistics and visual inspection of detection histograms (Buckland *et al.*, 1993). Consequently, the estimator chosen to compute the density estimate was the negative exponential key function with the cosine series expansion.

Results

From 138 point counts, there were a total of 56 detections of kaka, however only 34 of these were analysed in DISTANCE, after the truncation of data at 90 meters and the exclusion of kaka detected in flight. The estimated density of kaka in the Mt Bruce Reserve is 0.09 kaka per hectare with an estimated total population of 82 kaka (table 1).

Table 1: The density (D) per hectare and total population (N) values of kaka in the Mt Bruce Reserve with corresponding 95% confidence intervals and percentage coefficient of variation derived by DISTANCE.

Population estimate	Value	95% CI		% CV
		Low	High	
D	0.09	0.04	0.19	40
N	82	38	177	40

Throughout the survey most detections of kaka (single or groups) occurred on routes A and D (fig.3), which were both located near the National wildlife centre (Appendix 1). There were few detections of kaka (groups or single) on routes B and C (fig. 3). These routes were positioned to the north-east and south ends of the reserve respectively and thus were located a fair distance from the National Wildlife Centre (Appendix 1). Most detections of kaka occurred aurally through vocalisations with fewer visual detections of kaka (fig. 3).

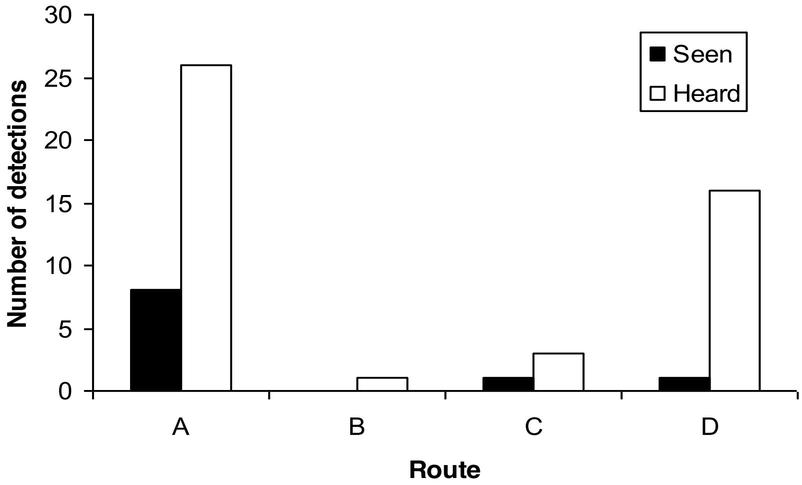


Figure 3: The total number of visual (black) and aural (white) detections of kaka (in groups or single) on each of the four routes (A, B, C and D).

There is a 70% chance of detecting kaka in the Mt Bruce Reserve at any given point and the detection of kaka in the Mt Bruce Reserve decreases further away from the point (fig. 4).

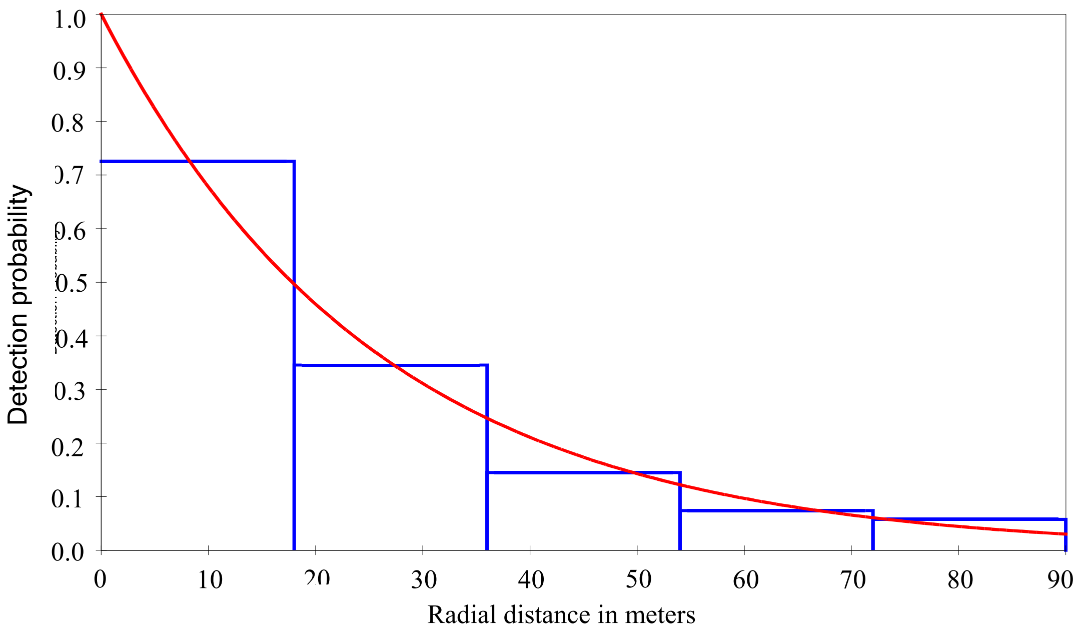


Figure 4: The detection function g(y) of kaka in Mt Bruce Reserve plotted into five intervals and truncated at 90 meters, illustrating the probability of detection of kaka by radial distance from the points. The model (red line) is a negative exponential cosine

Discussion

Kaka abundance and density in Mt Bruce Reserve

The abundance estimate produced by distance sampling was 82 kaka in the Mt Bruce Reserve. Based on feed station records and breeding data there are a minimum of 54 kaka and an estimated maximum of between 80-100 kaka currently in the Reserve (R. Berry, pers. comm.). Thus, the abundance estimate produced by distance sampling appears to be relatively accurate and reliable. However, the kaka abundance has been potentially underestimated because the surveys took place during the kaka breeding season, when kaka are particularly elusive, especially nesting females (Greene *et al.*, 2004). In this instance surveying at this time was unavoidable and while it is generally acceptable to survey kaka in November (Greene *et al.,* 2004), the kaka population at Mt Bruce had started breeding by mid November. Therefore, in the future, it is recommended that the Mt Bruce kaka surveys be completed no later than the end of October.

The density estimate derived from distance sampling was 0.09 kaka per hectare in the Mt Bruce Reserve. This is significantly lower than the density of kaka that the Mt Bruce Reserve is thought to be able to support which is 1.57 kaka per hectare. It is also an exceptionally smaller density estimate than the kaka population in the Waipapa Ecological Area, with the most recent estimate being 0.6 kaka per hectare (Greene *et al.*, 2004). This is expected, considering that Pureora forest is an area on the mainland that contains one of the largest flocks of North Island kaka (Berry, 1998). Thus, the density of kaka in the Mt Bruce Reserve is relatively low however as aforementioned, this could be an under estimation due to the survey taking place in the breeding season.

There was a noticeably higher density of kaka in the area of the Reserve closest to the National Wildlife Centre. There are multiple probable reasons for this. Firstly, all the artificial nest boxes are located near the NWC, (in order to monitor the nests easily); this causes more kaka to use that particular area during the breeding season (when the survey took place). Secondly, it is possible that kaka using natural nest sites are choosing to nest near the feed stations that provide a guaranteed food source, which is vital throughout the breeding season. Thirdly, kaka have high site fidelity (Berry, 1998) and tend to have small home ranges but do fly large distances, returning to core areas (Greene *et al.*, 2004). The front area of the Reserve was the release site of the kaka ten years ago and the higher density of kaka using this area could reflect that. Nevertheless, the higher density of kaka in the front of the Reserve is concerning because it could mean the Reserve can hold a significantly lower density of kaka than the 1.57 kaka per hectare as initially thought. Further research on the movements of kaka throughout the Reserve is recommended. Also, the erection of another feeding station on the opposite side of the reserve should also be considered, with the intention of encouraging kaka to use other areas of the reserve.

Precision and meeting distance assumptions

While the kaka abundance and density estimates appear to be reliable and accurate the precision of these values needs to be questioned. The confidence intervals for both population estimates are relatively narrow (table 1), but quite imprecise (CV= 40%). This is perhaps a result of low numbers of detections in the survey (only 34 from 138 point counts) and the potential violation of the distance assumptions.

An important requirement of distance sampling is that for point count methods, 80-100 detections of a species are required to calculate a reliable distance- detection function (Buckland *et al.*, 1993). The 34 detections used for distance analysis in this study falls well below the required number of detections, causing a lack of precision in the population estimates. However, for elusive species such as kaka, the effort required to achieve this number of detections is considerably great. In this study it was particularly difficult to achieve these high numbers of detections with the density of kaka being very low on two of the four routes. While the low detection rate could be a result of the breeding season, in the future to overcome this problem, it is recommended that other than survey in October at the latest, more transect routes should be set up within the Reserve, with less replicates of each route.

There is a significant problem with the potential violations of the distance sampling assumptions, particularly the accurate measurement of radial distances. This resulted as most kaka were detected through estimating the distance to their vocalisations. While this is expected and is in accordance with other bird studies (Dunn *et al.*, 2006), counts involving estimating distances to singing or calling individuals are extremely vulnerable to error (Wunderle, 1994). This is because estimating distances to calls are imprecise and provide many biases of unpredictable magnitude (Hutto and Young, 2003). Additionally, kaka move frequently making it difficult to determine whether vocalisations in different places are from the same individual or many different ones, especially if the birds are never seen, as is often the case in forested habitats. Thus, over-estimating the number of birds detected is probably common (Hutto and Young, 2003). To ensure that distances to kaka calls are estimated as accurately as possible, observer training is essential (Dunn *et al.*, 2006). However this uses up valuable resources that few conservators have, and often even experienced observers lack precision (Hutto and Young, 2003).

Other survey methods

There are three main survey methods used to estimate parrot populations (Casagrande and Beissinger, 1997). The first technique is roost surveys, which are used in small islands where most roosts can be found. The second and third techniques are point or line transects respectively. (Casagrande and Beissinger, 1997). Other common survey techniques include tape-recorded playback of calls (Wunderle, 1994) and mark recapture models (Moorhouse and Greene, 1998). For this study, roost surveys were not an option due to logistics including the size of the reserve and the fact that only one person was conducting the survey. However, the call playback and mark recapture techniques were considered.

Kaka call playback

Tape- recorded playback of vocalisations are often useful to enhance the likelihood of detection of a rare or secretive species (Wunderle, 1994). Kaka are responsive to tape-recorded playback vocalisations and this method is used to entice them into mistnets (Wilson *et al.*, 1998). This method was trialled in this study, by playing out recorded vocalisations of a flock of kaka, in the hope it would attract any kaka in the area close to the observer and make any kaka in the area more visible. The taped vocalisations were played out at each survey station on all four routes for five minutes, followed by five minutes of silence in which individuals were counted (Wunderle, 1994). This method was found to be ineffective and was thus discarded. The reason for the lack of response is unclear. However possible reasons include that perhaps the kaka were less responsive to calls during the breeding season, or the played out calls were the wrong type (the played out calls were those used when they are flying), or perhaps the calls were too quiet to be heard by any kaka.

Mark- recapture

The mark-recapture technique was considered in this study to produce an abundance estimate using resightings of the colour bands on the kaka. The mark-resighting sessions would have taken place at the feed stations for convenience, as kaka in the forest are very elusive and because accurately identifying leg bands of kaka in the forest is very difficult (Moorhouse and Greene, 1998; pers. obs). However, the use of this technique was discarded because conducting the mark-recapture surveys using the feeding station meant that a vital assumption of Petersen-Lincoln estimate was violated. This was that all animals have the same probability of being resighted (Lettink and Armstrong, 2003). This occurred as some individuals use the feed stations daily and others are only seen very rarely, therefore producing large biases. Furthermore, the kaka using the feedstations vary throughout the year, causing additional bias to the estimates. However, the main reason for not using this method is because it will not be suitable for monitoring the kaka populations in the future. This is because kaka fledglings are no longer being colour banded as it has become too labour intensive considering the current size of the population (R. Berry. pers. comm.). Hence, the mark-resighting method does not account for kaka that are not colour banded and not using the feed stations which will hopefully be a significant portion of the population in the future.

Conclusion

The suitably of distance sampling for monitoring kaka abundance at Mt Bruce

The result of this pilot study indicates that distance sampling is a suitable method for monitoring the abundance of kaka in the Mt Bruce Reserve. The abundance estimate derived from distance sampling appeared to be relatively reliable and accurate despite the breeding season complication. However, to further confirm this conclusion, further pilot studies should be conducted over the next few years before and/or after the breeding season.

There is concern over the violation of distance assumptions, especially the accurate estimate of radial distances and low number of kaka detections. Perhaps the biggest down fall of distance is the need for high numbers of detections, which is particularly concerning in low density areas such as Mt Bruce where the effort required to effectively model the detection probability may be too costly (Greene *et al.*, 2004). The low number of detections may be due to surveys during the breeding season which will be determined in future surveys. Despite the concerns of potential violations of assumptions, this method would still produce much more reliable and precise estimates than relative measures of abundance such as five-minute point counts. Perhaps my biggest concern about distance sampling is one that is not mentioned often in the literature, which is the DISTANCE program itself. In my experience the program DISTANCE is difficult to use despite the numerous sources available to assist users including an excellent book and help from more experienced users (Buckland *et al.*, 1993). Hence, DISTANCE would not be suitable for someone with little or no experience in using the program. Thus, conducting distance sampling is also not appropriate in areas were the user does not have a basic knowledge of the program, as may be the case at Mt Bruce. However, the various problems of time constraints, costs and lack of program knowledge might be overcome by allowing Massey University students to conduct the surveys and analysis as part of their course. However, if this is not the case and Mt Bruce finds that it is too costly to produce reliable results using distance, then the use of mark-recapture using the feed stations, should be further investigated until the density of kaka at Mt Bruce is high enough to get large numbers of detections with less effort than is needed currently.

In conclusion, despite the potential biases associated with using distance sampling it still appears to be the best method available for monitoring the abundance of kaka in the Mt Bruce Reserve especially if Mt Bruce is able to make use of the Massey University students, who will also greatly benefit from the experience. Further pilot studies using distance sampling do need to be conducted to ensure that the method is precise and reliable before it is adopted completely as the kaka abundance monitoring tool.

Acknowledgements

Firstly, thank you to all the wonderful staff at Mt Bruce. This project could not have taken place without you and I loved my time at Mt Bruce! A huge thank you particularly Tom Studholm for giving up your precious time to provide me with valuable advice and help with getting around the Reserve. Also a huge thank you to Raelene Berry for your advice and help with the kaka. Thank you to Katie Peircy for coming tramping with me those first few times to ensure I didn't get lost in the huge Reserve, it meant a lot! Thank you to Grant Blackwell for your guidance and help with the distance program and my methods, you have no idea how much I appreciated it and how much it meant to me! My biggest thank you goes to my mum and Liam Dunbar for proof reading this for me, but especially for all your support throughout the year and the duration of the project.

References

Barraclough, R.K. 2000. Distance sampling: a discussion document produced for the Department of Conservation. *Science and research internal report 175*, Department of Conservation, Wellington.

Bibby, C., Jones, M. and Marsden, S. 1998. Expedition field techniques: Bird surveys. Expedition field advisory centre, London, UK.

Beggs, J.R. and Wilson, P.R. 1991. The kaka *Nestor meridionalis*, a New Zealand parrot endangered by introduced wasps and mammals. *Biological conservation* 56: 23-38.

Berry, R. 1998. Reintroduction of kaka (*Nestor meridionalis septentrionalis*) to Mount Bruce Reserve, Wairarapa, New Zealand. *Science for conservation 69*, Department of Conservation, Wellington.

Buckland, S.T., Anderson, D.R., Burnham, K.P. and Laake, J.L. 1993. Distance sampling: Estimating abundance of biological populations. Chapman and Hall, London, UK.

Bull, P. C., Gaze, P.D. and Robertson, C.J.R. (1985). *The atlas of bird distribution in New Zealand.* Ornithological society of New Zealand, Wellington.

Buller, W.L. (1888). *A history of the birds in New Zealand.* 2nd edn. The author, London.

Casagrande, D. G. and Beissinger, S.R.1997. Evaluation of four methods for estimating parrot population size. *The condor* 99: 445-457.

Department of Conservation fact sheet. 2005. Key facts about rodent control in Mount Bruce Scenic Reserve. Department of Conservation, Masterton.

Dunn, E.H., Bart, J., Collins, B.T., Craig, B., Dale, B., Downes, C.M., Francis, C.M., Woodley, S. and Zorn, P. 2006. Monitoring bird populations in small geographic areas. *Special publication: Canadian Wildlife service*. Environment Canada, Ottawa, Ontario.

Greene, T. 2003. Distance sampling populations of New Zealand birds- estimating kaka and kereru abundance. *DOC Science Poster 64*. Department of Conservation, Wellington.

Greene, T.C., Powlesland, R.G., Dilks, P.J. and Moran, L. 2004. Research summary and options for conservation of kaka (*Nestor meridionalis*). *DOC Science Internal Series 178*. Department of Conservation, Wellington.

Heather, B.D., and Robertson, H.A. 2005. *The field guide to the birds of New Zealand*. Viking, London.

Holland, G. and Collen, R. 2000. Kaka population re-established. Releases in Mount Bruce area. *PsittaScene* 12 (3): 4-6.

Hounsome T.D., Young, R.P., Davison, J., Yarnell, R.W., Trewby, I.D., Garnett., B.T., Delahay, R.J., Wilson, G.J. 2005. An evaluation of distance sampling to estimate badger (*Meles meles*) abundance. *Journal of zoology, London* (266): 81-87.

Hutto, R.L. and Young, J.S. 2003. On the design of monitoring programs and the use of population indices: a reply to Ellingson and Lukacs. *Wildlife society bulletin* 31: 903-910.

Lettink, M. and Armstrong, D.P. 2003. An introduction to using mark-recapture analysis for monitoring threatened species. *DOC Science Internal series 28*. Department of Conservation, Wellington.

Moorhouse, R.J. and Greene, T.C. 1998. Research plan for kaka (Nestor meridionalis) 1996- 2002. Department of Conservation, Wellington.

Moorhouse, R., Greene, T.C., Dilks, P., Powlesland, R. Moran, L., Taylor, G., Jones, A., Knegtmans, J. Wills, D., Pryde, M., Fraser, I., August, A. and August, C. 2003. Control of introduced mammalian predators improves kaka (*Nestor meridionalis*) breeding success: reversing the decline of a threatened New Zealand parrot. *Biological conservation* 110: 33-44.

Mt Bruce. (n.d). Location map. www.mtbruce.org.nz

Thomas, L., Laake, J.L., Strindberg, S., Marques, F.F.C., Buckland, S.T., Borchers, D.L., Anderson, D.R., Burnham, K.P., Hedley, S.L., Pollard, J.H., Bishop, J.R.B. and Marques, T.A. 2006. *Distance 5.0. Release "2"*. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/

Wilson, P.R., Karl, B.J., Toft, R.J., Beggs, R.J. and Taylor, R.H. 1998. The role of introduced predators and competitors in the decline of kaka (*Nestor meridionalis*) populations in New Zealand. *Biological conservation* 83 (2): 175-185.

Wunderle, J.M (Jnr). 1994. Census methods for Caribbean land birds. *Forest service, General technical report: 98*. United States Department of Agriculture, New Orleans, Lousiana.

Appendix 1

The four transect routes (A-D) marked by blue within the reserve, with each point count station (1-13). The orange line is the public track, the yellow lines are ridge lines and the pink lines are all other trap lines including valley floors and edges.