Effect of hunting and predation on kea, and a method of monitoring kea populations

Results of kea research on the St Arnaud Range

DOC SCIENCE INTERNAL SERIES 181

Graeme Elliott and Josh Kemp

Published by
Department of Conservation
PO Box 10-420
Wellington, New Zealand

DOC Science Internal Series is a published record of scientific research carried out, or advice given, by Department of Conservation staff or external contractors funded by DOC. It comprises reports and short communications that are peer-reviewed.

Individual contributions to the series are first released on the departmental website in pdf form. Hardcopy is printed, bound, and distributed at regular intervals. Titles are also listed in the DOC Science Publishing catalogue on the website, refer http://www.doc.govt.nz under Publications, then Science and Research.

ISSN 1175-6519

ISBN 0-478-22588-1

In the interest of forest conservation, DOC Science Publishing supports paperless electronic publishing. When printing, recycled paper is used wherever possible.

This report was prepared for publication by DOC Science Publishing, Science & Research Unit; editing and layout by Lynette Clelland. Publication was approved by the Manager, Science & Research Unit, Science Technology and Information Services, Department of Conservation, Wellington, New Zealand.

CONTENTS

Effect of hunting and predation on kea, and a method of monitoring kea populations

Results of kea research on the St Arnaud Range

Graeme Elliott[1] and Josh Kemp[2]

[1] Department of Conservation, Private Bag 5, Nelson, New Zealand

[2] Zoology Department, Otago University, PO Box 56, Dunedin, New Zealand
Present address: Department of Conservation, Private Bag 5, Nelson, New Zealand

ABSTRACT

Kea *Nestor notabilis* were studied on the St Arnaud Range near Nelson, South Island, New Zealand between 1992 and 1999. Population simulations were undertaken to assess the impact of hunting and predation on kea, and the sustainability of continued killing of problem birds. Predators, probably mainly stoats and possums, were found to have reduced kea populations and increased the likelihood of extinction considerably, though the kea population on the St Arnaud range appears to be quite stable. The hunting pressure that kea suffered during the late 19th and early 20th centuries was unsustainable. Given the birds' relatively high extinction risk, continued killing of kea is unjustifiable. A method of monitoring kea populations is described.

Keywords: Kea, *Nestor notabilis*, hunting, predators, population monitoring.

Elliott, G.; Kemp, J. 2004: Effect of hunting and predation on kea, and a method of monitoring kea populations: results of kea research on the St Arnaud Range. *DOC Science Internal Series 181*. Department of Conservation, Wellington. 17 p.

1. Introduction

Many of New Zealand's endemic birds have declined or become extinct since the human-related destruction of forest habitat, and the introduction of mammalian predators, which started about 1000 years ago. Parrots, being hole-nesters, are particularly vulnerable to predators while nesting, and five of the six parrot species resident on New Zealand's main islands have declined dramatically over the last 150 years. In contrast, kea *Nestor notabilis* remain widespread in the montane areas of the South Island, and their curiosity and habit of congregating near roads and ski fields gives the impression they are still common. However, recent estimates put their population at only 1000–5000 (Diamond & Bond 1999; Anderson 1986) and it is not known whether the population is secure or declining.

The kea's survival is all the more remarkable given the persecution it has suffered over the last 150 years for its habit of attacking sheep. About 150 000 kea were intentionally killed between 1870 and 1948 (Cunningham 1948) and although kea hunting dramatically decreased when kea became protected, a few birds are still killed by Department of Conservation staff when they attack sheep, and an unknown number are illegally killed. Conservation managers need to know whether this continued 'harvest' is sustainable or whether kea need some positive conservation management.

We studied kea in on the St Arnaud Range near Nelson Lakes National Park between 1992 and 1999 with the aim of answering the following questions:

1. Is the kea population increasing, stable or declining?
2. What effect have hunting and predators had on kea populations?
3. Can kea populations sustain a continued 'harvest'.
4. How are kea populations best monitored?
5. What further work is required on kea?

Most of this work is described in detail in two papers that have been submitted for publication (Kemp & Elliott, in press and Elliott & Kemp, in press). This report summarises the findings of the two papers, describes a monitoring protocol for kea and makes recommendations for kea management and research.

2. Study area

Our study was centred on the Rainbow Ski Area (hereafter referred to as the 'ski field') (41°53′S, 172°52′E) on the St Arnaud Range, 30 km by road from the village of St Arnaud, in the Nelson District of the northern South Island. Kea from the neighbouring Travers, Wairau and Six Mile valleys regularly visit the ski field and these valleys comprise our 17 000-ha study area (Fig. 1). The valleys are glaciated and U-shaped in cross section, often with grassy flats on the valley floor (c. 600–700 m a.s.l.). The steep valley sides support continuous evergreen forest (up to the treeline at about 1400 m). Red beech *Nothofagus fusca* and silver beech *N. menziesii* dominate the canopy from the valley floors up to about 950 m; above this and to the treeline, mountain beech *N. solandri* var. *cliffortioides* forms the canopy. Above the treeline are snow-tussock

Chionochloa spp. grasslands in which grow a variety of alpine and subalpine shrubs and herbs such as *Celmisia* spp., *Podocarpus nivalis* and *Hebe* spp. Higher still, on mountain peaks reaching 1600–2011 m, are bare rock and fellfield. Lake Rotoiti and the ski field road allowed access to the valleys within the study area.

3. Methods

3.1 KEA CAPTURE

We made regular visits to the ski field car park during the June to October ski season each year between 1992 and 1999 to capture, radio-tag and band kea that gathered there to scavenge and steal food from skiers. Kea also congregate at the military camp at Dip Flat when it is in use, and we occasionally visited and caught birds there.

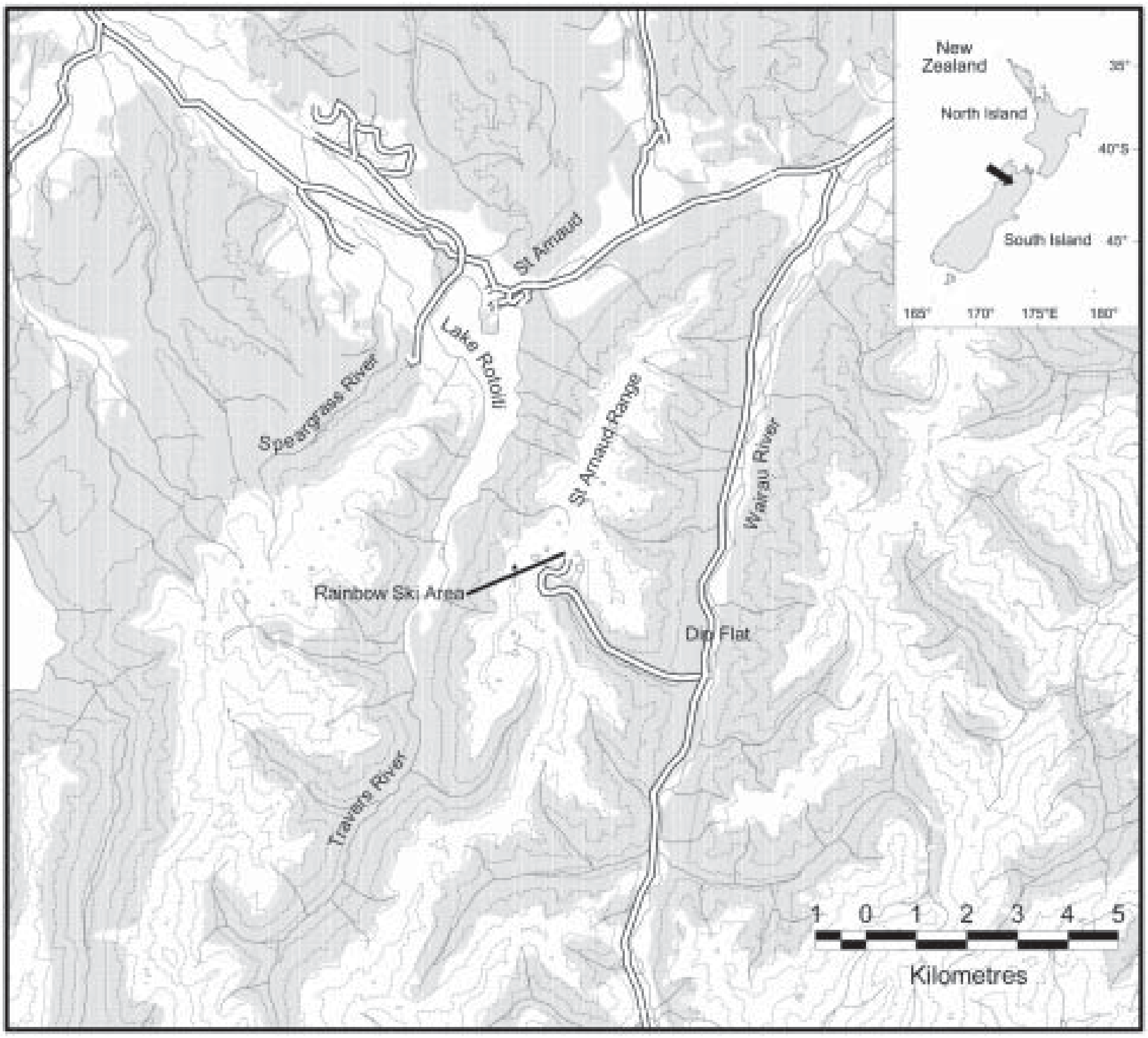

Figure 1. The study area. Dotted lines are 300 m contours and stippled areas are forest.

We mostly caught subadult (< 3 years) kea of both sexes, and adult males, all of which regularly visited the ski field. Adult females only rarely visited the ski field, those that did nested within 3 km of it. In contrast, males with nests up to 6 km away regularly visited the ski field.

We also banded and radio tagged nearly fledged chicks from any accessible nests we found, particularly in January 1998 and 1999.

3.2 KEA SURVIVORSHIP

We regularly searched for all radio-tagged birds throughout our study area using hand-held receivers with yagi aerials, with which we were almost certain to detect a signal if we were in the same valley as the bird and within 2 km of it. During the breeding season (July–January) we repeatedly searched for every radio-tagged adult in our study until we found its nest, were confident it was not nesting, found its body, or concluded it had migrated out of our study area.

We radio-tagged eleven near-fledging chicks during three summers of our study and in three subsequent summers we flew at 2500–3500 m, in a radio-telemetry equipped fixed-wing aircraft, over all forested mountains within a 50-km radius of the nests. Following the flight, we visited all of the birds on foot to see if they were alive. We assumed that birds we could not find from the air had migrated out of our search area because reception and coverage from the plane was exceptionally good and we were just as likely to detect a dead bird as a live one. For example, one transmitter was buried under 2 m of rock, yet we detected its signal from over 2 km away.

3.3 FINDING AND MONITORING NESTS

We found kea nests mostly by tracking adult male kea on foot using portable receivers with Yagi aerials, and birds were repeatedly tracked during the breeding season until we found their nests or were confident they were not breeding (methods are described in detail in Kemp & Elliott, in press). Once it was found, we checked each nest every 2–3 weeks until it either failed or the chicks had fledged.

3.4 COUNTING KEA

During regular trips to the ski field we also counted all the kea present between 4:30 and 5:30 pm after the ski field closed. This was simply undertaken by walking around the ski field buildings and car parks and identifying all birds present. Since most birds carried a radio-transmitter or were banded, most could be individually identified.

Estimates of the size of the kea population visiting the ski field were made using mark-recapture analysis; in particular, we used Bowden's estimate (Bowden 1993), implemented in the program 'Noremark' (White 1996).

3.5 POPULATION MODELLING

We undertook a Monte-Carlo simulation of our kea population using the productivity and survivorship data we collected. By incorporating estimates of hunting mortality of kea near Arthur's Pass (Jackson 1969) and by manipulating our estimates of the rate of predation of kea adults and nests, we assessed the impact of hunting and predation on kea populations over the last 150 years. We also assessed the likely population trajectory of kea in the future. The simulation is described in detail in Elliott & Kemp (in press).

In order to rank the parameters in our model by how much they contributed to the uncertainty in the model's predictions, we calculated parameter uncertainty coefficients using the method of Hunter et al. (2000).

4. Results

For a detailed account of the results, consult Kemp & Elliott (in press) and Elliott & Kemp (in press). The following is a brief summary of results of significance to the management of kea.

We captured and radio-tagged 39 kea which we monitored for an average of 2.5 years each. We found 44 nests in 25 sites and were able to assess the nesting success of 40 of them.

4.1 NESTING

All nests sites were either on the ground, under large boulders (16%), amongst jumbles of rocks (24%), in cavities in rock bluffs (40%), in holes amongst the roots of trees (16%), or in hollow fallen trees (4%).

The first eggs were laid in late July and the last chicks usually fledged by mid January, except in 1998, when two birds re-nested and the last chicks fledged in late March. One of the re-nests was after a nest failure, but the other was after the successful raising of a first brood. These are the first records of kea nesting twice in one breeding season.

Eggs and chicks disappeared from 35% of the nests we monitored and at two of these nests definite sign of stoat predation was found.

Nesting success increased with altitude—high altitude nests were more successful than those at low altitude.

During all but one year of our study, almost all of the adults bred, but during 1996 we found no nests in our study area.

4.2 SURVIVORSHIP AND PRODUCTIVITY

Parameters associated with survivorship and productivity that we were able to measure in our study are presented in Table 1.

Two parameters were not measured directly but estimated from combinations of other parameters: productivity was 0.339 female chicks per adult female, and female annual survival was 0.895.

TABLE 1. SURVIVORSHIP AND PRODUCTIVITY OF KEA.

PARAMETER	MEAN	N	SE	L95	U95
Survival from 2 years to 3 years	1.000	5		0.478	1.000
Survival from 1 year to 2 years	0.909	11		0.587	0.998
Fledgling survival	0.941	17		0.713	0.999
Probability of a breeding year	0.778	9		0.400	0.972
Probability of breeding	0.930	43		0.809	0.985
Daily nest survival	0.993	2285		0.989	0.996
Average successful clutch size	0.917	30	0.108	0.705	1.128
Probability of surviving nest predation	0.857	7		0.421	0.996
Adult non-breeding survival	0.944	89		0.874	0.982
Proportion of failed nests due to accident	0.133	15		0.595	0.983
Probability of renesting after success	0.043	23		0.001	0.220
Probability of renesting after failure	0.143	14		0.018	0.428
Proportion of males in clutches	0.500	18		0.260	0.740

4.3 POPULATION MODELLING

Our simulations of kea populations indicated that hunting and predators had a large effect, and kea populations are now smaller and more vulnerable to extinction than they were 150 years ago. The simulations indicated that the 100-year extinction risk of kea in the 1850s was about 0.8% whereas it is now about 32%. Kea populations were under the greatest pressure in the middle of the 20th century when they faced both predators and hunting—if the level of hunting and predation that kea suffered in the 1950s had continued for 100 years, there is a 70% chance they would have become extinct.

It is possible that high nesting success at high altitude might act as a buffer against increasing numbers of predators. Kea mainly forage near the tree line, so nest sites in these areas are likely to be favoured over those at lower altitude which are further away. Because kea populations have declined, increasing proportions of the remaining birds should be able to nest in productive high-altitude sites. Nesting success should increase, and therefore counteract the impact of predators. If this shift to high altitude nests really does occur, our simulations predicted that it would reduce the extinction risk of current kea populations from 31.6% to 12.8%.

Parameter uncertainty analysis indicated that nesting success and female survival are the two parameters for which a reduction in uncertainty through larger sample sizes would most increase confidence in the simulations' predictions.

4.3.1 Counting kea

Table 2 shows the results of kea counts carried out at the ski field on 11 afternoons during the ski season in 1994. Using a mark-recapture population estimate (Bowden 1993), we estimate that 25 kea (95% confidence intervals 22–29) were using the ski field. The coefficient of variation of Bowden's estimate was much less than that of the number of birds counted at the ski field, indicating that Bowden's estimate would provide a more sensitive indicator of population change than would simple counts.

We undertook a power analysis by simulation to determine the number of counts that would be needed to detect a decline of 25% or greater over 10 years. We regarded a counting regime as sufficiently powerful when 80% of regressions of the log of the simulated counts against time were significant at the 10% level and we tested a range of counting regimes in which the starting number of kea and the number of counts carried out each year were varied. We found that the number of counts necessary to detect decline was given by:

$$\textit{number of counts per year} = \frac{40}{\textit{average number of birds counted}}$$

as long as about three-quarters of the birds observed in the counts were banded and as long as all the bands of the banded birds could be read.

TABLE 2. KEA DETECTED AT THE RAINBOW SKI FIELD DURING 11 AFTERNOON COUNTS IN 1994.

	DATE										
BAND NO.	19 JUL	19 JUL	28 JUL	3 AUG	4 AUG	3 SEP	4 SEP	5 SEP	23 SEP	23 SEP	5 OCT
14334	1	1	1	1		1	1	1			
14335	1	1			1			1			
27341	1		1	1	1			1	1		
14333		1		1			1		1		
14337		1	1	1	1	1		1	1		1
27342		1									
27343		1				1		1	1	1	
27347		1				1		1	1		
21626			1			1		1	1	1	
31312				1	1	1		1			1
21629						1				1	1
21624							1	1			
21627							1				
31315							1				
14336								1			
21622									1		
21630									1	1	
31314									1	1	1
31310											1
unbanded	1	1	1			1	1	1	1	1	1
unbanded	1	1	1			1	1	1	1		1
unbanded			1				1	1			
unbanded								1			
Number counted	5	9	7	5	4	9	8	14	11	6	7

5. Discussion

The main potential predators of kea nests in montane beech forest in the northern South Island are stoats and possums *Trichosurus vulpecula*. In a conservation trapping programme in nearby forest, stoats and possums were common, whereas cats *Felis catus* and ferrets *Mustela furo* were relatively rare and hedgehogs *Erinaceus europaeus* only common near the edge of farmland (Genevieve Taylor, pers. comm.). The only nest failure that we can confidently attribute to a specific predator was caused by a stoat. However, possums are known nest predators of other species (Sadlier 2000), and have been observed preying on kaka nests (Ralph Powlesland pers. comm.). If possums can prey on kaka eggs and chicks, then they should have little trouble preying on kea eggs and chicks.

During his study of kea near Arthur's Pass in the 1950s and 1960s, Jackson (1960, 1963, 1969) found no evidence of predation of kea or their nests, and the nesting success he recorded was significantly higher than in our study. Although there is no reason to suppose that stoat numbers have changed since Jackson did his research, possum numbers have almost certainly risen, since they only arrived in the area at about the time Jackson was doing his research (Pracy 1974). If possums are a significant predator of kea nests, then the lack of possums near Arthur's Pass during Jackson's study could explain the higher kea nesting success that he recorded.

Why should kea nest success be higher at high altitude? Most of the nest failures we observed were probably caused by predators and this suggests that predators were either less common or less effective at high altitude. While there is no evidence that stoats are less abundant at high altitudes, possum density usually declines with altitude (Efford 2000).

Our estimate of 47% nesting success for kea is much greater than the 10% recorded for kaka nesting in tree cavities near our study site between 1985 and 1996 (n = 20 nests, Wilson et al. 1998), and our study provides a possible explanation for kea nesting more successfully than kaka. Kea nest mostly near the tree-line where possums are rare. Kaka, in contrast, can only nest at relatively low altitudes where there are trees with holes large enough for their nests and where possums are more common. Kea also nest earlier than kaka, so kea nests are less exposed to the increase in stoat numbers that occurs each summer when young stoats become independent.

Our modelling indicates that kea have suffered substantially since the arrival of humans and introduced predators in New Zealand. The significant effect of predation and hunting suggests that kea populations declined following the introduction of mammalian predators and hunting in the 1800s, but that the decline has slowed or even stopped. The process of decline has probably been reasonably complicated, with stoats, possums and hunting pressure causing successive waves of decline in kea numbers (Fig. 2).

Stoats were introduced to New Zealand in 1884 and quickly spread throughout the country (King 1990).

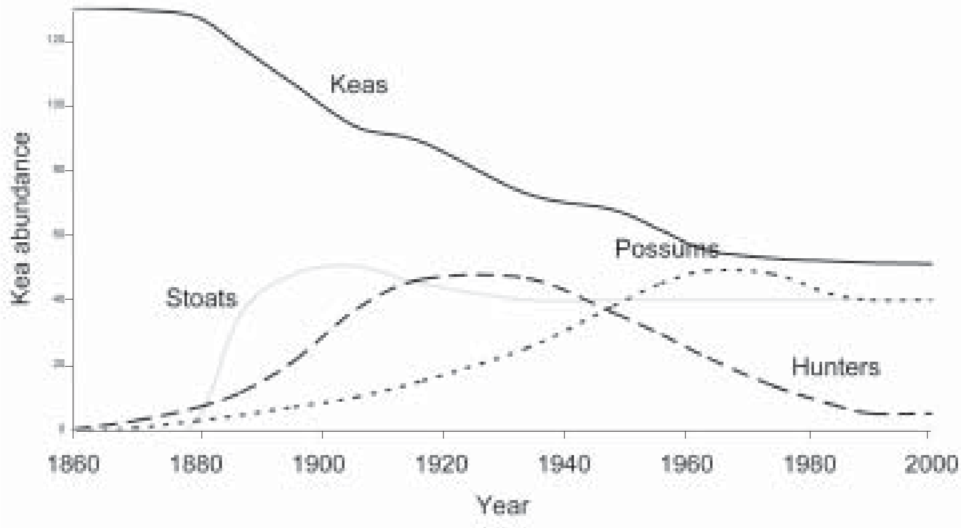

Figure 2. Schematic representation of the likely chronology of kea decline and its relationship to hunting pressure and the colonisation of stoats and possums.

Possums were introduced earlier than stoats, though the bulk of introductions occurred at about the same time as stoats (in the late 1800s). However, they spread much more slowly and did not colonise the South Island high country until after the 1950s. They have still to colonise a few parts of the country and have yet to reach their peak densities in others (Cowan 1990).

Hunting kea started as soon as the high country was colonised in the 1860s, and probably reached its peak during the 1920s and 1930s. It continued under a government bounty scheme until 1971 (Anderson 1986), by which time 150 000 kea had been killed. Kea received full legal protection in 1986 and except for a few birds legally killed by the Department of Conservation, they are only rarely (and illegally) hunted. Our estimate of the effect of hunting is based on data from the 1950s and 1960s, by which time hunting had declined, so the effect of hunting during its peak would have been even greater.

During the time that we were studying kea, we investigated several methods of monitoring their populations, but only marking and counting birds at the ski field showed any promise. Kea are too sparsely distributed and too variable in their conspicuousness to be reliably counted away from those places where they habitually gather. We found that it was very difficult to count the birds around the ski field buildings unless most of them were banded, and banding the birds greatly decreased the variance around the estimated number of birds when using mark-recapture estimates such as Bowden's (1993). For these reasons, individual marking will have to be an important part of any monitoring regime. A regime for kea monitoring is described in the appendix.

6. Conclusions

1. Is the kea population increasing, stable or declining?

The kea population on the St Arnaud Range appeared to be quite stable during our study, but our confidence in this prediction is not great. We can only say we are 50% confident that it is not declining and only 68% confident that it will not go extinct within 100 years.

If possums are as important a kea predator as we predict, then we can expect further declines in kea populations in areas which have only recently been colonised by possums, particularly the south-west of the South Island. Kea will probably benefit from intensive possum control and planning of possum control operations should take this into account.

2. What effect have hunting and predators had on kea populations?

Both hunting and predation seem to have dramatic effects on kea populations which are now much smaller, more isolated, and much more vulnerable to extinction than they used to be. It is likely that kea populations in areas where possums have only recently colonised will decline further in the near future.

3. Can kea populations sustain a continued 'harvest'?

No. To use the destruction of kea as a tool in their management we would need to be confident that the population was stable or increasing and safe from extinction. The destruction of kea by Department of Conservation staff is only justifiable when the failure to kill some birds would result in a much larger illegal kill of kea.

4. How are kea populations best monitored?

By regular counts of marked birds at sites where they gather. See appendix 1. We recommend that annual kea monitoring be undertaken at three or four sites in the South Island. One in the north, probably the Rainbow ski field, one in Canterbury and one in Otago or Southland.

5. What further work is required on kea?

We cannot be very confident of the predictions of our simulations because the estimates of survival and productivity on which they were based were made from small samples and had large confidence intervals. Collecting more data on kea survival and productivity would increase our confidence in the simulations' predictions. However, the two parameters that might lead to the greatest increase in prediction confidence are the two parameters which would require the most effort to improve. Collecting further data on female survival and nesting success would require further full-time research on kea.

Kea populations have almost certainly declined over the last 100 years and they now have an unacceptably high extinction risk. Even if most kea populations were approximately stable, they are clearly much more vulnerable to extinction than they used to be. Scarce conservation resources would be better spent increasing kea density through appropriate predator control, than in refining estimates of population trajectory.

However, our failure to identify the cause of most of our nest failures means that predator control could easily be focused on the wrong predators. The highest priority for future kea research should be to identify the causes of the high rate of nest failure.

Because our simulations cannot confidently predict the future population trajectory and because the kea population is relatively small and vulnerable, monitoring kea numbers is also important.

7. Acknowledgements

This work was originally undertaken by GE under contract to the Department of Conservation (Science Investigation no. 1453), but was completed by JK as part of a Masters thesis at Otago University.

We are grateful for the financial contributions of the Department of Conservation, the World Wide Fund for Nature New Zealand (WWF-NZ), the Royal Forest and Bird Protection Society of New Zealand, the New Zealand Lotteries Commission, the J. S. Watson Conservation Trust (Royal Forest and Bird Protection Society), the Miss E.L. Hellaby Indigenous Grassland Research Trust, AMI Insurance Limited, and the New Zealand Native Forest Restoration Trust.

We thank Dr Ian Jamieson of Otago University for his support and supervision of JK's work.

Staff of the Department of Conservation's St Arnaud Area Office provided support and co-operation throughout the study. Without this, the study would not have been possible.

We would also like to thank the numerous and enthusiastic field assistants who were essential to the safe completion of this study. Major contributors were Rhys Buckingham, Alan Knowles, Les Moran, Simon Torr, Andrea Goodman, Rachel Johnstone and Angus Small. Smaller, but no less useful contributions were provided by Stephen Beatson, Amanda Smale, Paul Maxwell, Kahlil Lawless, Micah Kemp, Nic Etheridge, Mark Pengally, Moira Pryde, Dave Butler, Hannah Edmonds, Dirk, Cees Bevers, Ian Jamieson, Frances, Nicola Smith, Rebecca Smith, Nadine Parker, Pete Gaze, Jane Maxwell and Peter Lawless.

8. References

Anderson, R. 1986: Keas for keeps. *Forest and Bird 17*: 2–5.

Bowden, D.C. 1993: A simple technique for estimating population size. Department of Statistics, Colorado State University, Fort Collins, Colorado. 17 p.

Cowan, P.E. 1990: Brushtail possum. Pp. 68–98 in King, C.M. (Ed.): The Handbook of New Zealand Mammals. Oxford University Press, Auckland.

Cunningham, J.M. 1948: Number of keas. *New Zealand Bird Notes 2(7)*: 154.

Diamond, J.; Bond, A.B. 1999: Kea, bird of paradox. University of California Press, Berkeley.

Efford, M. 2000: Possum density, population structure and dynamics. Pp. 47–61 in Montague, T.L. (Ed.): The brushtail possum. Manaaki Whenua Press, Lincoln, New Zealand.

Elliott, G.; Kemp, J. In press: Historical changes and current status of a kea (*Nestor notabilis*) population: A population viability analysis. *New Zealand Journal of Ecology*.

Hunter, C.M.; Moller, H.; Fletcher, D. 2000: Parameter uncertainty and elasticity analyses of a population model: setting research priorities for shearwaters. *Ecological Modelling 134*: 299–323.

Jackson, J.R. 1960: Keas at Arthur's Pass. *Notornis 9*: 39–58.

Jackson, J.R. 1963: The nesting of keas. *Notornis 10*: 319–326.

Jackson, J.R. 1969: What do keas die of? *Notornis 16*: 33–4.

Kemp, J.; Elliott, G.: In press: Nesting success of kea (*Nestor notabilis*) in New Zealand southern beech (*Nothofagus* spp.) forest. *Notornis*.

King, C.M. 1990: The handbook of New Zealand mammals. Oxford University Press, Auckland. 600 p.

Pracy, L.T. 1974: Introduction and liberation of the opossum (*Trichosurus vulpecula*) into New Zealand. New Zealand Forest Service Information Series No. 45.

Sadlier, R. 2000: Evidence of possums as predators of native animals. Pp. 126–131 in Montague, T.L. (Ed.): The brushtail possum. Manaaki Whenua Press, Lincoln, New Zealand.

White, G.C. 1996: NOREMARK: population estimation from mark-resighting surveys. *Wildlife Society Bulletin 24*: 50–52.

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

Appendix 1

MONITORING KEA AT SKI FIELDS

1. Some places where kea gather attract mostly juvenile birds, and the number varies from year to year with the productivity of the adult birds in the surrounding country. Sites where adults gather are likely to produce more reliable indications of population changes. Several visits to a potential counting site should be undertaken to ensure that adult kea are regularly present.
2. Kea need to be individually marked for counting so a programme of catching and banding will have to precede and be carried out concurrently with a counting programme. Coloured bands are required for individual identification and can be obtained from Andy Grant at Canterbury Conservancy, Department of Conservation. The aim should be to have at least 75% of the birds individually marked.
3. Counts of keas at ski fields will be closely related to the actual number of birds visiting ski fields only if the counts are carried out in a very standardised manner. Kea should be counted by one person, for the same length of time, at the same time of day, under similar weather conditions, and at the same time of year each year. In our experience, kea habitually gather at the end of the day in ski field car parks to scavenge rubbish and dropped food, so counts at this time of day are likely to produce the highest counts. Lunchtime counts might also be good.
4. Counts should be undertaken by one person walking around the ski field car parks and buildings and recording the identity of all birds present. The sex and age of all birds should be recorded to reduce the possibility of counting unbanded birds twice and to provide extra information on age and sex distribution that might be used in later analysis. Counts should last an hour. Counting and banding can be carried out simultaneously only if the counter takes no part in the banding, i.e. there have to be enough people present to capture and band kea without the help of the counter.
5. After an initial series of 4 counts, the average number of birds present at the ski field can be calculated. The number of counts required each year is then:

$$\textit{number of counts per year} = \frac{40}{\textit{average number of birds counted}}$$

6. Counts should be analysed at the end of the second and each subsequent ski season. Bowden's (1993) estimate of the number of birds present can be calculated using the program 'Noremark' (White 1996). Estimates of the number of birds present can be analysed by regressing the log of the counts + 0.5 against year, using an ordinary least-squares regression package—Excel will do. Alternatively, counts could be analysed more rigorously using a Poisson regression with a log link and 'quasi-likelihood' in a specialised statistics package.