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Population Estimates of Kea in Arthur's Pass National Park

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POPULATION ESTIMATES OF KEA IN ARTHUR'S PASS NATIONAL PARK

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ABSTRACT

The population dynamics of a local group of Kea (*Nestor notabilis*) was studied at a refuse dump in Arthur's Pass National Park over the course of three successive summers. The mean number of birds that foraged at the dump during the summer was estimated as 20 juveniles, 10 subadults, and 36 adults. An average of 11% of these birds were females. The number of adults was quite stable across years. The total population of Kea in this area was estimated to be between 88 and 119, or in the order of 0.018 to 0.040 birds per hectare. Mortality did not exceed 16-20% per year for adult and subadult birds, but it was probably higher for younger birds. Male juveniles all appeared to disperse from the area within the first two years; female juveniles, on the other hand, were frequently resighted in subsequent seasons. This difference in behaviour was statistically significant. The abundance of fledglings suggested that as few as 10% of adult males may breed in any given year.

INTRODUCTION

Despite the interest that has been shown in the behaviour of the Kea (Potts 1976, 1977, Keller 1972, 1975, 1976, Diamond & Bond 1991) and the success of several zoos at breeding them in captivity (Lint 1958, Schmidt 1971, Keller 1972, Mallet 1973), remarkably little is known of the numbers and status of Kea in the wild. The commonly cited estimate of an aggregate wild population of between 1000 and 5000 birds (Anderson 1986) was derived by assuming an average population density of 2 - 10 birds per 8400-ha quadrat and multiplying by the 487 quadrats in the South Island in which observers had reported seeing at least one Kea (Bull *et al.* 1985). The resulting estimate may be correct, but there are no available data that would confirm the assumed population density. It amounts, therefore, to little more than a guess. Jackson (1960) surveyed the wintering Kea population from Arthur's Pass Village north to Temple Basin in Arthur's Pass National Park and made extensive observations of nesting success (Jackson 1963) and mortality (Jackson 1969). Clarke (1970) has made a more recent set of observations in Nelson Lakes National Park, but no quantitative estimates of the Kea population in Arthur's Pass have been made in the 30 years since Jackson's research. We present here the results of a small study, over three consecutive summers, of the Kea in the southern portion of the Bealey Valley in Arthur's Pass National Park.

METHODS

Study site

The study site was a refuse dump at the confluence of Halpin Creek and the Bealey River, 3.2 km south of Arthur's Pass Village at 700 m a.s.l. in Arthur's Pass National Park. There has been a dump in this area for many years; according to Jackson (1962), Kea have foraged there at least since 1956. Birds were banded and counted during three successive summers: 19 November to 9 December 1988, termed the "1989" season; 7 - 27 January 1990, termed the "1990" season; and 30 December 1990 to 19 January 1991, termed the "1991" season. The three seasons corresponded to different points in the reproductive cycle. In 1989, the young of the year were still on the nest; in 1990, fledging was at its peak, and the young birds were still being fed by their parents; in 1991, fledging had been completed for several weeks.

Banding

Kea were captured in the first 2-3 days of each season and were individually marked with numbered monel metal bands and coloured plastic bands. Sex was determined on the basis of bill length and overall size (Bond *et al.* 1991), and the birds were assigned to age classes on the basis of visual markings (Lint 1958, Schmidt 1971, Keller 1972, Mallet 1973). Fledglings, in the summer of their emergence from the nest, have a bright yellow-orange eye ring, cere, and mandible, and a light yellow cast to the crown feathers. Juveniles, which are birds in their second summer, have a pale yellow eye ring, cere, and lower mandible, but no yellow crown. In addition, because they have not yet undergone a moult, their feathers are very dull and worn. Subadults, which are birds in their third or fourth summer, retain an incomplete yellow eye ring, but have a dark cere and bill. In adults, the eye ring, cere, and bill are all dark brown. A total of 66 birds were banded in the course of the study.

Counts

Each season, after completing banding, we conducted a series of hourly counts at the dump site. At each count, we recorded the number of Kea in each of the four age categories and noted band combinations. Between 83 and 111 of the counts in each season were "prime" counts, in that they took place during the times of peak activity for the birds: 0600-0900 and 1600-2100. To estimate the local population, we considered these prime counts as a set of "recaptures" of marked individuals. The pool of marked individuals for each season consisted of Kea that had been banded in that season, as well as any Kea that had been banded in previous years that were observed at the dump during the 2-3 day banding period. To estimate mortality and dispersion, we recorded all banded Kea sighted in the course of the season, whether or not the observation was made during a prime count.

RESULTS

For each season, Table 1 lists the number of prime counts, the size of the pool of banded birds, the number of total observations and the number of resightings of banded individuals. Using the Bailey modification of the Lincoln Index (Begon 1979), we have computed estimates of the local population size for each age class. The Bailey modification, which is simply to add 1 to each category before computing the ratio, produces more stable results when the number of banded individuals is limited. Thus, for Table 1, 1989 Juveniles, $(8+1)^{*}(342+1)/(167+1) = 18.4$.

Adults and subadults were not separated in the 1989 censuses. The tabled estimates for these two categories were extrapolated by multiplying the estimated total for both groups combined (45.2 birds) by the proportion of each age class in the banded sample (15.8% subadults to 84.2% adults). Because we were unable to ensure correct sex identification of unbanded birds during the counts, we did not obtain separate population estimates for males and females.

The proportion of the estimated population that had been banded was usually between 40 and 70%. Only with the very large number of juveniles in the 1991 season did our banding proportion fall below 25% of the population. We can, therefore, have reasonable confidence in the accuracy of the estimates, provided that the behaviour of banded birds, in terms of the frequency of their use of the dump, did not differ significantly from that of unbanded birds (Begon 1979).

Resightings of banded Kea are summarised in table 2. To reflect as closely as possible the level of mortality or dispersal in the population, all observations made during a given season were included, irrespective of whether they were made during a prime count. Two birds that were not seen again at the dump in subsequent seasons were sighted later elsewhere in the park by R. Brejaart. As these Kea had, in fact, survived, they were

TABLE 1 — Estimated population numbers from mark/recapture analysis

Season	No. of Counts		Fldg	Juv	Subad	Adult
1989	83	No. banded	0	8	3	16
		Total obs	0	342	--- 462 ---	
		Banded obs	0	167	--- 173 ---	
		Popn est	0.0	18.4	7.1*	38.1*
1990	111	No. banded	5	4	5	24
		Total obs	216	166	183	574
		Banded obs	148	83	103	303
		Popn est	7.3	8.0	8.9	35.9
1991	94	No. banded	3	7	5	25
		Total obs	82	675	105	299
		Banded obs	50	157	36	178
		Popn est	6.5	34.2	14.5	35.2

*Extrapolated from a combined total by multiplying by the proportion in the banded sample.

included as resightings in Table 2. There were also two birds banded in 1989 that were not seen in 1990 but were resighted in 1991. Both were immature birds at banding and reappeared as adults. Both are included as resightings in 1990 because they were clearly alive during that season.

The column headed "Percentage Resighted" in Table 2 is not a mean, but rather the aggregate proportion of recurrence, obtained by pooling data from all three recovery periods. We determined the significance of differences in percentage resighting between each pair of categories using Fisher exact probability tests. Each of the other three groups differed significantly from Male Juveniles ($p \leq 0.3$); none of the other comparisons attained statistical significance ($p > 0.5$).

To estimate the dispersion of the local population, we have listed our observations at the dump of Kea that had been banded by other researchers (K. Wilson and R. Brejaart) in nearby areas. Table 3 lists the banding locations, their approximate distance from Halpin Creek dump, the number of birds banded at that location, and the number, age, and relative sighting frequency of birds later seen at the dump. The first four locations are all within the Bealey River catchment: Arthur's Pass Village is upriver to the north of Halpin Creek, Coach Road is downriver to the south, and Goat

TABLE 2 — Resightings of previously banded birds

A. Adult males

Season	No. Banded	Resightings 1 yr later	Resightings 2 yrs later	Percentage Resighted
1989	16	14	9	76.9%
1990	9	7		

B. Subadult males

Season	No. Banded	Resightings 1 yr later	Resightings 2 yrs later	Percentage Resighted
1989	3	3	1	80.0%
1990	4	4		

C. Male juveniles and fledglings

Season	No. Banded	Resightings 1 yr later	Resightings 2 yrs later	Percentage Resighted
1989	7	1	0	7.7%
1990	5	0		

D. Female juveniles and fledglings

Season	No. Banded	Resightings 1 yr later	Resightings 2 yrs later	Percentage Resighted
1989	1	1	1	66.7%
1990	4	2		

Pass and Edwards Hut are above the bushline on the Mingha and Edwards Rivers, respectively, which are both tributaries of the Bealey. Bottle Flat is west of Arthur's Pass, in the Otira River drainage. The Craigieburn birds were banded at several locations in Craigieburn Forest Park, which borders Arthur's Pass National Park to the south.

TABLE 3 — Observations at Halpin Creek dump of birds banded elsewhere

Banding Location	Distance from Halpin Creek	No. Banded	No. & Age Observed	Frequency of Observation
Coach Road	1.2 km	1	1 adult	very common
Arthur's Pass Village	3.2 km	14	1 adult	regular, but rare
Edwards Hut	6.3 km	1	1 juv	common
Goat Pass	8.4 km	4	1 adult	seen twice
Bottle Flat	10.0 km	3	0	
Craigieburn	18-20 km	45	1 juv	seen twice

DISCUSSION

Population size

On the basis of the mark/recapture data (Table 1), the mean numbers of each of the three older age cohorts that made use of the dump are estimated as:

20.2 juveniles + 10.2 subadults + 36.4 adults = 66.8 birds

The number of adults was quite stable across years, varying from the mean by only one or two individuals. The number of juveniles, on the other hand, was highly variable from one season to the next.

To extrapolate from these averages to the mean size of the local population, we must make some assumptions about dump use and its relationship to sex. Judging from the trapping frequency at this location, 7/66 = 10.6% of the birds that came to the dump were females. Applying this proportion to our mark/recapture results, we would estimate a mean local population of 7.1 females and 59.7 males. This yields a sex ratio of over 8:1, suggesting that females probably do not attend such foraging aggregations in direct proportion to their abundance. Depending on what we assume the true sex ratio to be, we will, therefore, arrive at different estimates of the total local population.

It is possible that the true sex ratio is 1:1 and that the only reason that females are in the minority at the dump site is that they do not commonly attend feeding aggregations. On the other hand, sex ratios estimated from collections of Kea specimens are also strongly biased in favour of males. Bond *et al.* (1991) analysed two sets of morphological data, one from sexed specimens, mainly from museums, and the other from live, wild-caught birds. They found a sex ratio of 63:32 or 2:1 in the former data set and 91:37 or 1.5:1 in the latter. They also reanalysed the results of a study by Campbell (1976) and suggested that his data were consistent with a sex ratio of 86:45 or 1.9:1.

The male bias in these data sets could, of course, have resulted from an understandable tendency of human researchers to collect mainly from foraging aggregations. It seems safest, however, to derive separate population estimates, one using the ideal 1:1 ratio and the other using the mean ratio from the collection data in the literature, which was 2.1:1. In the former case, we derive a liberal estimate of the local population of 2 * 59.7 = 119.4 birds. In the latter case, the true number of females in the local population would have been 59.7 / 2.1 = 28.3, for a conservative estimate of 88.0 birds.

Population density

In the absence of radio-tracking data, we cannot be certain of the area from which these birds were drawn. Nonetheless, two sources of information may provide rough estimates of dispersion. The first consists of observations of Kea flight patterns as they arrive at or depart from the dump site. Kea are essentially forest birds (Jackson 1960, Guest 1975); they range from the valley floors up to the bushline, with routine forays into tall subalpine scrub (Wilson 1990). As a result, they generally fly up and down the river valleys, seldom crossing the intervening ridgecrests. We observed that most birds making use of the Halpin Creek dump entered and departed from the south, heading down the Bealey River toward its confluence with the Waimakariri. Except on days with gusting northwest winds, which would impede the progress of any birds flying upriver, very few Kea came down from the north, from the direction of Arthur's Pass Village. When we watched departing Kea for as long as we could follow them with field glasses, many flew down the Bealey to where the Mingha River entered it from the east, and then flew up the Mingha Valley. From these observations, we derived a first approximation to the dispersion area of the Halpin Creek birds by measuring the forested area of the Bealey catchment from the southern edge of Arthur's Pass Village to its confluence with the Waimakariri, including the Mingha and Edwards Valleys. This area comprises about 3600 ha.

A second source of dispersion information is provided by observations at the dump of birds that had been banded at other locations by K. Wilson and R. Brejaart (Table 2). One adult that was banded 1.2 km south of Halpin Creek was a frequent visitor at the dump in all three seasons. A juvenile that was banded at Edwards Hut, which lies within our initial catchment estimate, was also commonly seen in the 1991 season. Only one adult from the 14 Kea that were banded at Arthur's Pass Village, 3.2 km to the north, was ever seen at the dump, however, and he appeared only 2-3 times in each season. Of the other 52 birds that had been banded at greater distances from Halpin Creek, only two were ever observed at the dump, and those only on a few, isolated occasions.

If we draw a circle 3 km in radius about the Halpin Creek dump, it includes all of the lower Bealey Valley and much of the lower Mingha, but just fails to reach Arthur's Pass Village. The area of this circle is 2800 ha, which seems to be an absolute minimum estimate for the area of dispersion. A 4-km circle, incorporating the village and surrounding peaks, encompasses about 5000 ha. This seems, on the basis of the low frequency of observation of village birds, to be a probable maximum. Additional support for these radial limits comes from Wilson's (1990) study of Kea in Mt Cook National Park. She determined that breeding adults seldom ventured farther than 1.5 km from their nest site, while non-breeding animals ranged over about 6 km of river valley.

If the limits of our estimated area are 3000 - 5000 ha and those of our estimated population are 88 - 119 Kea, we calculate a population density of between 0.018 and 0.040 birds per hectare. In 1960, Jackson estimated the density of Kea in the Temple Basin area at the northern end of the Bealey Valley at about 8 per square mile, which converts to 0.032 birds per hectare. Our estimates are, thus, similar to those obtained for an adjacent region 30 years ago.

Mortality and dispersal

Adults and subadults: Resightings of previously banded birds (Table 2) suggest that adults and subadults are fairly reliably present from one year to the next, with about 75% - 80% of the birds being resighted in successive seasons. The frequency of resightings was probably affected by the stage in the reproductive cycle. In the 1990 season, for example, fledging was at its peak, and fledglings were still being regularly fed by adults. In the 1991 season, in contrast, fledging was largely completed by the time of our observations, and instances of adults feeding fledglings were much rarer. It could well be, therefore, that the reduced frequency of resightings of adults between 1990 and 1991 simply reflected a reduction in the time that adults spent at the dump, once they no longer had to feed offspring.

The relative constancy in numbers of adults, in spite of a regular yearly loss of banded individuals, suggests that the nearby habitat is saturated, that some ecological or behavioural limit is constraining their numbers. If this is true, we can compensate to some degree for the influence of the reproductive cycle by obtaining a separate estimate of the loss of adults from the local population in terms of the proportion of the adult cohort that were subadults in the previous season. In 1990, for example, there were 17 adults in the population that were known from observation in 1989. Of these, two (11.8%), were birds that had been subadults in 1989. Similarly, in 1991, there were 21 adults that were known from 1990. Of these, four (19.1%) had been subadults in the previous season. On the basis of these data, the rate of loss of adults from the local population seems to have been about 16% per year.

The proportion of this loss that was attributable to mortality, as opposed to emigration into adjacent regions, cannot easily be assessed. One of the 1989-banded adults that failed to reappear in 1990 is known to be dead: his body was recovered not far from the Halpin Creek dump. A second lost adult, banded in the same season, is known to have emigrated: he has since been seen several times in another area. If even as little as one-third of a 16% yearly loss represented emigration, the median life expectancy of a subadult Kea would be about 5 years, and more than 10% of the adult population would be over 20 years of age, a reasonable life expectancy for a parrot in the wild.

Even if we assume negligible dispersal, we still obtain a minimum feasible estimate of 75% adult survivorship, much higher than Jackson's (1969) computation of 63.2%. Jackson's estimate is unusually low for an endemic species, however (Spurr 1979). This may have resulted from his having based his calculations on the recovery of 41 dead, banded birds, ignoring resightings of live birds. If the probability of death is not uniform across individuals, for example, if some birds are inherently weaker or more susceptible to disease, using only data from known dead individuals tends to inflate the apparent mortality rate.

Juveniles and fledglings: Although females were relatively uncommon in these aggregations, our results indicate that female juveniles and fledglings were resighted as reliably as adults or subadults (Table 2). Male juveniles and fledglings, on the other hand, were very rarely seen again. This evidence strongly suggests that male juveniles generally disperse in the first two years, while females tend to remain in the area over subsequent seasons. Jackson (1969) noted that juveniles aggregate in large, wandering flocks in the winter and settle in new locations by the spring. It is not clear, however, whether the local persistence of females is a result of their not having joined the juvenile males in these wandering aggregations, or whether they flock with the males in the winter, but return to their previous home ranges in the spring.

For male juveniles, discriminating dispersal from mortality is extraordinarily difficult. Since there were, on the average, twice as many juveniles as subadults, one might surmise that true juvenile mortality could be in the order of 50%. This would accord with the substantial winter mortality (68%) noted by Jackson (1969) in first-year birds. A comparison of mean cohort numbers at one location makes several untested assumptions, however. In particular, if the dump is more attractive to juveniles than to subadults, such a comparison will yield an inflated estimate of juvenile mortality.

Reproduction and recruitment

Because young birds appear to stay with and be fed by their parents for at least the first month to six weeks after fledging (Jackson 1963), the number of fledglings observed in a given season provides a rough approximation to the natality of the local population. A productivity of about seven fledglings per season (Table 1) suggests that there were perhaps three successful nests in the local area, based on our observations of the coherence of fledgling flocks, as well Jackson's (1963) estimate of clutch size. Even if more fledglings emerged after our season ended, or if some young birds did not follow their parents to the dump, it seems unlikely that there were more than half again as many as we observed, especially because the peak of fledging was clearly long past at the time of our 1991 observations. An estimate of three to four nests is also supported by Jackson's (1963) mean nesting density of one Kea nest per four square miles (= 1036 ha). If our estimate of 3000-5000 ha for the dispersion of the local population is correct, this would lead us to expect three to four nests.

If adult mortality is 16%, the mean population of 36.4 adults requires an addition of 5.8 new birds every year to maintain stable numbers in the cohort. Assuming a 20% yearly loss of subadults, these 5.8 recruits would have come from a pool of 7 to 8 subadults in the previous year. This is less than the mean estimated population of subadults in the area, suggesting that recruitment into the adult cohort could come entirely from the local population of subadults, and that migration of new adults into a region may not be necessary to maintain adult numbers. In contrast, the mean number of juveniles far exceeds what could be maintained from the yearly local productivity of fledglings, especially in view of Jackson's (1969) estimated mortality in the first year. It seems likely that the Halpin Creek dump, indeed, the entire Bealey Valley, is a population sink for dispersing juveniles, providing a reliable food resource for animals that have not yet developed adult foraging skills.

These data suggest that no more than four to six of the resident males may have bred during any season, which is to say that perhaps 90% of the adult males were non-breeders. There is no reason to believe, however, that such a low level of reproductive effort is characteristic of the species. Given the inherent variability in productivity of high mountain habitat, one would expect that the proportion breeding could vary greatly from one year to another. The relative constancy in numbers of fledglings for 1990 and 1991 may have been a sampling artifact. In addition, this estimate of the proportion of non-breeders assumes that adults and fledglings were drawn to the dump from similar areas. Wilson (1990) suggests that the home ranges of non-breeding adult males may be up to four times the area of those of breeding birds. If this is true for the fledglings, as well, at least within the initial period of dependence on their parents, the non-breeding adults at the dump may have been drawn from a wider geographical area than the fledglings, resulting in an overestimate of the proportion of non-breeding birds.

Population status

The density of Kea in the area of Halpin Creek approximates the levels Jackson (1960) obtained in Temple Basin, further to the north. This suggests that, at the very least, there has not been a dramatic decline in the number of Kea in the Bealey Valley and its tributaries over the last 30 years. However, this statistic provides little information about the status of Kea in areas that are more remote from human settlements and the supplemental food they provide. Jackson (1960) extrapolated from his study of Temple Basin, speculating that the density of Kea in the back country could be about 12% of that in the Bealey Valley. He may have guessed correctly, but his extrapolation technique is of dubious validity. Some support for his assessment has, however, been provided by Clarke (1970) in his observations of Kea in a fairly remote area in Nelson Lakes National Park.

The data compiled by Bull *et al.* (1985) are difficult to use for population estimates because their observers recorded only the presence of a given species, rather than the number of individuals encountered. Nonetheless, it is noteworthy that their observers were roughly twice as likely to report encountering at least one Kea in the Bealey Valley as in less-visited parts of the park (82% of observer-days in the lower Bealey Valley, 49% in adjacent quadrats, and 40% in outlying regions). Because of the all-or-none nature of these data, the difference between the Bealey Valley and the outlying areas could well have been much larger than it appears. It is possible, for example, that most of the observers in the Bealey Valley saw 5 or 10 Kea in reporting the species "Present," while those in more remote parts of the park had seen only one.

If we take Jackson's (1960) judgement of 0.0036 birds per hectare in the back country as a rule of thumb and apply it to the Bull *et al.* (1985) survey, we come up with 30.5 birds per 8400 ha quadrat, or a total wild population of about 15 000 Kea, three times as large as Anderson's (1986) conjectured maximum. Whether this estimate is any more trustworthy remains to be seen. The issue can be resolved only by a systematic effort to band and census Kea in more remote regions of the Southern Alps. Until such data become available, we must keep in mind the possibility that the Kea that we see around car parks, ski fields, and refuse dumps are, in fact, a majority of the birds in the vicinity. If this is true, Anderson's (1986) reckoning of the total population could prove to have been fairly accurate.

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