WHAT DO KEAS DIE OF?

By J. R. JACKSON

ABSTRACT

The evidence collected during a ten-year banding study of Keas is considered. It is concluded that starvation is the most important cause of death.

INTRODUCTION

An analysis of causes of death is basic to the understanding and conservation of any animal. This paper is a discussion of Kea mortality.

It would seem that starvation is the main cause of death; that all Keas have experience of disease and injury; and perhaps most Keas have eluded predators. Keas have a strict peck-order and social regulation of their numbers may be important. This regulation may result in starvation or illness of the doomed individual but seldom is the immediate cause of death. A bad season, as 1957-58 summer, can greatly reduce the number of Keas but again is not an immediate cause of death.

Where Keas and men meet, man directly and indirectly causes the death of many Keas. Man is certainly the most important predator.

KNOWN DEATHS OF BANDED KEAS

The cause of death of 74 banded Keas in the vicinity of Arthur's Pass is shown in Table 1.

TABLE 1

Cause	*Number of Deaths*	*Totals*
Shot	22	
Trapped and destroyed	7	
Drowned in water tanks	4	
Electrocuted	4	
Run over	4	
		41
Starvation	5	
" Scouring "	2	
Dislocated shoulder	1	
Destroyed because of injuries	2	
" Natural "	21	
Unknown	2	
		33
Total		74

The deaths of Keas in the first group are caused by man. Even some in the second group are suspect. In Westland and in National Parks the Kea is a protected bird and it is an offence to harm it. Elsewhere it is unprotected and many are quite legally destroyed on the sheep runs of the Southern Alps. If a Kea is shot where Keas are protected the culprit is hesitant to admit it. However,

many have been generous enough when they noticed that the Kea had been banded to report its death. Especially suspect is the category " run over."

Of two other Keas, which " scoured " and died, one had an empty gut and was a very light weight; and the second may have been poisoned. The Kea with a dislocated shoulder is listed separately for birds seldom dislocate a wing but rather break a bone. It is suspected that a muscular necrosis had set in, as described below, as in some Keas taken into captivity about the same time. The big group of natural deaths includes skeletons found hidden under tussocks and moraine boulders, away from human habitation and where the Kea presumably crept to die.

Two of the starving Keas, band numbers L1965 M. and L7110 M. died within one week of banding. They had been very light at banding, 0.74 K.g. on 8/5/60 and 0.66 K.g. on 21/5/66 respectively. Their slow reactions were noted. Each fed in a drum of rubbish, 5 yards away and hidden from other Keas. If a careful approach were made the bird would ignore the slight noise and the flushing of other Keas. It could be caught in the drum. Neither was wary. L1965 was dissected after death. In its stomach were stones and lumps of rotten wood, material providing no sustenance, i.e. it had a depraved appetite.

L1204 F., a first year hen, was found 22/7/61 soon after death. She weighed 0.50 Kg, the lightest full grown Kea weighed. These deaths are listed according to months in Table 2.

TABLE 2

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1st Year Keas	0	1	0	1	2	2	4	4	4	5	2	0	25
Other Keas	2	1	2	5	4	6	0	10	7	8	2	0	47
All Keas	2	2	2	6	6	8	4	14	11	13	4	0	72
31 natural deaths and 4 run over	2	1	1	5	3	4	3	8	4	2	2	0	35
Starving Keas					1	1	1	2					5

In the autumn as nesting finishes adult Keas may die, as they go into moult, perhaps in poor condition. The greatest mortality for all Keas is from June to September when food is most scarce. Then green droppings (due to biliverdin) of starving Keas can often be noted. This late winter and spring part of the year will be of special interest in the following tables, which provide further evidence of starvation.

The further life after banding is shown in Table 3.

The number of months of survival of those Keas which died less than a year after banding is shown in Table 4.

TABLE 3

years	0	1	2	3	4	5	6	7	8	Total
Banded as 1st year Keas	34	7	5	2	2					50
Other Keas	10	4	3	1	1	0	1	1	1	22

TABLE 4

months survival	0	1	2	3	4	5	6	7	8	9	10	11	Total
1st year Keas	4	9	3	5	2	0	1	3	1	1	4	1	34
Other Keas	2	0	2	0	1	0	0	1	2	0	0	2	10

In both tables "other Keas" provides a control for "1st year Keas."

These tables show the large loss of Keas in their first year, especially soon after banding. Some of these Keas were inexperienced, recently fledged Keas. Others were banded and died in the spring when there is a large moving population, spurred by hunger.

Another control is the construction of a survival table, Table 5. This follows Haldane (1955), 2. Keas which died before their first January after banding are not entered; the first year in the table is from this January until the December of the same year.

TABLE 5

Dated Banded	Number Dead	Years	1	2	3	4	5	6	7	8	9	10
1956	5	10	1	2		1			1			
57	6	9	2	1			1	1		1		
58	4	8	1	1	2							
59	3	7	2				1					
60	9	6	4	4			1					
61	4	5	3	1								
62	3	4	1		2							
63	4	3	4									
64	0	2										
65	3	1	3									
Total	41		21	9	4	1	3	1	1	1	0	0

From these results the annual survival rate, S, and its complement, the annual mortality rate (1 — S) can be calculated.

$$S = (63.2 \pm 6.6)\%$$
$$(1 - S) = (36.8 \pm 6.6)\%$$

The Kea with the greatest known longevity is 26959 F. She was banded as an adult 10/8/56 and was still alive 21/1/68. She has lived at least 15 years.

RESULTS OBTAINED FROM LIVE BANDED KEAS

As described in Jackson (1960), 3, most Keas about Arthur's Pass township are banded by the time I leave after a visit. A month later when I make another visit unbanded Keas have appeared. An analysis of the appearance of unbanded Keas at Arthurs Pass is presented in Table 6 and provides evidence that young Keas wander in their first two or three springs. A large number of Keas have been banded not in the autumn, but in the spring, six months or more after they have been fledged. Also in August and September adult Keas move further from their homes for these are the hungiest months.

Besides the statistical results my records contain several recoveries of individual Keas to show the spring wandering. L1961 M. was banded at Arthurs Pass 17/4/60 when in his first year. He remained about the township through the winter and was seen there on 28/8/60. He was not seen later that year. He was seen 25/2/61 on the Edwards Valley bottom flats (three miles from the township) and later the same day another two miles away by the large Edwards Valley waterfall. He recognised me at nightfall 20/8/61 at the foot of the Pyramid, Hawdon Valley, three miles further on and eight miles east of the township. He was back at Arthurs Pass township 10/9/61 and remained there during that September. He was there again on 14/10/62. On 6/10/63 his home area on the Bruce Spur, six miles south of the township, was found.

TABLE 6

Keas newly banded

rate per month 1956-66

	Jan	Feb	Mar	Apl	May	June	July	Aug	Sep	Oct	Nov	Dec
Juveniles	3.4	1.8	5.7	1.6	2.6	3.2	5.7	9.6	11.0	10.3	5.6	5.6
Adults	0.6	0	0	0	0.4	1.1	1.2	4.8	3.1	2.1	1.1	0
Total number	40	18	57	16	30	39	62	115	113	112	60	50

Banded Keas identified

rate per month

	24.4	13.1	20.1	9.5	14.8	23.2	29.4	45.5	43.7	46.4	29.8	23.8

TABLE 7

Month banded	Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number remaining more than 2 years	3	0	4	1	2	4	5	15	7	4	3	9
Average short stay in months	5.3	0.9	4.2	4.0	6.0	4.2	5.2	3.3	2.6	3.7	4.2	5.3
Standard deviation	7.9	1.7	6.0	5.8	6.3	5.2	6.6	5.1	4.5	6.0	6.3	6.5

In autumn many juvenile Keas gather into large flocks, of fifty or even one hundred birds. Perhaps there is such a flock every 50 square miles. Unfortunately these flocks are not present in the same place in succeeding years. This makes the number banded in autumn very irregular from year to year. The Keas banded in spring arrive in small groups to scavenge in places such as Arthurs Pass. The autumn-banded Keas tend to remain about Arthurs Pass longer. Table 7 is for juvenile Keas, divided into two categories, those that remain more than two years, and those with a short stay, less than two years. This table should be considered with Table 6 showing the number banded each month.

It can be seen that a large number of Keas settle in August and September, perhaps because then there are empty spaces after the late winter losses of adults, but the average stay is brief in the spring months, for there is a large number of unsettled young Keas.

The weight of Keas increases during the winter and the variance of the weight increases, too. There are both heavy and very light Keas in winter. Three very light Keas, L1965, L7110 and L1204, have been mentioned. The results for mean weight with its standard error, and the variance with its standard error, are given in Table 8 (in the appendix) and Table 9. A close examination of Table 8 shows that the greatest number of first-year Keas reach their maximum weight in June, and in May have their largest variance. This suggests that in May a heavy mortality of inexperienced light-weight young Keas occurs. The maximum for adults is a month later; their skill probably enables them to find food for a month longer than the first-year Keas. This is contrary to the indications of Table 2.

Also in the spring the distribution of weights of adult hens is bimodal. There are some heavy hens. Perhaps they are in egg.

TABLE 8

Month	1st year ♂		Other ♂		1st year ♀		Other ♀	
	Mean. μ Kg./100	Variance. σ^2 $(\text{Kg.}/100)^2$	μ	σ^2	μ	σ^2	μ	σ^2
Jan.	87.7 ± 1.6	42.3 ± 15.5	92.1 ± 1.5	36.1 ± 13.2	69.7 ± 1.2	16.7 ± 3.0	76.6 ± 1.5	25.0 ± 4.5
Feb.	86.4 ± 1.7	51.5 ± 17.7	92.5 ± 4.0	62.3 ± 50.9	76.0		70.7 ± 1.6	18.7 ± 10.6
Mar.	88.8 ± 1.7	88.8 ± 22.9	91.6 ± 4.2	73.0 ± 51.1	73.1 ± 1.2	32.5 ± 10.3	78.4 ± 1.8	34.3 ± 15.2
Apr.	94.6 ± 1.6	90.9 ± 22.3	95.0 ± 3.1	47.5 ± 32.8	78.0 ± 1.9	40.2 ± 18.1		
May	93.8 ± 3.6	170.3 ± 62.5	98.0 ± 2.6	33.0 ± 23.1	75.0 ± 2.9	41.5 ± 29.1	75.0 ± 4.5	123.5 ± 86.4
June	97.0 ± 1.7	62.9 ± 19.1	97.3 ± 3.9	188.8 ± 80.8	79.8 ± 2.4	35.6 ± 27.3	83.0 ± 2.8	139.5 ± 46.5
July	96.6 ± 1.2	52.2 ± 12.5	99.2 ± 0.8	12.6 ± 4.2	73.4 ± 3.3	94.8 ± 47.4	88.3 ± 2.7	125.8 ± 44.5
Aug.	94.6 ± 0.8	43.6 ± 7.9	95.4 ± 1.5	83.2 ± 15.9	76.2 ± 1.4	56.1 ± 12.9	82.1 ± 1.3	74.3 ± 16.7
Sep.	92.4 ± 0.9	42.2 ± 8.4	96.9 ± 1.0	28.2 ± 7.8	78.7 ± 1.0	31.0 ± 8.0	81.8 ± 0.8	17.5 ± 4.9
Oct.	91.5 ± 1.0	58.9 ± 8.0	90.4 ± 1.4	48.5 ± 11.5	75.8 ± 1.3	57.9 ± 14.7	79.0 ± 2.0	72.9 ± 25.0
Nov.	91.3 ± 1.4	47.4 ± 14.0	94.4 ± 3.7	95.3 ± 56.4	77.9 ± 1.3	30.8 ± 10.0	80.9 ± 1.3	22.8 ± 8.9
Dec.	88.9 ± 1.4	52.4 ± 14.3	88.0 ± 2.4	28.5 ± 20.2	74.9 ± 1.4	33.6 ± 11.5	79.0 ± 2.4	46.4 ± 24.9

TABLE 9

Kea weights averaged through the year

Kea age and sex		Mean weight and standard deviation
Juvenile	Male.	$(92.4 \pm 8.7)\ \frac{Kg}{100}$
Adult	Male.	95.7 ± 7.4
Juvenile	Female.	75.9 ± 6.1
Adult	Female.	80.3 ± 7.0

THE BAD SEASON — OCTOBER 1957 - MAY 1958

When my study was beginning it was complicated by an eight-month period of very bad weather, a period general over the West Coast of the South Island and the Southern Alps. In each month the rainfall was greatly above average, especially from October to March, probably the significant months for the Kea.

Table 10 sets out the rainfall at Arthurs Pass in 1957-58, compares it with the mean (the figures were kindly given by the Meteorological Office) and the expectation found by interpolation in Seelye (1947), 5, Table III. The expectation of the total is found by treating it as a month and interpolating improperly.

TABLE 10

Rainfall at Arthurs Pass

Month	October	November	December	January	February	March	Total
1957-58	26.67in	24.35	47.01	19.38	20.34	20.41	158.16
mean	17.5	13.3	14.4	14.8	13.8	11.2	85.0
ratio	1.52	1.83	3.27	1.31	1.47	1.82	1.88
expectation	0.128	0.041	0.006	0.263	0.223	0.106	0.031

December was the worst month with an expectation of 0.006, or such a month is expected once in thirteen years approximately. This month is remembered by the Boxing Day storm 26-27/12/57 when the Waimakariri River broke its banks at Christchurch and the Arthurs Pass rail and road routes to the West Coast were both closed for some months. Between 9 a.m. on the two days 11 inches of rain fell, expected once in 12 years but between 2 p.m. 26/12/57 and 2 a.m. 27/12/57 9 inches fell, which Dr. M. A. F. Barnett, then Director of the Meteorological Office, reckons can be expected " roughly once in 50 years." There were frequent storms.

This period caused a great reduction in the Kea population. Perhaps it was reduced to two thirds normal, as the 1958 number in Table 11 suggests. The average number banded per year from 1957 to 1965 inclusive is $\frac{905}{9}$ or 100.6.

TABLE 11

Year	1956	57	58	59	60	61	62	63	64	65	66	Total
Number	49	156	70	60	131	119	105	103	82	79	22	976

Chicks were found dead in their nests, eating of eggs was first noticed, and many parent Keas disappeared. Usual foods failed. Among the plants that did not flower that summer were snow totara *Podocarpus nivalis,* snow tussock *Danthonia flavescens,* mountain flax *Phormium colensoi, Dracophyllum longifolium,* and five-finger *Nothopanax simplex.* That summer there was little nectar, and the following winter few berries. Starvation was the immediate cause of death of many Keas that summer.

ILLNESS AND DISEASE

Keas are afflicted with disease as other living flesh. Table 12 lists illness or indication of disease noted among 44 Keas of all those banded.

TABLE 12

Illness	*Number of Cases*
Unusually harsh grating call	1
Sniffing and sneezing	5
Blind eye with a cataract	1
Blind eye, perhaps caused by a wound	1
Bleeding nose	3
Colour breaks, all noticed on the head	17
Dislocated shoulder	1
Left wing down, permanently	1
Left wing down, temporarily	2
Bad co-ordination as in S. Vitus Dance	1
Stumbling and walking on tarsi	1
Thick tarsii	4
Bumble foot	2
Cracks in the joints of the toes	2
Growth, perhaps cancerous, on the foot	1
Itchy foot	1
Septic wound	2
Severe scouring	3
Grossly underweight	3
Permanently irregular plumage	1

Twenty-two of these cases, the colour breaks, the thick tarsi and the irregular plumage, are probably genetic or developmental. The colour breaks may develop later in life. I have several instances of not having noticed colour breaks in well-known Keas for some years. It is most interesting that all the colour breaks recorded are on the head, perhaps because I pay most attention to this part of the body but more probably because the break is explained as the outcome of the complex development of the head in the embryo. Most often a colour break is indicated by yellow instead of green, i.e. the feather follicle is not synthesizing melanin, and the bubbles resulting in the Tyndall effect may be flooded with liquid so that the blue portion of the green is lacking. The yellow colour remains.

There are several throat complaints; staphylococcal infection is the cause of the bumble feet, the septic wounds and perhaps the cataract. Here it is relevant to mention that bites by Kea fleas cause pustules on me which take a week or more to heal, quite unlike ordinary flea bites; apparently the severe bite is caused by the staphylococci carried by these fleas.

"Scouring" is indicative of food poisoning by some bacteria in the gut.

L1907 F. was the Kea with a wing down during 5 years and suffered no ill effects from this condition. L2415 M. was noticed 16/1062 with a dislocated wing. He was caught by running down. His wing was set by Mr. W. L. C. Purdie, a Christchurch veterinarian but unfortunately the wing would not stay in place. L2415 was returned to Arthurs Pass but would not leave its open cage and died.

At about the same time six Keas were captured and sent to Prof. J. A. R. Miles, of the Department of Microbiology, Otago Medical School. They all died soon after arrival as if of a contagious disease. Necroses of the muscles and the liver were found. A virus disease was suspected but the pathogen could not be found. Probably L2415, which was in contact with these other Keas for an hour or so, suffered from the same condition.

Mr. J. Kikkawa took several blood samples on 20/8/60 and found a wide variation in blood count. A Kea with a slightly low count would suffer no ill effects. However, overcrowding of Keas in winter causes a haemolytic anemia, a stress condition and a typical psychosomatic illness. Both the highest caste Keas, at the top of the peck order and the lowest are liable to develop this anemia. A healthy Kea may succumb in a fortnight.

PARASITES

Among parasites of Keas are:

an analgesid mite;

the lice:
1. *Neopsittaconirmus kea* (Kellogg) 1907
2. *Colpocephalum pilgrimi* (Price) 1967
3. *Heteromenopen kea* (Kellogg) 1907

and 4. *Echinophilopterus sp.*, believed to be a new species;

the flea *Parapsyllus nestoris* (Smit) 1965;

the psychodid flies
1. *Psychoda severini* (Tonnoir)

and 2. *Psychoda spatula* (Satchell)
identified by Dr. L. W. Quate of the Bernice P. Bishop Museum.

There are threadworms *Capillaria sp.* in most Kea intestines.

In addition, sandflies *Austrosimulium ungulatum* annoy recently fledged Keas in December and January.

Perhaps the most serious parasite is the flea. Autumn nests are very heavily infested. No instances have been noticed of these fleas congregating on the neck of checks, and causing a severe loss of plumage and weight as occurs with prions, attacked by another flea of this genus. Often the fleas carry large numbers of mites, part of the nest fauna.

The very large nest fauna includes:

mites 1. Eviphididae
2. Hypoaspidinae
3. Acaridae
and 4. Oribatidae.

There are many flies, especially blowfly maggots; Staphylinid and Dermatisid beetles; and, most conspicuously, the large beetle *Necrophilus prolongatum.*

INJURY

Table 13 lists the injuries noted of 69 Keas among the 976 Keas banded.

TABLE 13

Injury	*Number of Cases*
Temporary limp, sometimes with a minor wound visible	29
Permanent leg injury, so the leg is useless, often with a badly set femur or tarsus and atrophied muscles	12
Loss of foot	4
Permanent toe injury with badly knit bones	4
Broken wing	2
Bruised and bleeding chest	2
End of lower mandible broken off	1
Bleeding eye	1
Tail feathers missing	1
A small patch of temporarily missing plumage on the head	5
Cut on the face	2
Swelling under the band	7

These injuries are possibly of three causes:

1. Keas often feed on slips and steep faces where stones are liable to bounce down. Occasionally a bouncing stone would catch a Kea as it flushed. Also Keas know how to shelter on a rib from an avalanche, yet some may be caught.
2. The scar left after an unsuccessful attack by a predator.
3. Mistakes in flight, especially after dark and in a storm.

If these causes are conceded then at first sight as many wing injuries as leg injuries would be expected. Indeed, considering the comparatively large area of the wings, the fact that predators such as the Falcon *Falco novaezeelandiae* and the Black-backed Gull *Larus dominicanus* attack in flight, and, especially, the fact that the gull batters with its wings, more wing injuries would be expected. The smaller number of wing injuries shown in the Table is probably because a bird with a broken wing soon dies. However, a healthy Kea is extraordinarily tough. One Kea with a broken humerus glided 200 yards across the Bealey River to where a group of Keas were feeding.

Again facial imperfections are noticed. Perhaps these are caused by fighting. The large number of band injuries were caused not by the band being put on improperly but because a band prevents normal swelling of the leg, following a foot injury.

[M. Davis

Plate XIX — Female Kea eating one of her eggs, 6 p.m. 21/1/62.

Certainly injury would seem as important as illness as a cause of death.

PREDATORS

Several times I have seen Falcons attack Keas but always unsuccessfully. When a Falcon attacks a single Kea, the Kea rolls over and parries the blow, and at the first opportunity falls into the cover of the forest or the shelter of a large boulder. Similarly when Keas hear a Falcon they take shelter. And when in the open on a river flat or above the bush line they carefully watch any large bird flying high above. To do this it is necessary for them to twist the head sideways and while in this stance all the Kea's attention is occupied.

When a Falcon attacks a Kea among a flock of Keas in flight the Keas behave differently. The Falcon seeks to attack one Kea but is disconcerted by the interest the other Keas take in him. Soon he has Keas all around him, following him up as he climbs to swoop again. The Falcon flees. This behaviour is similar to that of the Red-backed Parrot, *Psephotus haematonotus,* when attacked by predators, as described by Forshaw (1962), 1.

Magpies *Gymnorhina hypoleuca* are often mentioned as attacking Keas. I have seen no instances. Keas are intensely interested in flocks of flying Magpies and often take flight to join them. Several times I have seen one or two Keas flying straight able to keep up with a flock of twenty or thirty Magpies which fly with loops and side slips. The Magpies take no notice of the Keas.

The relationship of Black-backed Gulls and Keas is uneasy. Normally Keas take precedence but in the air these gulls do not hesitate to attack a single Kea. Or if one or two Keas are feeding in a rubbish dump and fresh food is put out a dozen Gulls will descend, push in and guzzle the delicacies. Possibly significant behaviour of Keas is their retreat to the forest from feeding in the open on a river flat when the sun reaches them. Black-backs are late risers and come flying up the valleys about the same time as the sun reaches down into the valley.

In a riverbed in mid-summer Black-billed Gulls *Larus bulleri* and Black-fronted Terns *Chlidonias albostriatus* will attack a Kea perched on a log. A Kea takes no notice of their attacks. Similarly Keas take no notice of Wekas *Gallirallus australis.* However, a Weka could attack an unguarded nest.

During the last hundred years Keas have shared their environment with rats *Rattus spp.* and stoats *Mustela erminea.* I have found no evidence of these animals affecting Keas. However, it was interesting to find a successful Weka nest by the lake at the terminal face of the Douglas Glacier, South Westland, heavily infested with both rat fleas, *Nosopsyllus fasciatus* and Kea fleas. Twice I have found a dead opossum *Trichosurus vulpecula* within five yards of a Kea nest. The opossum frequently chooses holes similar to a Kea nest as a den and perhaps these two opossums prospected the Kea nests.

SOCIAL REGULATION OF KEA NUMBERS

Keas have a strict peck order. Grossly underweight Keas are at the bottom of the peck order and among these Keas a haemolytic anemia develops, all evidence of social regulation.

On occasion, the Kea hen destroys her own eggs and chicks (see photo). I have known five nests where the eggs have been eaten and one where the chicks were trodden into the floor of the nest. In the latter case many Keas were about when the chicks were killed. The hen left this nest to make a new nest two miles away and her cock disappeared.

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