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Kakapo on Little Barrier (Hauturu) Island

Annual report for the year July 1994 - June 1995

by

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Abstract

Kakapo (*Strigops habroptilus*) breeding activity on Little Barrier (Hauturu) Island was monitored throughout the 1994-1995 season. An *ad libitum* supplementary feeding programme was run concurrently. Male breeding activity began very early in the season and subsequently the most intense booming season recorded on Little Barrier was recorded. Two copulations are thought to have taken place and two nests were found. Both clutches were infertile however. Rat control grids were established around both nests to remove kiore (*Rattus exulans*) but these appeared to have limited success. Infrared cameras were used to monitor one male's courtship behaviour and a female on a nest. The substantial decrease in the percentage of fertile eggs produced on Little Barrier (Hauturu) since 1990 is discussed, as are other aspects of the ecology of kakapo. Recommendations are made.

1. Introduction

This report describes the results of the kakapo management and supplementary feeding programme on Little Barrier (Hauturu) Island during the period July 1994 – June 1995. The format closely follows the breeding activity reports of Lloyd and Powlesland (1990 and 1992), Greene (1993a and 1993b). This facilitates comparisons between years, particularly with reference to breeding activity.

Thirteen male and nine female kakapo were transferred to Little Barrier (Hauturu) Island between May and August 1982, mainly from southern Stewart Island. One male originally came from Fiordland. Since then three males (in 1991, 1992, 1994) and one female (in 1991) have died. Eighteen were still known to be alive at the time of writing. The continued survival of two females, which haven't been found in over 10 years, is unknown.

Male courtship activity (booming) was observed on five of the seven summers between the initial transfer of kakapo and 1989. No breeding occurred before 1989 so supplementary feeding of protein-rich foods was initiated in an attempt to induce and increase the frequency of breeding in the kakapo population (Powlesland 1989). Booming has been recorded every year since supplementary feeding began, and nesting has occurred in four of the six years since 1989. Two successful breeding attempts since 1989 have resulted in the recruitment of two males. There have been 11 unsuccessful nesting attempts.

2. Methods

2.1 MALE BREEDING ACTIVITY

2.1.1 Monitoring activity at booming sites

Booming sites or track and bowl systems (TABS) were inspected frequently from 7 October 1994 to 14 May 1995. Inspection frequency varied from almost daily, for easily accessible TABS, to monthly, for TABS that were inactive. Any sign attributable to kakapo, such as grubbing, vegetation trimming, feeding sign, faeces or feathers at or near these TABS, was noted. Four short (5-10 cm) sticks and two crossed sticks lying between the upright sticks were placed in each bowl and subsequent disturbance to these was recorded as evidence of male courtship activity.

2.1.2 Monitoring booming

During the breeding season night visual and/or aural watches were kept to a minimum to avoid disturbance. Booming was monitored using small voice-activated tape recorders (VARS – Olympus Models L100 and S928) using Olympus XB60 tapes. The VARs were wrapped in two plastic bags and hidden within 20 cm of the bowl. The VARs were used to determine the initiation of booming, and its intensity at various times during the season. The number of booms per bout (as well as chinging or other kakapo vocalisations) were noted from the beginning of a booming session. The number of booms for the first 25 bouts were averaged to give a indication of the intensity of booming. Diurnal booming was also noted.

A battery-powered video camera with infrared LED light source linked by cable to a monitor was used on a few occasions. It was used to monitor courtship behaviour at various TABS from a distance, mainly later in the season.

The Natural History Unit of Television New Zealand set up two remote controlled infrared cameras at TABS 9 (Thumb) on 18 December 1994. Luke's courtship behaviour was monitored on most nights from 2 January until 1 March 1995. His courtship behaviour was recorded for a planned documentary on kakapo.

2.1.3 Identification of males at TABS

Identification of males was determined by radio telemetry or capturing males near their TABS. Eight of the 12 known males were carrying transmitters and their proximity to active booming sites was monitored using radiotelemetry. VARs linked to a radio telemetry receiver were used to confirm identity at specific bowls. Near the end of the season two males were captured by hand near or at their TABS. The males, and Arab, were identified and fitted with transmitters.

2.1.4 Feather clusters

Clusters of feathers found at TABS can be a result of either copulation (Powlesland 1989) or fighting. Whenever TABS were visited the immediate area was examined for feathers. Feather clusters produced during copulation are typically restricted to a small area (1 m^2) and are close to an active bowl These are usually well mixed into the soil, and are mostly down feathers. Feather clusters thought to result from fighting are usually scattered over several metres, often some distance from active bowls. They are occasionally mixed with the substrate, but usually lie on the surface or caught on low vegetation. Contour feathers make up the bulk of the feathers, and they are often broken and may have small pieces of skin attached to their bases.

2.1.5 Feather counts

During the course of the supplementary feeding and booming site inspection any feathers found were collected, recorded and unusual features, such as stress breaks, were also recorded. This information provided a way of assessing seasonal feather loss, and gave an indication of the health of birds.

2.2 FEMALE BREEDING ACTIVITY

2.2.1 Monitoring female movements using radiotelemetry

All six female kakapo known to be alive on Little Barrier (Hauturu) were carrying radio transmitters during the period July 1994 to June 1995. The position of every female was monitored almost daily by radio triangulation from the beginning of January to the end of March. This allowed us to identify movements to TABS, and the possibility of mating attempts. Outside this period their general location was monitored at least every five days.

2.2.2 Monitoring nesting

Any female suspected of mating was monitored daily by radio triangulation. If her roosting location had not changed for seven days it was assumed she was nesting. The female was then located to this and to locate the nest for subsequent intensive management/monitoring.

A battery-powered infrared camera was set up with a view of the nest cavity to enable regular monitoring of the nest with minimal disturbance. This was connected by cable to a television monitor distant from the nest (>70 m). The camera was set up when the female was off the nest. To do this we monitored the female's movements by radio telemetry from before dusk and waited until she was well away from the nest.

After Wendy had abandoned her nest, a thermohydrograph was used to record relative differences in temperature and humidity between the inside of the nest and the immediate outer surroundings.

2.3 RODENT CONTROL AROUND NESTS

To reduce the possibility of predation of kakapo eggs by kiore (*Rattus exulans*) intensive control of rats was undertaken around the nests. Following is a precis of the nest protection that was carried out. Details of the 1994-1995 nest protection programme can be found in Harper (1995).

Two nest protection programmes had been carried out on Little Barrier (Hauturu) Island in previous seasons. In both cases the protection grid consisted of six covered poison bait silos containing brodifacoum-laced grain, placed at 50 m intervals on a 50 m radius around a nest. The nest protection in 1991 appeared to be successful in that two chicks were raised (Lloyd and Powlesland 1992). In 1993 a similar regime may not have protected the sole chick produced, as it disappeared shortly after hatching (Greene 1993b).

To provide better protection of kakapo nests, the 1994-1995 season nest protection protocol of the Kakapo Recovery Programme (Owen 1994) proposed a more intensive nest protection regime than was used in 1991 or 1993.

The goal of the protocol was 'total eradication of kiore at and near each nest until nestlings are considered large enough to be out of danger' (which is currently regarded as approximately 1 kg, or about six weeks of age (Don Merton, pers. comm.)).

Local eradication was to be achieved through a three-stage poisoning and trapping programme, as follows:

1. immediate eradication of rats resident at and near nest sites (i.e. within ca. 40 m of nests) through intensive trapping;
2. eradication of rats within ca. 100 m radius of nest, through poisoning; and
3. prevention of re-invasion of the target area through a combination of ongoing intense poisoning and trapping.

The protocol suggested that 48 poison bait stations and 36 traps were to be set out at 16 m intervals on concentric squares 33 m apart, extending for 100 m in each direction from the nest. The outer square would be 200 m by 200 m, enclosing approximately 4 ha.

A meeting was held on 24 January on Little Barrier Island (Don Merton, Ian McFadden, Mike Thorsen, and Grant Harper) regarding the nest protection grid proposed in the protocol. It was decided that the protocol guidelines would possibly not provide sufficient protection. A more intense layout was considered as more likely to give faster knockdown of the resident kiore population and better ongoing protection of the nest. It was also felt that it would be better to strive for complete initial eradication of kiore and reduce trapping effort once the resident rats were removed.

As a result of trapping trials, snap traps placed under mesh formed the main portion of the grid.

The following modifications were made to the protocol guidelines:

1. The inner circle of four snap traps was increased to eight on a square and allocated the letter E.

2. An extra circle (C) of 24 snap traps was set out between circuits B and D as shown on the protocol (Owen 1994).
3. On circuit B every second poison bait station had a snap trap set in place as well as the bait station.
4. After consultation with the National Kakapo Programme coordinator about disturbance to the nesting kakapo, extra snap traps and Sherman cage or Elliot traps were placed within 6 m of the nest.

The poison bait stations used were the Rentokil 'yellow submarine' type, in place with number 8 wire where possible, or held down using roots and/or rocks. They were baited with Rentokil wax baits with a sucaryl lure and/or Talon 50WB.

The nest protection grids were serviced every three days, and snap trap baits or poison baits were replaced as necessary.

2.4 HOME RANGES AND MOVEMENTS

Sixteen of 18 kakapo known to be alive on Little Barrier (Hauturu) Island were fitted with transmitters for at least part of the year. Their positions were obtained by triangulation on their transmitter signals. This involved taking a compass bearing on the direction of the peak signal strength for each bird from at least three known sites; bearings were plotted on a large contour map. Geographic error was assumed to be constant as bearings were taken from from fixed sites. The level of accuracy was considered sufficent to attain a general idea of where individual birds were usually resident. All triangulation was carried out during the day when the kakapo were assumed to be roosting. We attempted to obtain an accurate fix at least once a week. This method of triangulation is described in greater detail in Moorhouse (1985).

The map of home ranges was compiled using all the positions for each bird for the year. Locations of individuals captured or seen were also included. When drawing boundaries of home ranges, conspicuously outlying plots were excluded. The boundaries of home ranges are approximate because the error of radio triangulation due to terrain is likely to be significant at times and because some birds only had transmitters on for part of the year, so only a limited number of fixes could be obtained.

2.5 NATURAL FEEDING

All feeding sign that could be attributed to kakapo was noted. There is likely to be a bias towards feeding sign that is readily seen within the observer's field of view (i.e. ground level to 1-2 m above head height). Feeding sign in the canopy is generally unlikely to be seen. Despite these limitations the observations do provide an indication of the range of foods and food preferences of kakapo on Little Barrier (Hauturu) Island.

2.6 SUPPLEMENTARY FEEDING

The aim of supplementary feeding on Little Barrier Island is to maximise the breeding potential of kakapo by supplying a readily available year-round *ad libitum* food source (Powlesland and Lloyd 1990, James *et al.* 1991, Powlesland and Lloyd 1994). Increasing and maintaining a kakapo's body weight using relatively protein-rich foods has been suggested as a method for kakapo to attain breeding condition more regularly than has occurred naturally (Powlesland and Lloyd 1994). On Stewart Island, Kakapo appeared to obtain their protein requirements from mast-fruiting tree species, and were known to breed every third or fourth year (Powlesland *et al.* 1992).

Supplementary foods provided to kakapo on Little Barrier (Hauturu) Island had to he readily available, able to be stored for a fortnight, preferably organically grown, transportable to the feeding stations without damage, generally inexpensive, and palatable to kakapo. Most of the protein component of the supplementary diet came from almonds, walnuts, sunflower seeds and nuts. Carbohydrates were mainly provided by apple and kumara. Honey water was also offered during the winter months.

A variety of other foods were offered to birds during the year to test whether the food was liked and to vary their diet. These included kiwifruit, nashi pears, turnip, 'Crunchy combo' sprouts, fresh corn on the cob, pollen, mandarin, and string beans.

Water was offered throughout the year

Up to nine kakapo took supplementary food during the 1994-1995 season (four adult females all year, one adult female for about half a year and four adult males virtually all year). The food was supplied *ad libitum* at individual feeders within each kakapo's home range. Each bird had unlimited access to the food all year. The quantity of food was adjusted regularly depending on the individual bird's preferences. This allowed birds to eat as much as they wanted of a given food, while minimising waste. Kumara and apple were organically grown, or washed and peeled if not organically grown. Food was replenished and feeders cleaned every second day from the beginning of October until 2 May, and then every third day, as the food kept better during the cooler winter months. The quantities of food taken were recorded.

Food hoppers were changed each time food was replenished and taken back to base, washed and disinfected. Water hoppers were emptied, cleaned, and refilled at each visit. Every month the water hoppers were replaced, the old ones being returned to base for washing and disinfecting. In most cases two feeding sites were maintained for each bird and the hoppers were swapped between the two feeding stations monthly. This aimed to minimise the build-up of fungus and possible pathogens caused by spilt food, rat activity, and trampling of the soil. Three feeding sites were set up on painted plywood platforms (approx. 1 m^2) level with portions of the summit boardwalk. Hygiene was easier to maintain around the platforms than at feeding stations on the ground.

Several other males (Bill, Ox, Merty, Joe) not on the regular supplementary feeding programme were offered nuts from mid-January to mid March, while

they were actively booming, with the hope of both sustaining booming and preventing 'excessive' weight loss. The provision of the food was at intervals of up to a week due to the distances involved in getting to the TABS. Quantities of food given and taken were not recorded.

2.6.1 Feeder design

Kakapo hoppers are half-cylinders of rotary moulded plastic with flap lids. They slot into short sections (approx. 14 cm) of half-round plastic pipe attached to aluminium standards and are able to be changed easily. The hoppers are sited 15-20 cm above a varnished wooden platform on which a kakapo stands to reach into the hoppers.

2.6.2 Training kakapo to take supplementary food

The method employed to train kakapo to take supplementary food generally involved bait-lines of kumara, apples, and sometimes nuts placed in a territory. The food was placed about 20 cm above the ground on wire stakes to deter kiore from eating it. The stakes were sited 20-30 m apart. The aim was to ensure that the bird came into contact with all the baits.

In July 1994, two females – Flossie and Jean-were put into large enclosures in order to train them to take supplementary food. Flossie learned to use a feeder and took supplementary food until 5 January 1995, when she left the area. Jean, who did not use the feeders, escaped from the enclosure twice before the attempt was abandoned.

2.7 KAKAPO WEIGHTS

Kakapo were routinely weighed when caught for transmitter changes. Automatic scales were used, when operational, to weigh birds that were using feeders.

2.8 RODENT CONTROL

Kiore were trapped to control their numbers around feeding stations and to minimise interference and fouling of food. Numbers of rats caught were noted and used as a rough index of rat numbers through the year.

3. Results

3.1 MALE BREEDING ACTIVITY

3.1.1 Monitoring activity at booming sites

The 1994-1995 breeding season was the longest and most intense for male kakapo recorded since their release on the island (Table 1).

TABLE 1. KAKAPO ACTIVITY AT TRACK AND BOWLS (TABS) IN 1989-1994

BREEDING SEASON	LENGTH OF SEASON	NO. OF ACTIVE MALES	NO. OF ACTIVE TABS	NO. OF DAYS ACTIVITY RECORDED	ESTIMATED NO. OF ACTIVE TABS NIGHTS
1989-90	Late Dec-Mid Apr	11-13	26	140	964
1990-91	Early Oct-Early Apr	10	31	190	1357
1991-92	Early Oct-Late Mar	11	24	167	1068
1992-93	Early Oct-Mid Apr	9	23	202	1048
1993-94	Early Oct-Early Apr	9-10	17	189	877
1994-95	Late July-Mid May	11-12	18	222	1194

TABLE 2. KAKAPO TRACK AND BOWL (TABS) ACTIVITY ON LITTLE BARRIER (HAUTURU) ISLAND.

BIRD	TABS NO.	DATE ACTIVITY STARTED	DATE BOOMING FIRST RECORDED	DATE ACTIVITY FINISHED
Barnard	7	19 Jul	31 Dec	22 Apr
Snark(?)	19	22 Jul	-	14 Apr
Snark(?)	20	22 Jul	3 Dec	12 May
Luke	9	23 Jul	10 Nov	5 May
Blades(?)	17	21Oct	1 Jan	19 Mar
Bill	24	8 Nov	4 Dec	14 May
Ox	21	8 Nov	3 Dec	14 May
Dobbie(?)	8	11 Nov	3 Dec	22 Apr
Arab	49	12 Nov	31 Dec	6 Apr
?	50	18 Nov	-	27 Feb
Merty	31	23 Dec	7 Jan	28 Mar
Merty	27	24 Dec	27 Mar	14 May
Joe	33	24 Dec	7 Jan	16 Apr
Snark(?)	34	8 Jan	21 Feb	5 May
Richard H	47	14 Feb	21 Feb	23 Feb
Richard H	48	14 Feb	25 Feb	12 Apr
Dobbie(?)	51	12 Apr	-	18 Apr

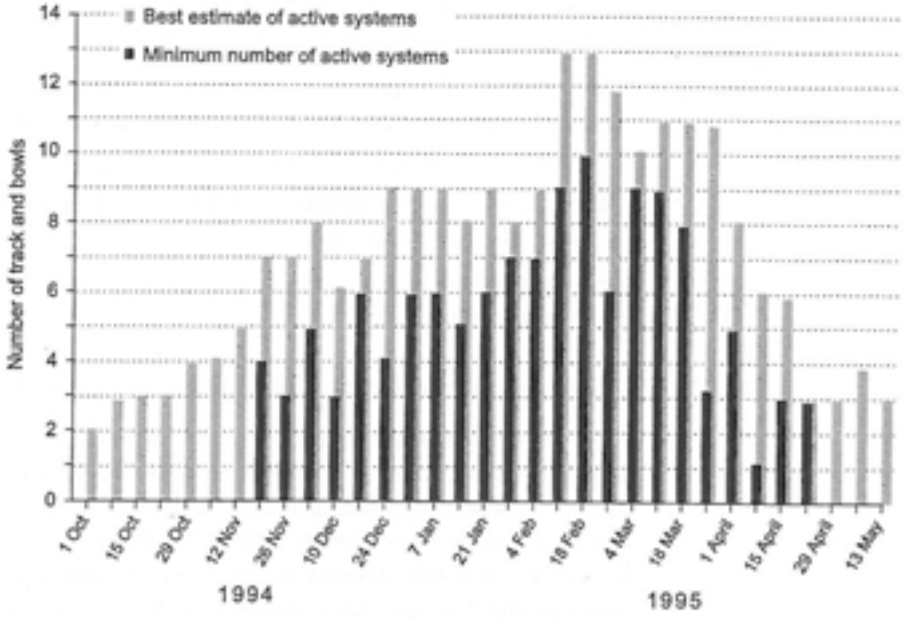

FIGURE 1. KAKAPO TRACK AND BOWL SYSTEM (TABS) ACTIVITY ON LITTLE BARRIER (HAUTURU) ISLAND, 1994–1995.

There were 52 known track and bowl systems (TABS) on Little Barrier (Hauturu) Island during the period July 1994-June 1995, one more than in the previous year. Many of these sites have, however, been unused for several years. Activity attributable to kakapo was detected at 18 of the 52 TABS during the 1994-1995 breeding season 2). Of particular interest is the significant reduction since 1989 in the number of TABS being tended by males.

The number of systems used by male kakapo each night during the period 1October 1994 to 13 May 1995 is shown in Figure 1. Disturbance activity attributable to male courtship displays was first noted on TABS 7 on 19 July with grubbing and vegetation clearing. Similar activity was also noted at TABS 19 and 20 in late July. TABS 9 was active by 23 September. Bowl activity was noted at TABS 17 when it was first visited on 21 October. TABS 21 became active by 13 October and TABS 24 by 8 November.

Booming was first recorded on 10 November at TABS 9, by which time five TABS (TABS 9, 17, 20, 21, 24) were continuously active. By 2 December seven TABS (TABS 7, 8, 9, 17, 20, 21, 24) were continuously active and booming had been recorded at five of the TABS.

TABS 49 became active on 10 December, and TABS 31 and 33 by 22 December.

It was estimated that by the height of the booming season, around 1 February, 13 TABS were being tended by 11 males, including at least one four-year old bird. This young sub-adult male, Stumpy, was seen to grub at TAB 8 on one night. This activity was sporadic, however.

Late activity began at TABS 34 and 52 on 12 January and continued intermittently. These bowls was probably being tended by Snark when he wasn't tending TABS 20. Another late starter was Richard Henry at TABS 47

and 48, which were initially grubbed on 15 February. This was the first time he had been recorded booming on Little Barrier (Hauturu).

TABS 7 was the first continuously active bowl to cease continuous activity (29 March). From 6 April activity declined, although 3 bowls were still active on 14 May. One bowl (48) was tended on 30 June (TABS 48).

Luke, at TABS 7, was monitored by infrared TV from 2 January to 1 March and a record of all observation kept.

Snark possibly boomed at TABS 34 and 20 alternately through the latter part of the breeding season.

3.1.2 Monitoring booming using tape recorders (VARs)

VARs were used more than during the previous year, reflecting the longer breeding season. The VARs were regularly moved from one active bowl to another. One VAR was damaged by a kakapo, making it unusable. Booming was first recorded on 10 November at TABS 9 (Luke). The first TABs to show signs of activity was not necessarily the first at which booming was recorded (Shorten and Thorsen pers. comm.). TABS 7 was active by 19 July, some skraking was recorded by 4 November, but booming was not recorded until 31 December.

3.1.3 Monitoring of booms per bout

The number of booms per bout was measured as it provides a measure of booming intensity, and may provide a measure of male display quality. The average number of booms per bout is shown in Table 3. Ox (TABS 21) recorded the highest number of booms per bout averaging 16.3. Joe and Merty, who were removed from the main TABS concentration around the summit area, also produced relatively high counts at 15.5 and 13.92 booms/bout respectively. Bill also produced an average of 14 booms/bout and

TABLE 3. AVERAGE NUMBER OF BOOMS PER BOOMING BOUT FOR MALE KAKAPO ON LITTLE BARRIER (HAUTURU) ISLAND 1994-1995.

MALE	TABS	MEAN NO. OF BOOMS PER BOUT	S.D.	NUMBER OF BOOMS RECORDED
Ox	21	16.30	8.92	n=147
Joe	33	15.50	10.00	n=87
Merty	31	13.92	5.62	n=96
Bill	24	13.69	6.53	n=287
Richard H	47	13.07	5.70	n=47
Blades	17	12.1	5.25	n=168
Barnard	7	11.53	5.03	n=188
Woodpile	8	10.17	4.29	n=29
Arab	49	9.43	5.28	n=129
Luke	9	8.63	3.99	n=205
Snark (?)	34	8.11	3.93	n=53

Arab, who were assumed to have had matings, averaged 11.53 and 9.43 booms/bout. Booming recorded from TABS 34 and thought to be Snark averaged only 8.11 booms/bout. This may reflect his relative youth (15 years old, Merton 1982) compared with the other males.

3.1.4 Daytime booming

Table 4 shows the number of booming bouts recorded in daytime during the 1994 - 1995 breeding season. Daytime booming was heard on 34 occasions on a total of 25 days over a 129 day period from 2 December to 10 April. This compares with 26 occasions during 1989-1990, 43 for 1990-1991, 18 for 1991-1992, and 19 in 1992-1993. Daytime booming was heard at all times of the day and in all weather.

TABLE 4. OCCURRENCES OF DAYLIGHT BOOMING.

FORTNIGHT BEGINNING	NO. OF OCCURRENCES	ESTIMATED NUMBERS OF ACTIVE TABS
1 Dec	1	6
16 Dec	1	6
30 Dec	6	7
13 Jan	6	8
27 Jan	8	9
10 Feb	4	10
24 Feb	3	10
10 Mar	4	9
24 Mar	0	7
7 Apr	1	5

Booming was heard during the day by observers inspecting TABS and replenishing feeding stations. It may have been prompted by observer disturbance. Daytime booming generally occurred close to active TABS, was subdued and only lasted a few minutes at the most. Other vocalisations were not heard during the day.

3.1.5 Site fidelity

Using a combination of radiotelemetry, VARs and trapping of males not carrying transmitters, we were able to identify most of the males using TABS. Table 5 shows the site fidelity of males with respect to TABS for the past six years. Seven of the males used the same sites as last year. Five males have used the same site for at least the last three years.

3.1.6 Feather clusters

Clusters of feathers were found at, or near, active booming sites on five occasions between 11 January and 10 April. The feathers found at TAB 7 on 11 January were consistent with previous evidence of copulation, and a few down feathers ground into a boardwalk near TABS 49 were also regarded as

TABLE 5. TABS FIDELITY OF MALE KAKAPO 1989–1994.

TABS	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95
7	Barnard	Pegasus	Pegasus (?)	Rob	Rob then Barnard	Barnard
8-49	Arab/Snark	Arab	Arab	Arab	Dobbie (?) and Arab	Stumpy and Arab
9	Luke	Luke	?	Luke	Luke	Luke
20-21	?	Snark	?	Ox	Ox	Ox and Snark
24-25	?	Bill	Bill	Bill	Bill	Bill
16/17-18	?	?	?	Blades	Blades	Blades
12-50	Barnard	?	?	Barnard	Barnard	?
33	Joe	?	?	?	Joe	Joe
31	?	?	?	?	Merty	Merty
47-48	-	-	-	-	-	Richard H
34	-	-	-	-	-	Snark (?)

probable evidence of copulation. The other three feather clusters were probably the results of fights. These are summarised as follows:

8 March: Evidence for fight at TABS 20.
An apparent fight between Ox and the owner of TAB 20 (Snark?). A trail of 11 contour feathers and three down feathers was found 15 m east of TABS 20, and a four contour down feathers were found just west of TABS 20.

5 April: Evidence for fight near TABS 7.
A trail of 20 down feathers and eight contour feathers south of TABS 7 was found leading off and down to the west side of the track. This was thought to be a fight between and Dobbie. Dobbie had been active in this area for the previous 10 days, and had been grubbing just south of TABS 7 at TABS 51.

10 April: Fight or preening.
A group of 13 contour feathers, 12 down feathers, and one face feather was found under a boardwalk between TABS 7 and TABS 49: a possible fight between Dobbie and again, as Dobbie was still active in the area.

3.1.7 Feather counts

Down and contour feathers were found on most days throughout the booming season. There was a marked increase in the number of feathers (down, contour, and remiges) found near booming sites and feeding stations from about mid April 1995, which was later than in previous years. Feathers were usually found individually or in small numbers, but larger groups were occasionally found, probably where a bird had stopped to preen. The increase in the number of feathers found corresponds closely with the decline in TABS activity and the onset of post-breeding moult (Fig. 2).

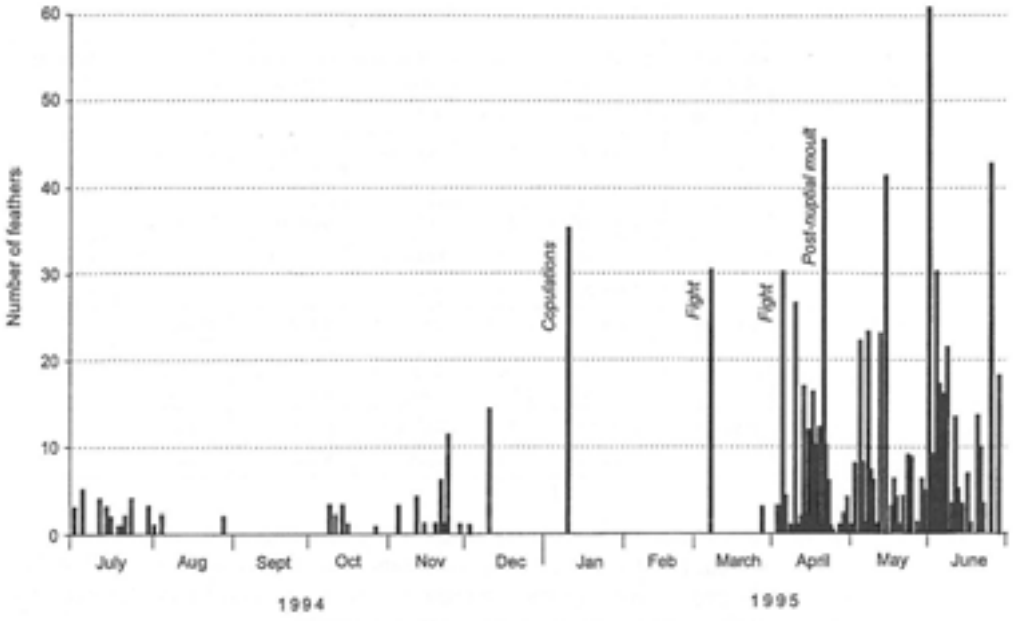

FIGURE 2. NUMBER OF KAKAPO FEATHERS FOUND ON LITTLE BARRIER (HAUTURU) ISLAND, JULY 1994-JUNE 1995.

3.2 FEMALE BREEDING ACTIVITY

3.2.1 Summary

Tables 6 and 7 summarise female breeding activity on Little Barrier Island since kakapo were released in 1982.

TABLE 6. KAKAPO BREEDING ACTIVITY ON LITTLE BARRIER (HAUTURU) ISLAND 1982-1995.

SEASON	BOOMING HEARD	NO. OF ACTIVE MALES	START OF ACTIVITY	END OF ACTIVITY	COPULATION FEATHERS?	NESTS FOUND?
1982-83	No	0	--	--	No	No
1983-84	Yes	3-5	?	Mid Apr	No	No
1984-85	Yes	c.8	?	Mid Apr	No	No
1985-86	Yes	>7	Early Jan	Mid Apr	No	No
1986-87	No	3-5	Late Dec	Late Jan	No	No
1987-88	Yes	7-8	Early Jan	Mid Mar	No	No
1988-89	Yes	9	Early Jan	Mid Mar	No	No
Supplementary feeding begins Sept 1989						
1989-90	Yes	11-13	Late Dec	Mid Apr	Yes	Yes
1990-91	Yes	10	Early Oct	Early Apr	Yes	Yes
1991-92	Yes	11	Early Oct	Late Mar	No	No
1992-93	Yes	9	Early Oct	Mid Apr	Yes	Yes
1993-94	Yes	9-10	Early Oct	Early Apr	No	No
1994-95	Yes	11-13	Late Jul	Mid May	Yes	Yes

TABLE 7. COPULATION DETAILS 1989-1995.

BREEDING SEASON	DATE OF COPULATION	TABS	PROBABLE MALE	PROBABLE FEMALE	% FERTILE EGGS	OFFSPRING
1989-90	12 Jan 90	24	Bill	?	?	--
	26 Jan 90	7	Pegasus(?)	Heather	100 (n=1)	--
1990-91	2 Jan 91	24	Bill	Wendy	100 (n=3)	Dobbie
	12-13 Jan 91	24	Bill	Heather	50 (n=2)	--
	19 Jan 91	7	Pegasus	John-Girl	100 (n=2)	Stumpy
	22 Jan 91	49	Pegasus	?	?	--
1992-93	31 Jan 93	21	Ox	Wendy	33 (n=3)	--
	2 Feb 93	24	Bill	Wendy	--	
	11 Mar 93	9	Luke	Jean	0 (n=2)	--
1994-95	11 Jan 95	7	Barnard	Heather	0 (n=2)	--
	11 Jan 95	49	Arab	Wendy	0 (n=2)	--

All six known females were monitored closely during the 1994-1995 breeding season. Two females - Wendy and Heather - are known to have nested. Both are thought to have mated on the night of 9-10 January in the region of TABS 7 and TABS 49. Both females produced infertile clutches.

A third female – Maggie - may have laid eggs without mating. She was found on 19 February with a brood patch, but had not been recorded near any active TABS, and was not known to leave her home range. A subsequent search and intensive monitoring did not find any evidence of a nest. Maggie has produced eggs, apparently without mating, in a previous breeding season (Lloyd and Powlesland 1992).

Two other females-Jean and Bella-moved close to active TABS on at least one occasion each but did not appear to have mated and did not nest. Jean, in particular, moved widely across the southeastern quadrant of Little Barrier (Hauturu) Island during the booming season. Bella did not generally move far from her home range but was recorded moving 2 km (in a straight line) across four valleys on 15-16 March. The one remaining female-Flossie-apparently did not visit an active TABS. During the breeding season she moved from her supplementary feeding station near an active TABS (ca. 750 m) to an area several kilometres from the nearest active TABS.

Apart from Jean and Flossie, three other females had been feeding at supplementary feeding stations almost continuously for five years before the 1994-1995 breeding season. Wendy began feeding at feeding stations in the winter of 1990 (Powlesland and Lloyd 1992). The nesting females did not feed exclusively at the feeding stations during the nesting period. Jean is the only non-supplementary fed female to produce eggs, in 1993. She apparently mated with Luke at TABS 9, and produced an infertile clutch (Greene 1993b).

3.2.2 Breeding details for each nesting female

Heather

Summary Heather was caught and her transmitter replaced on 11 August. She moved from her normal home range to the region of TABS 49 by 9 January. She remained here until 11 January, when she was located near the TABS 7, where she had probably mated with Barnard the previous night. She roosted near TABS 7 until 14 January when she was located in the upper Tirikakawa stream. By 15 January she was located in her normal home range. She was found on her nest on 25 January. Two, (possibly three) eggs were seen on 28 January. Two eggs were confirmed on 6 February.

A rat eradication grid was established around the nest over the next few days. The nest was monitored for the next month. On 4 March, when the eggs had failed to hatch, they were candled. All the eggs were clear, indicating that they were infertile. The eggs were blown and the contents sent off for analysis. They were subsequently as infertile.

Wendy continued to sit on two artificial eggs until they were removed on 12 March. She subsequently abandoned the nest.

Weight Mean weight prior to supplementary feeding = 1.24 kg (n=13, sd 0.121).

Weights recorded since supplementary feeding began:
15 November 1990: 1.70 kg
26 November 1990: 1.88 kg
Nested January 1991
11 October 1991: 1.55 kg
7 August 1992: 1.47 kg
21 September 1992: 1.50 kg
15 September 1993: 1.71 kg
11 August 1994: 1.75 kg

Mean weight = 1.65 kg (n=7, sd=0.149)

Previous breeding history During the 1989-1990 breeding season Heather nested, but the nest failed when a single nestling died at about six days old during a wet, cold period (Lloyd and 1990).

Heather nested again in the 1990-1991 breeding season, but the nest failed also. One egg was infertile, and the other egg was fertile but contained a dead embryo (Lloyd and 1992). This is the only confirmed record of a female breeding in two successive years.

Supplementary feeding Heather has been consistently taking supplementary food since late 1989.

Pre-nesting movement Heather moved up to near TABS 49 on the night of 9 January and was in the area from 9-10 January.

Copulation details Heather was located near the summit on 11 January. Copulation feathers were found approximately 10 m north of TABS 7. Possible copulation feathers were also found on the boardwalk near TABS 49. This sign has been attributed to a mating between Arab and Wendy. Heather probably mated with at TABS 7.

She remained near to the Summit until 14 January then she moved back towards her usual home range. Heather was located in her home range on 15 January.

Nest log Heather was monitored closely for the next week and, since she had not moved her roost site, she was checked on 25 January. She was found to be on a nest. On 28 January two, possibly three, eggs were seen. A two-egg clutch was confirmed on 6 February. She was monitored by infrared camera from 22 February. Observations were as follows:

31 Jan. 1994:	Tent erected ca. 70 m from nest site. Heather had her first substantial feed last night.
1 Feb. 1994:	Did not leave nest last night.
2 Feb. 1994:	Left nest at 0030. Went to hopper to feed. Away for about 25 minutes.
3 Feb. 1994:	Left nest to feed.
4 Feb. 1994:	Did not leave nest.
7 Feb. 1994:	Heather left nest at 2230 on 6th for 1 hour 40 min. Fed mainly away from the feeder. Two eggs confirmed.
10 Feb. 1994:	Heather left nest from 2230-2300 and 0637-0705.
11 Feb. 1994:	2018-2025 at nest entrance. 2054 left nest for 59 minutes. Eggs checked and OK.
15 Feb. 1994:	Heather fed at her feeder last night.
17 Feb. 1994:	Did not leave to feed last night.
18 Feb. 1994:	Left nest at 2024 and returned at 2118.
22 Feb. 1994:	Video infrared camera put into nest when she left at 2030. She returned at 2230
24 Feb. 1994:	Off nest at 2030 and returned at 2145.
27 Feb. 1994:	Severe electrical storm last night. Some water getting into nest and Heather trying to move eggs to drier ground. Cover placed over entrance to stop the worst of rain getting into cavity.
2 Mar. 1994:	Eggs now overdue. Heather got off nest at 2010 and returned at 2045 after feeding near nest on natural food.
4 Mar 1994:	Heather left nest at 1902 hr. Eggs candled and found to be clear. Probably infertile. Eggs replaced with two plastic ones. Heather returned at 2100 and immediately settled on artificial eggs. She had apparently been feeding within 200 m to the west or northwest of the nest.
11 Mar. 1994:	Heather did not leave nest last night.
12 Mar. 1994:	Heather left at 2015 hr. She moved quickly away to southwest into valley. Camera and artificial eggs removed.

Heather's nest The altitude of the nest was approximately 300 m a.s.l. The nest was located at the end of a 2 m long cavity in a fallen puriri (*Vitex lucens*). The nest site was on the top edge of a slope facing east to southeast. The nest cavity was 2 m long, with an entrance that measured 600 mm high by 200 mm wide. A diagram of Heather's nest is given in Appendix 1.

The vegetation in the vicinity of the nest consisted mainly of kauri *(Agathis australis),* northern rata *(Metrosideros robusta*) and mature kanuka (*Kunzea ericoides*) forest, with a subcanopy of nikau (*Rhopalostylis sapida*), mapou *(Melicytus australis)* mahoe (*Melicytrus ramiflorus*) and *Cyathea* sp. A thick

understorey of hangehange (*Geniostoma rupestre*), mangemange (*Lygodium articulatum*), kiekie (*Freycinetia banksii*), supplejack (*Rhipogonum scandens*), *Gahnia* sp., and *Blechnum* sp. was also present.

Nest protection The nest protection grid for Heather's nest was set up between 25 and 28 January. All the traps were set off on 1 March and removed by 9 March.

Wendy

Summary: Wendy was caught and her transmitter replaced on 17 August. She moved from her normal home range to just south of Garrick's Mistake on 7-8 January. She then moved up to near TABS she probably mated with Arab on the night of 10-11 January. By 12 January Wendy was back down near Garrick's Mistake again and was found in her usual home range by 14 January. She was found on her nest on 3 February. One egg was seen. The egg was probably laid sometime between 21 January and 3 February.

A rat control grid was established around the nest over the next two days. A camera was placed in the nest cavity on the evening of 9 February, and three eggs were confirmed. The nest was monitored for the next month. The eggs were candled on 5 March when they had failed to hatch after a minimum of 31 days of incubation. Two of the three eggs were clear, indicating that they were infertile. One of the eggs was 2/3 full of dark fluid suggesting an early dead embryo. The eggs were blown and the contents sent off for analysis. All three were subsequently confirmed as infertile.

Wendy continued to sit on three artificial eggs, until they were removed on 11 March. She subsequently abandoned the nest.

Weight Mean weight prior to supplementary feeding = 1.31 kg (n=10, sd 0.152).
Weights recorded since supplementary feeding began.
14 October 1989: 1.85 kg (non-supp. fed)
Began supplementary feeding winter 1990 (Powlesland and Lloyd 1991).
Nested January 1991
31 March 1991: 1.47 kg
14 July 1991: 1.52 kg
6 October 1991: 1.53 kg
7 August 1992: 1.67 kg
Nested January 1993
15 September 1993: 1.88 kg
17 August 1994: 1.70 kg

Mean weight 1.63 (n= 6, sd = 0.152)

Previous breeding history During the 1990-1991 breeding season Wendy mated with Bill at TABS 24. She laid three eggs, one of which was infertile. The remaining two eggs hatched. One chick disappeared at ca. 30 days. The remaining chick, a male, Dobbie, fledged and has been to the Little Barrier kakapo population (Lloyd and Powlesland 1992).

Wendy nested again in January 1993, after mating with Ox and Bill with a day between matings. She laid three eggs. One chick hatched, but disappeared

after three days. The remaining eggs failed to hatch and were found to be infertile (Greene 1993b).

Supplementary feeding Wendy has been taking supplementary food since the winter of 1990 (Powlesland and Lloyd 1992).

Pre-nesting movements Wendy was located near Mistake on 8 January, which is approximately halfway between her usual home range and the summit TABS. Wendy was located near TABS 49 on 11 January.

Copulation details On 11 January copulation feathers were found approximately 10 m north of the western summit bowl (TABS 7) and probable sign of mating was found on the boardwalk about 15 m northwest of TABS 49. Wendy was the closest female to TABS 49 on the night of 10-11 January and probably mated with Arab on the nearby boardwalk. Heather had also been located nearby during this period but is thought to have mated with Barnard.

Wendy had moved down to Garrick's Mistake by 12 January and was back at her usual territory by 14 January.

Nest location and description Wendy used the same nest site she used during the 1992-93 season. The altitude of the nest is at c. 330 m a.s.l. It was in a large chamber beneath a 6 m high stump of a large northern rata, the top of which had broken off in the last 3-4 years. Details of the nest site are provided in Appendix 2. The floor of the chamber consisted of a fine tilth of chewed wood and powdered rotten wood. The nest site aspect was on a moderate slope facing west.

The predominant vegetation in the vicinity consisted of mixed kauri (*Agathis australis*), hard beech (*Nothofagus truncata*), tawaroa (*Beilschmiedia tawaroa*), taraire (*B. taraire*) northern rata (*Metrosideros robusta*), kohekohe (*Dysoxylum spectabile*), with an often thick understory of mangemange (*Lygodium articulatum*), kiekie (*Freycinetia banksii*), supplejack (*Rhipogonum scandens*), hangehange (*Geniostoma rupestre*), toropapa (*Alseuosmia macrophylla*), and nikau (*Rhopalostylis sapida*).

Nest log Wendy was found on her nest on 3 February. One egg was seen. An infrared video camera was placed in the nest on 10 February when she left the nest from 2120-2150 hr. Three eggs were subsequently confirmed.

The number of nest inspections undertaken during incubation was considerably higher than for other nests in previous seasons owing to the use of an infrared camera. Wendy showed a little interest in the camera initially but ignored it for the rest of the incubation period. The use of the camera gave a substantial amount of information on activity of female kakapo at the nest which has hitherto been unavailable. A detailed nest log was recorded. On 5 March Wendy's eggs were candled and found to be infertile. She had probably been incubating for about 35 days. Her eggs were replaced with three artificial eggs. Her nest was also dusted with pyrethrum powder, as it appeared she was having trouble with mites or fleas. Subsequent analysis of the nest material did not confirm that ectoparasites were present. On 11 March Wendy's artificial eggs were removed.

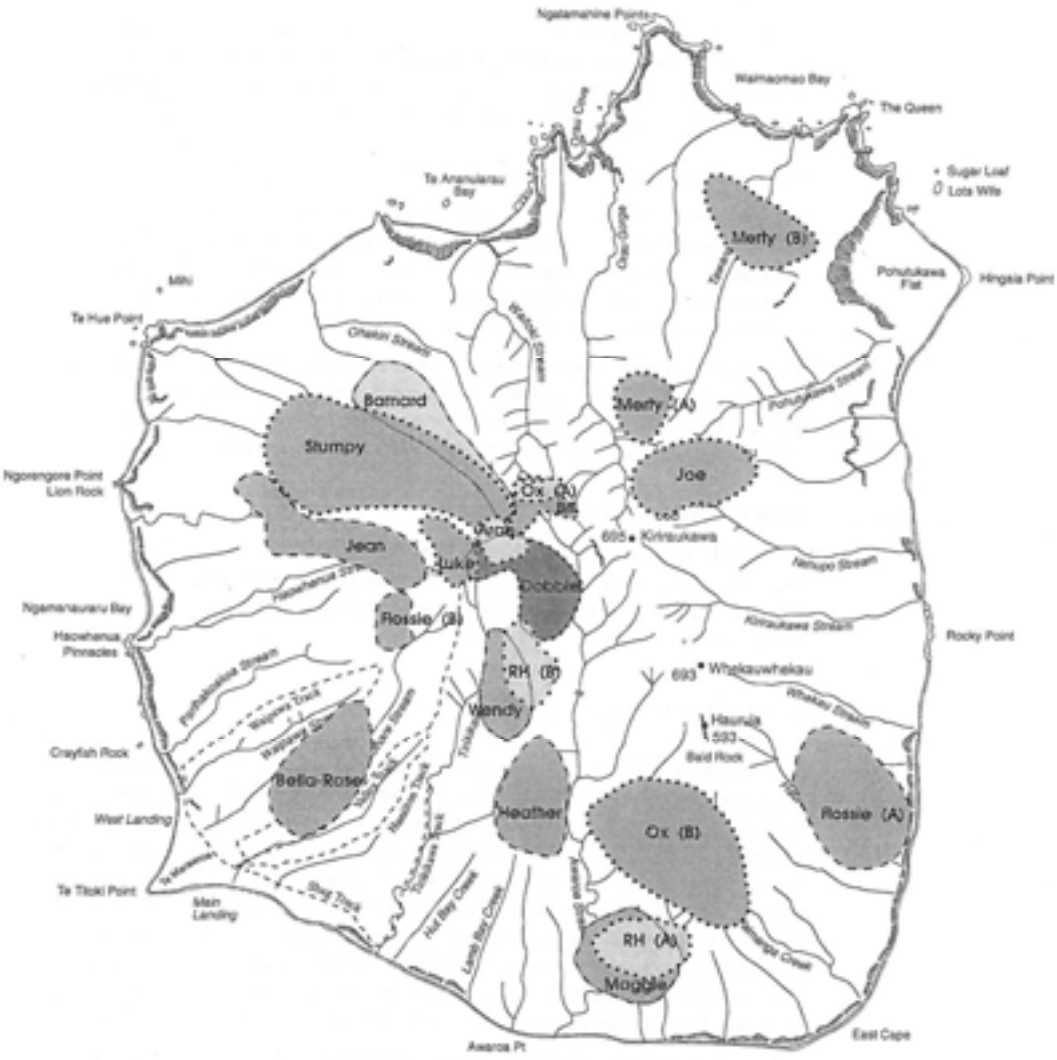

FIGURE 3. KAKAPO HOME RANGES JULY 1994 TO JUNE 1995.

3.3 HOME RANGES AND MOVEMENTS

The home range of kakapo with transmitters is shown in Figure 3.

3.3.1 Home ranges of females

All six female kakapo known to be alive on Little Barrier Island carried transmitters for the entire year. Five of the six female kakapo held single home ranges for the year (Fig. 3).

Flossie held a home range on the Thumb Track until early January 1995, when she moved to her previous home range at the south-east end of the island (R.

Shorten and M. Thorsen, pers. comm.). Flossie had been moved to the Thumb Track in July 1994 and had been introduced to a feeding station there.

3.3.2 Home range of sub-adult males

The two sub-adult males born in early 1991 were four years old at June 1995. Dobbie has appeared to consolidate his home range in the upper Track 20 area and spends considerable amounts of time in the vicinity of the TABS 8, where it is suspected he raids a nearby feeder. Stumpie has an extensive home range extending out to the west of the island.

The sub-adult males[1] home ranges are both close to their respective mothers' home ranges. Dobbie has a home range within 600 m of his mother's (Wendy). Stumpie has a home range that borders his mother's (John-Girl) previous home range (Moorhouse and Powlesland 1991). John-Girl died in 1991.

3.3.3 Home range of adult males

In general, the adult males remained near their TABS (and feeders) year round. Exceptions were who spent much of the non-breeding season to west of TABS 9, and Ox, who has a non-breeding season home range in the southeast of the island.

3.4 NATURAL FEEDING

Little Barrier (Hauturu) Island has a more diverse forest than Stewart Island and Codfish (Wheua Hou) Island (Moorhouse and Powlesland 1991, pers. obs.). The kakapo introduced to Little Barrier have retained the elastic food preferences found for birds on Stewart Island (Best 1984) and appear to have readily accepted a wide range of northern plant species as foods. Natural Kakapo feeding sign on Little Barrier (Hauturu) is summarised in Table 8. Possible preferential feeding on plant species found on both Little Barrier (Hauturu), Codfish (Whenua Hou) and Stewart Island still occurs and is shown in the number of feeding observations noted for *Gahnia* species and *Dracophyllum*, which have close relatives on Stewart Island.

Kakapo introduced to Maud (Te Hoiere) Island have also shown similar abilities to feed opportunistically on species previously unknown in the kakapo diet as well as taking familiar species (Crouchley *et al.* 1995).

3.5 SUPPLEMENTARY FEEDING

There are some difficulties in interpreting the precise quantity of food eaten by individual birds because kiore take an unknown quantity of food that kakapo drop at their feeders, and because kakapo will use feeders other than their own if they encounter them. The results discussed below will show general trends only.

For the analysis only the main supplementary food types that kakapo took apple, almonds, walnuts, brazil nuts) are shown.

TABLE 8. OCCURRENCE OF FEEDING SIGN ATTRIBUTABLE TO KAKAPO ON LITTLE BARRIER (HAUTURU) ISLAND. OCTOBER 1994-JUNE 1995.

NATURAL FOOD OBSERVATIONS			PLANT PART	NUMBER OF OBSERVATIONS PER MONTH								
				OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
Fungi							1	1				
PTERIDOPHYTA + Allies												
Blechnum	sp	*	pinnae		1	1						4
Blechnum	*capense*	**	pinnae		1							
Pteridium	*esculentum*	**	pinnae					3	1			1
GYMNOSPERMS												
Agathis	*australis*		leaf	1				5	5			
Phyllocladus	*glaucus*		leaf			1						
DICOTS												
Archeria	*racemosa*		leaf	2	2	1			3	1		
Beilschmedia	*tawaroa*		bark		1							
Dracophyllum	*traversii*	*	leaf base	5	3	5	2	7	6	3	5	16
			leaf				1	1				
Leucopogon	*fasciculatus*		leaf			1	2	2		2	1	
Metrosideros	*excelsa*		leaf					2				
			bark			1						
"	*fulgens*		leaf								3	1
"	*umbellata*	**	leaf									1
			bark			1	1					
"	*albiflora*		leaf					1	1			
			bark		1							
Pseudowintera	*axillaris*		stem									1
Weinmannia	*silvicola*		leaf						1		1	
			bark									1
MONOCOTS												
Astelia	*sp*	*	leaf		1			1			2	4
			leaf base	1	1							1
Carex	*dissata*	*	leaf		2							
Collespermum	*sp*		leaf					1				
			leaf base				1					
Dianella	*nigra*		leaf									3
Gahnia	*sp*	*	leaf	6	1	2	1		2			1
			leaf base	7	4		1	2	2	1	3	7
			seed			2	1	4				1
Cordyline	*banksii*		flower stalk			1						
Earina	*autumnalis*	**	leaf			2						
Freycinetia	*baueriana*		leaf	1	6	6	1	1			1	3
			fruit			1						
Phormium	*cookianum*	**	leaf		2					1	1	3
			seed pods				3	5				
BARK					3			1	1		2	7
ROOTS					1			1	1			13

** same species eaten by kakapo on Codfish (Whenua Hou) Island.
* same genus eaten by kakapo on Codfish (Whenua Hou) Island.
Sources : Buckingham *et al.* 1995, Cole and Roberts 1995a.

3.5.1 Pattern of consumption

A. Nesting females

Heather and Wendy's supplementary food consumption is shown under 'Heather' and 'Wendy' in Figure 4. Note the difference in total amounts consumed.

Heather did not rely on supplementary feeding as heavily as Wendy did, although she appeared to feed almost exclusively on nuts rather than the fruit and vegetables offered. Of interest are different patterns of consumption between the two females. Although both had a peak in consumption before and after the breeding season, Wendy's substantial (4.4 kg/month) peak in consumption in late March occurred at the time of abandoning her nest. She also fed largely on apple and kumara. Heather did not show this pattern, and by comparison her consumption of nuts increased slowly up to May.

B. Other adult females

All the females, including Heather and Wendy, tended to consume between 1000-1500 g of food per month (Fig. 4) with peaks in consumption in spring and autumn. This pattern mirrored known periods of natural weight gain (Merton *et al.* 1984).

Flossie was supplementary fed from July 1994 to early January 1995. During this time she made impressive weight gains (refer to 'Weights').

C. Adult males
In contrast to the females, the males did not show autumn and spring consumption peaks, but consumption tended to peak over the spring period (Fig. 4). Food take during the booming season was minimal. Arab's apparent food consumption was probably inflated through his food being raided by sub-adult males, but it is still substantial at a peak of 7 kg for one month.

3.6 WEIGHTS

Pre-breeding season weights for kakapo for the past five years are shown in Table 9.

A. Females

The four supplementary fed females were heavier than the one non-supplementary fed female, Jean. The supplementary fed females weighed from 1.65 kg to 2.33 kg (Mean = 1.86 kg). Jean weighed 1.3 kg. Flossie was supplementary fed for about six months of the year. During this time her weight went from 1.3 kg (8 July 1994) to 2.15 kg (14 November, using automatic scales). She left the area of the feeding station in early January. Five months later, without supplementary feeding, her weight had returned to 1.34 kg.

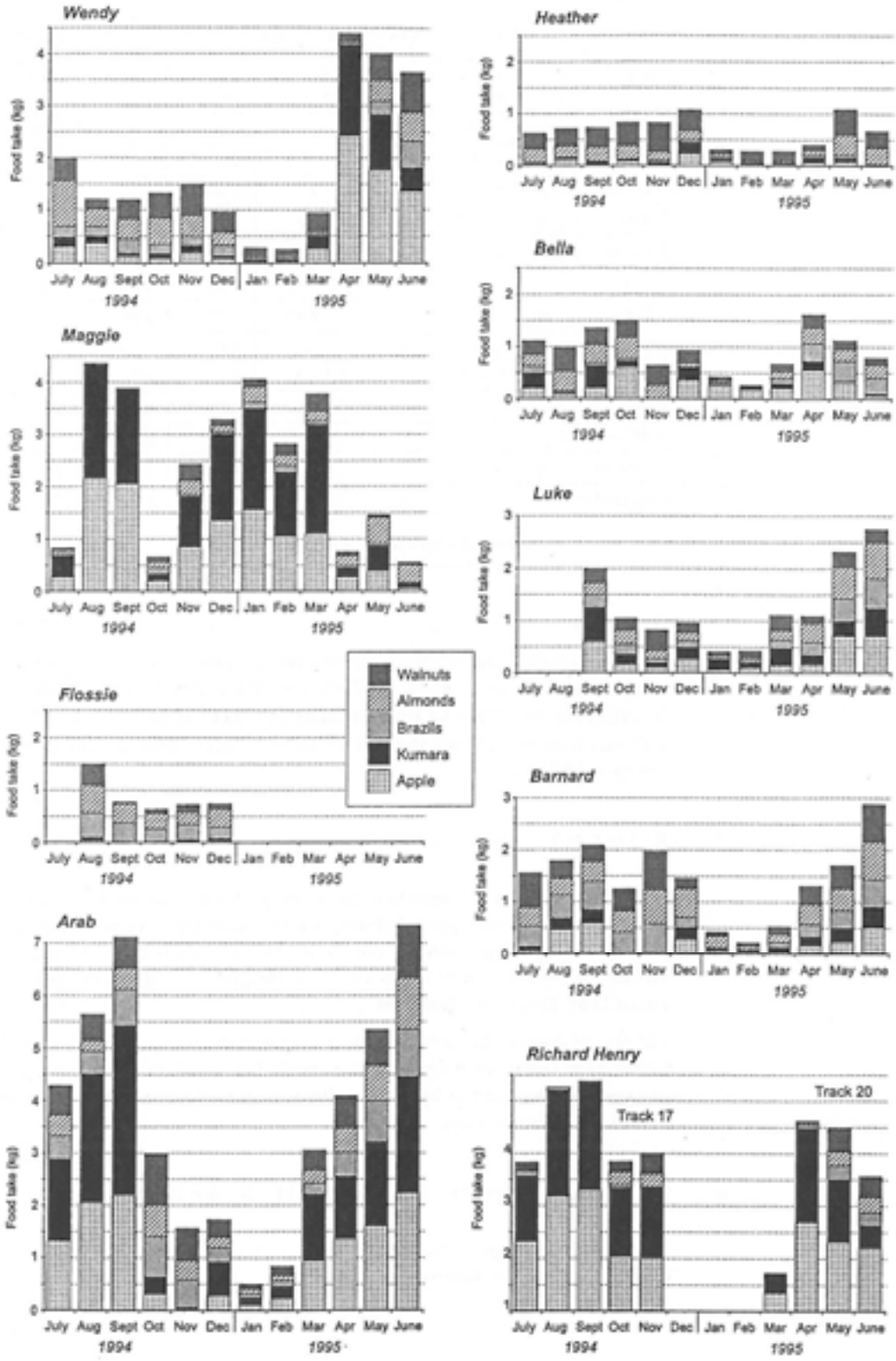

FIGURE 4. SUPPLEMENTARY FOOD INTAKE OF KAKAPO ON LITTLE BARRIER (HAUTURU) ISLAND JULY 1994–JUNE 1995.

TABLE 9. WEIGHTS (kg) OF KAKAPO ON LITTLE BARRIER (HAUTURU) ISLAND.

BIRD		1990-91	1991-92	1992-93	1993-94	1994-95	POST 1995
Maggie	sf	* 1.60	1.51	1.62	1.90	1.65	1.70
Heather	sf	* 1.88	1.55	1.50	1.71	* 1.75	---
Wendy	sf	* ---	1.53	* 1.67	1.88	* 1.70	---
Bella	sf	2.09	1.81	1.68	2.15	2.33	---
Flossie		---	---	---	1.17	2.10	1.34
Jean		---	---	* 1.33	1.35	1.30	1.23
Luke	sf	2.27	---	* 2.35	2.60	2.85	---
Arab	sf	3.20	---	2.51	2.95	* 2.95	2.19
Bill		* 1.80	---	* 2.25	2.45	2.65	---
Joe		---	---	---	---	2.23	2.59
Merty		---	---	---	---	2.78	2.01
Barnard	sf	---	---	---	---	* ---	2.02
Richard H	sf	---	---	---	---	1.97	---

* = kakapo that bred in that season
sf = supplementary fed kakapo

B. Males

Two of the supplementary fed males had heavier pre-breeding weights than the three non-fed males weighed (Barnard was captured and weighed late in the booming season). The two supplementary fed males weighed from 2.85 kg to 2.95 kg (mean = 2.90) and the non-fed males weighed from 2.23 kg to 2.78 kg (mean = 2.55 kg).

3.7 RODENT CONTROL

The numbers of kiore caught in traps at kakapo feeders are shown in Figure 5. The numbers of kiore peaked during autumn and early winter. The general trend, not surprisingly, follows the usual seasonal trends observed previously on Little Barrier (Hauturu) Island and other Hauraki Gulf islands (Watson 1956, Speed 1986, and Craig 1987).

The results suggest that the use of the rat traps at the kakapo feeding stations as a kiore population index appears to be justified, because the population follows the same seasonal trends noted elsewhere, despite the constant availability of food at the kakapo feeders.

3.8 INTERACTIONS WITH OTHER SPECIES

Infrared cameras provided information on two occasions of nocturnal interactions between kakapo and other birds.

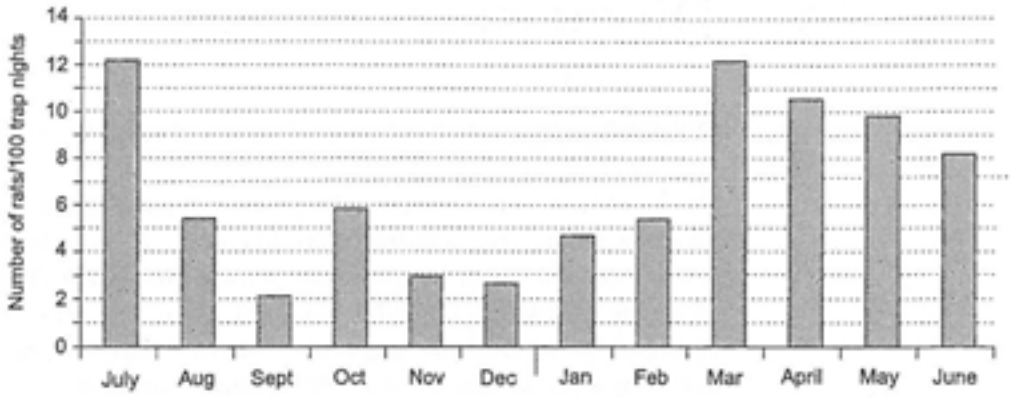

FIGURE 5. SEASONAL CHANGES IN THE NUMBER OF KIORE (*Rattus exulans*) CAUGHT AT KAKAPO FEEDING STATIONS IN 1994-1995.

3.8.1 Cook's petrels

A. Luke

A dead Cook's petrel (*Pterodroma cookii*) had been found near TABS 9 during the 1992-1993 breeding season and it was thought that a kakapo had killed it (Greene 1993b). Several dead petrels were found in the immediate vicinity of TABS 9 (Luke) during the 1994-1995 booming season. The infrared camera system provided a probable answer to the unusually high mortality of petrels in the area. Luke was recorded killing a Cook's petrel at his TABS on the night of 11-12 January. On this night and the night Luke 'played' with the petrel corpse and appeared to attempt copulation with it.

B. Wendy

A dead Cook's petrel was found 2 m from Wendy's feeder on 6 April. A trail of petrel feathers led from her feeder to the petrel corpse, which had an injured shoulder. It appeared that Wendy had been disturbed at her feeder and had killed the petrel. Dead petrels have also been found at Wendy's nest sites in two previous breeding seasons (Lloyd and Powlesland 1992, Greene 1993b).

3.8.2 Black petrel

On several nights Luke was seen to escort black petrels (*Procellaria parkinsoni*) off his TABS. The display involved spreading his wings and facing the petrel as it walked along the length of the TABS. He did not attempt to attack the black petrels as he had done previously with a smaller Cook's petrel.

3.9 PARASITES

3.9.1 Mites

Wendy may have had an infestation of mites at her nest site in February 1995. She vigorously scratched and preened during some of her incubation period. However, analysis of the nest material did not confirm the presence of mites.

4. Discussion

4.1 DEVELOPMENT OF A CENTRALISED LEK

The number of male kakapo on Little Barrier (Hauturu) active during the last six breeding seasons has remained relatively stable at 9-13 birds. The number of active TABS has, however, decreased during this period (Table 1). From highs of 26 and 31 TABS in the 1989-1990 and 1990-1991 seasons respectively, the total number of TABS has reduced to 18. This decrease appears to have been occurring since at least the mid 1980s. Thirty-five booming sites were recorded in 1986 (Moorhouse 1986).

Foster (1983) observes that exploded leks appear to develop as a trade-off between the need for males with a strong dominance hierarchy to be within vocal range of each other, whilst minimising disturbance to each other or a prospective mate. Of interest is the ability to the development of a communal lek site as previous studies of lekking species have been done at already existing lek sites. Male kakapo could have developed an increasingly lek for several reasons. They may have eventually centred on sites that are past sites of copulations or close to past sites of copulation, the best for booming from (auditory message to females), or close to other booming males (which may increase the likelihood of females arriving at their TABS).

4.2 CERTAINTY OF MATING PARTNERS

The identities of the birds involved in the two matings recorded this season are probable only. Wendy was near TABS 49 on the night before her probable mating, but was also close enough to TABS 7 to have mated there. The only evidence for a mating near TABS 49 was the presence of some down feathers on a nearby boardwalk. The position of both the probable copulation sites was also some distance from the TABS in question. Research into the genetics of the population should reveal the identity of mates at past copulation sites. The future use of scanners at TABS will reduce uncertainty in mate in mate identification.

4.3 MATE SELECTION IN FEMALE KAKAPO

The choice of a partner by a female kakapo is of vital importance to mating success. If we can identify the factors involved in mate choice we may use that to increase reproductive success and improve the genetic mix of the population.

Explaining selection of males by female kakapo on Little Barrier Island is hampered by a dearth of data: there have been only 10 recorded matings (Table 7).

A review of the information we have shows that Bill has been the most successful (dominant?) male with 40% of matings at TAB 24 (Table 10). Three matings have occurred at TAB 7, which appears to be the best site due to the

TABLE 10. MATING SUCCESS FOR MALE KAKAPO ON LITTLE BARRIER (HAUTURU) ISLAND 1982-1995.

MALE	TAB	NO. OF MATINGS
Bill	24	4
Pegasus/Barnard	7	3
Pegasus/Arab	49	2
Ox	21	1
Luke	9	1

intense competition for it (i.e., number of fights). Two matings have taken place at TAB 49. Luke has had one mating at TAB 9 as has Ox at TAB 21. Why has Bill been the most successful male?

Reviews of female mate choice in avian lekking species provide us with some possible explanations. Loffredo and Borgia (1986) stated that females probably use male courtship calls to select a dominant male. Hoglund (1989) has suggested that in some groups of lekking birds sexual selection has favoured acoustic displays rather than plumage differences between sexes.

If we review the acoustic displays of the males for the 1994-1995 breeding season (booms per booming bout: Table 3) we find that Ox (TAB 21) has the highest rate of booms per bout. The successful males for the season are seventh and eight on the boom per bout scale for all recorded males. Bill is fourth. The data do not appear to fit the theory.

This information, unfortunately, has some problems. Booming rates have large standard errors, and some birds may have been booming particularly well on the night of the matings but were not picked up by the data set (i.e. the data are too coarse).

Foster (1983) suggests that a male's lek site may be the reason why a female selects a particular male. Bill's site (TAB 24) is the lowest in altitude of the five mating sites discussed. TAB 7 is the highest. If there is any relationship between altitude and mate choice it seems that females are picking males with the lowest lek sites.

It seems likely that other factors more subtle than either booming intensity or altitude, affect mate choice and these are not being picked up by the current data collection. Clearly then, collection of vocalisation data, site information, and mate choice should continue in the hope that the reasons why female kakapo select a particular male can be identified.

4.4 KAKAPO WEIGHTS AND FERTILITY

4.4.1 Weight

Figure 6 shows the recorded weights of Wendy and Heather since they were introduced to Little Island and since supplementary feeding (SF) began. Female kakapo transferred from Stewart Island to Codfish Island have also undergone similar weight increases apparently in response to

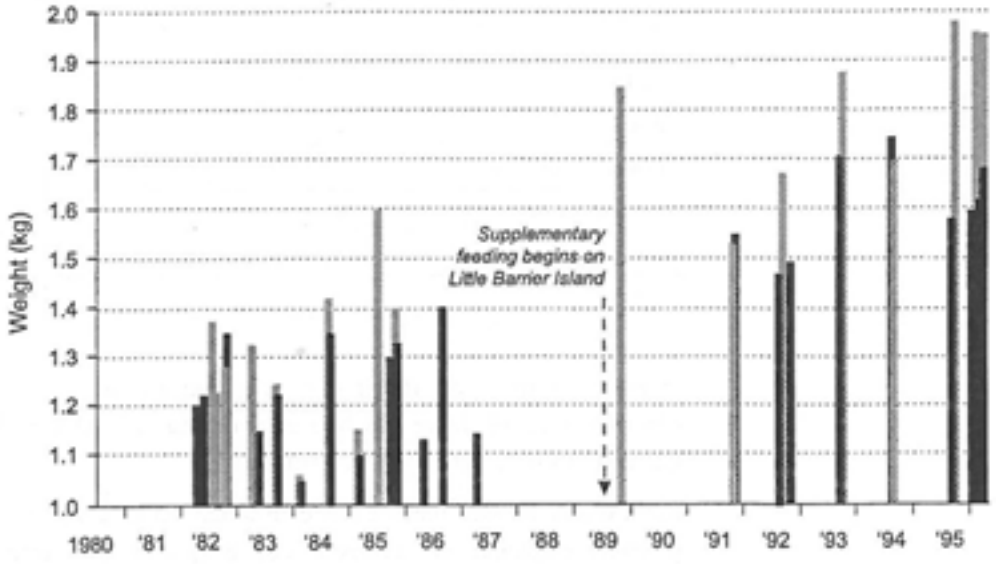

FIGURE 6. WEIGHTS OF WENDY (HATCHED) AND HEATHER (SOLID).

supplementary figures (data from Merton *et al.* 1984, Buckingham 1992, Buckingham *et al.* 1995, Cole and Roberts 1995a, Cole and Roberts 1995b).

In their original Stewart Island home kakapo were known to show 'maximum weights... prior to breeding and minimum weights both after breeding and in years when breeding does not occur' (Merton *et al.* 1984). We would expect, therefore, to be currently recording weights of any individual kakapo that fluctuate around a mean weight for that bird. This will depend on the season and whether it is a breeding year. Figure 5 shows, however, that the average weight for some individuals on Little Barrier Island has actually slowly increased since the inception of SF, with little fluctuation around the birds non-SF mean weight. Wendy, for example, has increased in weight, and has never been recorded below her mean weight since SF began. Hirons *et al.* (1984) found that weights of tawny owls were strongly positively correlated with the amount of visceral and subcutaneous fat that the owls carried.

On Little Barrier (Hauturu) Island the mean weight of female kakapo over the first seven years was 1.28 kg (exactly the same as the mean weight for females on Stewart Island - Merton *et al.* 1984). In October 1989, all the female weights increased substantially, the mean weight rising to 1.68 kg (Hodsell 1990), an increase of 31%. Wendy, who did not come onto the SF programme until 1990 (Powlesland and Lloyd 1992), increased from a seven year mean of 1.38 kg to 1.9 kg in October 1989, an increase of 38%. This is the sort of weight gain that can be expected when kakapo are about to breed (Merton *et al.* 1984). These weight gains suggest that, in at least one instance, the success of the first year of supplementary feeding was due to the females coming into breeding condition independently of SF.

Non-SF males on Little Barrier (Hauturu) have maintained average weights through numerous booming seasons only slightly less than the average weight for SF males. On Little Barrier (Hauturu) up until 1989 booming had been recorded on five of seven summer seasons but no breeding was recorded. Males maintained an average weight during this seven-year period of 1.86 kg (Hodsell 1990). SF was begun in September 1989 but in October 1989, all the

male kakapo (i.e. SF and non-SF males) had increased their average weight by 35% over the average weights recorded over the previous seven years (mean weight: 2.5 kg) (Hodsell 1990), suggesting that a breeding season was going to occur in the 1989-1990 season regardless of SF. Not surprisingly a breeding season did occur in (Lloyd and Powlesland 1990).

The mean weight of female SF kakapo on Little Barrier (Hauturu) is 45% more than the mean weight of females prior to 1989 and 45% more than the two non-SF females, Jean and Flossie. There is a negative correlation between SF female weights and fertility over the past five years (Fig. 6).

4.4.2 Fertility

For a comparison with Little Barrier Island, known fertility rates for Stewart Island and Codfish Island need to be reviewed. Overall fertility for the one breeding year on Codfish (Whenua Hou) Island is 84% (1992: five females, 12 eggs). In the two recorded breeding seasons on Stewart Island the average fertility of known females was 100% in 1981 (two females, four eggs in total) and 46% in 1985 (four females, 11 eggs in total). The mean fertility rate for these three seasons is 70% (19 fertile eggs/27 total). If this mean rate were applied to the Little Barrier population we would expect 14 fertile eggs, not the six produced.

The percentage of fertile eggs produced on Little Barrier (Hautum) by females that mated (i.e. excluding has decreased every year since nesting was first recorded in early 1990. Even ignoring the 1989-1990 season, when only one fertile egg was produced (Heather, 1990), the trend since 1991 shows decreasing fertility over the next three breeding seasons. Table 11 summarises kakapo productivity on Little Barrier Island since breeding began. Infertility is the major cause of loss of productivity, followed by the loss of chicks, possibly through predation by kiore.

TABLE 11. KAKAPO PRODUCTIVITY ON LITTLE BARRIER (HAUTURU) ISLAND 1990-1995.

SEASON	FEMALES MONITORED	NO. OF NESTS	SUCCESSFUL NESTS	NO. OF EGGS LAID	NO. INFERTILE	NO. OF CHICKS	CHICKS FLEDGED
1989-90	4	2	0	2	1	1	0
1990-91	5	4	2	8	3	4	2
1991-92	4	0	-	-	-	-	-
1992-93	5	2	0	5	4	1	0
1993-94	6	0	-	-	-	-	-
1994-95	6	2	0	5	5	0	0
Total	30	10	2	20	13	6	2

Of particular concern is the marked decline in the fertility of females which had previously produced fertile clutches (i.e. Wendy and Heather).

There are a number of possible reasons for decreasing fertility in birds (Boardman 1995). The main causes are:

a) Parent breeding behaviour problems
b) Reproductive tract abnormalities
c) Weather problems
d) Disease
e) Inbreeding
f) Parental age
g) Incorrect parental diet

We can probably rule out a to h as possible causes for infertility in Wendy and Heather on Little Barrier Island, as they have initially bred successfully (a, b, and c); there is no evidence to suggest the birds are diseased (d); and inbreeding (e) should not be a problem at this stage in the breeding programme. Parental age (h) would not be expected to affect fertility within a five-year time span for Heather, as she is only 14 years old (Merton 1982) so her reproductive capabilities should not be decreasing. It is possible that an aging Wendy may be becoming infertile, but we do not know if age affects fertility in kakapo in the same manner as other large parrots. The same conclusions (a to h) hold for male kakapo, especially if they continue to hold prime TABs.

Of these variables, diet (i) is the only one which has altered greatly, and a thorough analysis of the affect of diet on fertility should be undertaken on the kakapo.

Chance variation may affect the result, especially with a small sample size (20 eggs). The *trend* of decreasing fertility on Little Barrier (Hauturu) is cause for concern, however, with an overall fertilty rate of 30% at odds with the mean fertility of 70% for kakapo elsewhere.

Concern about the possibility of SF producing overweight, and therefore infertile, male or female birds has also been voiced from within the Department of Conservation kakapo management structure several times since SF began (Powlesland 1991, Powlesland and Lloyd 1992, Huntress 1992 in litt., Moorhouse 1993 in litt., Moorhouse *et al.* 1995).

4.4.3 Kakapo weights and supplementary diet

In captive birds and mammals incorrect diet can result in obesity, which in turn results in numerous physical disorders (Scott 1994, Holmes 1995). These include decreased fertility and poor breeding performance in captive birds Boardmanpers. comm.). Bird diets that are high in fat also 'lead to calcium and other vitamin and mineral deficiencies' (Jordan 1989). Roudybush (1992) states that 'supplementary diets need to provide nutrients without causing obesity and inhibiting foraging in wild birds.'

Some parrot breeders have suggested that, because of their size, large macaws are analagous to kakapo, and because macaws preferentially feed on nuts high in fat, kakapo should also be fed on a similar diet (D. Low, pers. comm.). But Clubb (1994) makes the points that 'macaws adapted to a diet ...high in fat' and 'macaws appear to need ... a higher level of dietary fat than other psittacine species.' Until SF was initiated kakapo were not exposed to a constant (year-round) supply of high-protein or high-fat foods. The high-protein foods (e.g. rimu fruit) were only available during the late summer and autumn when chicks were being raised.

Unlike gregarious macaws, kakapo are solitary. Kakapo hold large overlapping territories rather than sharing resource nodes (e.g. specific fruiting trees) as other parrots do. In the case of SF birds they have almost sole access to feeding stations, with little competition from other kakapo for food supply. SF kakapo could be regarded as the sole occupants of a 30 ha aviary with unlimited food. The similarities with captive parrots may not be that distant.

Kakapo are flightless with poorly developed pectoral muscles and breastbone keels (James *et al.* 1991). (1990) states that low basal (metabolic) rates in flightless birds are correlated with small pectoral muscle mass and kakapo are likely to have substantially lower energetic requirements than large flying parrots like Macaws.

Studies of some other supplementary fed wild birds have been similar to some of our findings about kakapo. Supplementary feeding of herbivorous american coots has had virtually no effect on clutch size or laying date (Arnold 1994). Supplemental fed lesser black-backed gulls clutch size was depressed by lack of protein, but not energy. Egg production appears to be limited by the supply of specific nutrients, in addition to normal protein requirements (Bolton *et al.* 1992, Alisaukas and Ankey 1994). Supplementary feeding of South Island kaka did not increase breeding frequency but did help adults provision chicks (P. Wilson pers. comm.).

However, the size of fat reserves in female tawny owls, coots, and ruddy ducks appears to influence whether they will breed or not (Hirons *et al.* 1984, Alisankas and Ankney 1985, Alisaukas and Ankney 1994). This does not appear to be the case with SF kakapo, as consistently heavy birds do not breed every year. Seasonal change in the condition of some birds influences whether they breed or not. After their study of SF birds, Bolton *et al.* (1992) suggested that 'where food supply varies in a predictable fashion, the timing of crossing of a certain (body reserve) threshold may provide a good indication of food availability later that season...', and '...in coots, fat reserves allow the female to "evaluate" whether she posseses the minimum required for a breeding attempt…' (Alisankas and Ankney 1985).

Kakapo were thought to breed on Stewart Island only when protein-rich foods were available (Powlesland *et al.* 1992). SF was suggested as a way to induce kakapo to breed more often by supplementing their usual herbivorous diet with protein-rich plant matter (Powlesland and Lloyd 1994). Foods used to supply the protein, and that kakapo regularly accepted, include almond kernels, walnuts, brazil nuts, and sunflower seeds. These foods are excellent sources of protein, but are also very high in levels of fat (Jordan 1989), which may be linked to an increasing incidence of egg infertility.

Although SF may have produced initial success in breeding with kakapo on Little Barrier in its current form (i.e. year-round *ad libitum* feeding of protein and fat-rich foods) it could be inhibiting breeding success.

SF may also have contributed to the ability of kakapo to breed in two successive summers culminating in the successful 1990-1991 breeding season (Lloyd and Powlesland 1992). It may be that SF is adding to a biennial cycle that may have developed on Little Barrier anyway. SF may have also contributed to the ability of some of the female kakapo on Little Barrier (Hauturu) to breed every two years, and to raise chicks. SF is still a useful tool,

but in its current rather crude form its goal of increasing productivity in kakapo is becoming increasingly distant. SF should not be discarded but major tuning of the programme is needed.

4.4.4 Continued supplementary feeding

It is recognised that a protein-rich diet is the most likely to bring females into breeding condition and therefore should be continued (Powlesland and Lloyd 1994). A year-round high-fat diet should probably be avoided however. The fact that high-fat nuts are now being fed to kakapo in large amounts is an artefact of the original need to provide a protein-rich food source that was easy to transport and store and that kakapo preferred. The high fat content of the nuts was a by-product of the need to fill this food preference. As the kakapo SF programme infrastructure has developed it has also developed the ability to provide the birds with high-protein food sources without the high fat content. Chickpeas, for example, when sprouted, are a low-fat, high-protein food source. These are already a popular food with current SF birds (especially if nuts are restricted, pers. obs.). Other sources of low fat protein include other sprouted legumes, fresh corn (popular with birds but seasonal), and millet.

The fact that kakapo presently eat large quantities of nuts throughout the year should not be a reason in itself to continue feeding nuts to them. If alternatives are available that provide sufficient protein, which was the original intention of the programme (Powlesland and Lloyd 1994), then they should be used in preference to dietary components continually high in fat.

In future in would appear prudent to manage the female diet to more closely resemble the prevailing food and breeding conditions. In view of a biennial periodicity in kakapo breeding activity on Little Barrier (Hauturu), two supplementary feeding regimes appear appropriate. A basic diet could be offered year round to maintain interest in the feeding stations. In a likely breeding year the females could be offered *ad libitum* amounts of high protein in the spring along with an increase in the carbohydrate content of the diet (e.g. kumara) so they gain weight. Kakapo on supplementary diets are capable of making significant weight gains in relatively short periods of time. Flossie made a 65% weight gain in four months (see 'Weights'), and Richard Henry made similar gains in less then four months in the winter of 1995 on a largely kumara and apple SF diet (refer to figure 14). Powlesland and Lloyd (1994) also noted this ability for SF birds to make substantial weight gains in short time periods.

If it is accepted that overweight birds could have reduced fertility it would seem prudent to bring the weights of SF females down to close, or maybe slightly above, their previous average non-SF weights.

The two-yearly periodicity of breeding activity on Little Barrier (Hauturu) since 1990-1991 may be the result of kakapo on the island having become used to fluctuations in the natural diet after a settling-in period. Kakapo were known to boom roughly every second year in areas of beech forest (which does not mast every two years (Henry 1904)) whereas podocarp mast seeding provides a strong cue to breed every four or five years on Stewart Island (Powlesland *et al.* 1992). Too few podocarps occur on Little Barrier (Hauturu) Island to provide this cue.

Since SF began most of the non-SF male birds have maintained weights only slightly below SF males (Table 9). During the summer on Little Barrier Island most of the non-SF males boomed better than SF males (on a booms per bout basis, refer table 3), many start booming earlier than most SF males (Table 2) and often maintained their TABS as long as SF males (Table 2). There is also a biennial periodicity developing in the intensity of booming, with every second summer (1990-1991, 1992-1993, 1994-1995) producing intense booming activity regardless of SF. It appears that SF is not improving the breeding performance of SF males over that of non-SF birds and could be contributing to infertility in the SF males. It should therefore be reduced significantly or phased out for male kakapo.

It appears that the SF programme has not increased the frequency of breeding on Codfish Hou) Island. Evidence points to kakapo productivity being strongly tied to mast fruiting of podocarps on Stewart Island and Codfish Island (Whenua Hou) *et al.* 1992, Buckingham 1992). At least three years of the SF programme has not as yet altered this and may not be able to change it. SF should continue, however, as an emergency 'back-up' food source if rimu fruit does not ripen and kakapo chicks become threatened with starvation as occurred in 1992 (Buckingham 1972). The females should be given a 'maintenance diet' like the Little Barrier females. A ‘protein/carbohydrate pulse' could be given to them prior and during the breeding season to improve and maintain their condition (e.g. from September to June). If they do breed in a rimu mast year, and the fruit does not ripen, we have the ability to provide large amounts of protein-rich food for the females and their chicks.

If there is a negative correlation between weight and fertility then the average weights of female kakapo on Codfish (Whenua Hou) Island are cause for concern. The average female weights have steadily climbed since the inception of SF in mid 1992 (Fig. 6) and are now around 2 kg, which is well above the average weight of female kakapo (1.28 kg) on Stewart Island. A similar scenario has also developed on Maud (Te Hoiere) Island, with both male and female birds being substantially heavier than the mean weight for those on Stewart Island (Crouchley *et al.* 1995).

If the SF programme continues in its present form it will probably not provide any more information than has already been gained in the past six years. On the contrary, it may produce more disappointing results. There is clearly an urgent need to modify the SF programme before the next breeding season.

5. Recommendations

In light of the continuing doubts about kakapo mate selection it would be useful to have more accurate methods for measuring the proximity of birds to TABS during the breeding season and confirm female site fidelity and copulations.

The Supplementary Feeding Programme has not delivered the results that were intended at its implementation six years ago and should therefore be modified by means of the following recommendations:

Significantly reduce the SF diet for males on Little Barrier (Hauturu) Island. Non-SF males appear to be booming as well, if not better in some cases, than SF males.

Remove year-round feeding of nuts from the SF diet of female kakapo on Little Barrier (Hauturu) Island, and reduce their weights slowly to their average weights at the initiation of SF feeding. Initiate protein-rich but low fat sprouted legumes (Chickpeas, peas, beans etc.). Small amounts of nuts could also be used in a breeding season.

Reduce the Codfish (Whenua Hou) Island SF programme to a purely maintenance diet during non-breeding years. Provide a high-protein diet to females prior to, and during, a breeding season (September to June).

6. Acknowledgements

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7. References

Alisaukas, R.T., Ankey, C.D. 1985. Nutrient reserves and the energetics of reproduction in american coots. *Auk* 102, 133–144.

Alisaukas, R.T., Ankey, C.D. 1994. Nutrition on breeding of female ruddy ducks: the role of nutrient reserves. *Condor* 96, 87–97.

Arnold, T.W. 1994. Effects of supplemental food on egg production in American Coots. *Auk* 111(2), 337–350.

Best, H.A. 1984. The foods of kakapo on Stewart Island as determined from their feeding sign. *N.Z. Journal of Ecology* 7, 71–83.

Boardman, W. 1995. Infertility and incubation problems in birds. *Gladdens Avitimes* 1(6), 7–9.

Bolton, M., Houston, D., Monaghan, P. 1992. Nutritional constraints on egg formation in the Lesser Black-backed Gull: an experimental study. *Journal of Animal Ecology* 61, 521–532.

Buckingham, R. 1992. Kakapo breeding on Codfish Island 1991–1992. Internal report, Southland Conservancy. Department of Conservation, Invercargill.

Buckingham, R., Torr, S., Leary, H., Cole, R. 1995. Management of Codfish Island October 1992–June 1993. Department of Conservation, Invercargill.

Clubb, S.L. 1994. Life history and medical management of Macaws. III International Loro Parque Parrot Convention, 89–100.

Cole, R., Roberts, A. 1995a. Management of Codfish Island July 1994–June 1995. Department of Conservation, Invercargill.

Cole, R., Roberts, A. 1995b. Management of Codfish Island July 1993–June 1994. Department of Conservation, Invercargill.

Crouchley, D., Brown, D., Climo, G. 1995. Kakapo on Maud Island. Annual Report. July 1994–June 1995. Department of Conservation, Havelock.

Foster, S. M. 1983. Disruption, dispersion, and dominance in lek-breeding birds. *The American Naturalist* 122(1), 53–72.

Greene, T.C. 1993a. Kakapo Breeding Activity on Little Barrier Island October 1991–March 1992. *Auckland Conservancy Technical Report Series No. 7*, Department of Conservation, Auckland.

Greene, T.C. 1993b. Kakapo Breeding Activity on Little Barrier Island October 1992–March 1993. *Auckland Conservancy Technical Report Series No. 8*, Department of Conservation, Auckland.

Harper, G.A. 1995. Protection of kakapo nests from predation on Little Barrier Island. Internal report. Kakapo Management Team, Department of Conservation, Wellington.

Henry, R. 1904. Reports to the Commissioner of Crown Lands, Dunedin. In: Report of the Department of Lands and Survey for the Year 1894–1904, by S.P. Smith. Government Printer, Wellington.

Hirons G.J.M., Hardy, A.R., Stanley, P.I. 1984. Body weight, gonad development and moult in the Tawny owl (*Strix aluco*). *Journal of Zoology*, London. 202,145–164.

Hodsell, C. 1990. Kakapo survey Little Barrier Island 12 September – 7 November 1989. *Auckland Conservancy Technical Report Series No. 3*. Department of Conservation, Auckland.

Hoglund, J. 1989. Size and plumage dimorphism in lek-breeding birds: a comparitive analysis. *The American Naturalist* 134(1), 72–87.

Holmes, B. 1995. The good life is killing America's fat rats. *New Scientist* 9 December, p.10.

Huntress, S. 1992. In: Kakapo Recovery Group Meeting 24–25 March 1992. Department of Conservation, Wellington.

James, K.A.C., Waghorn, G.C., Powlesland, R.G., Lloyd, B.D. 1991. Supplementary feeding of kakapo on Little Barrier Island. *Proceedings of the Nutrition Society of New Zealand* 16, 93–102.

Jordan, R. 1989. Parrot Incubation Procedures. Black Cockatoo Press, Australia.

Lloyd, B.D., Powlesland, R.G. 1990. Kakapo breeding activity on Little Barrier Island 21 November 1989–10 April 1990. *Science and Research Internal Report No. 83*, Department of Conservation, Wellington.

Lloyd, B.D., Powlesland, R.G. 1992. Kakapo breeding activity on Little Barrier Island: October 1990–June 1991. *Science and Research Internal Report No. 129*, Department of Conservation, Wellington.

Loffredo, C.A., Borgia, G. 1986. Sexual selection, mating systems, and the evolution of avian acoustical displays. *The American Naturalist* 128(6), 773–794.

McNab, B.K. 1990. Energetics and the evolution of the flightless condition in birds. *Int. Ornith. Congress. Acta XX. (Suppl.1990)*, p.268.

Merton, D.V. 1982. Kakapo transferred to Little Barrier Island. Internal memo. NZ Wildlife Service, Wellington.

Merton, D.V. 1995: 1981–1995. Internal memo. Department of Conservation, Wellington.

Merton, D.V., Morris, R.B., Atkinson, I.A.E. 1984. Lek behaviour in a parrot: the Kakapo *Strigops habroptilus* of New Zealand. *Ibis* 126, 277–283.

Moller, H., Craig, J.L. 1987. The population ecology of *Rattus exulans* on Tiritiri Matangi Island, and a model of comparative population dynamics in New Zealand. *N.Z. Journal of Zoology* 14, 305–328.

Moorhouse, R. 1985. Some aspects of the ecology of kakapo (*Strigops habroptilus*) liberated on Little Barrier Island. Unpublished MSc thesis, University of Auckland, New Zealand. 147pp.

Moorhouse, R.J. 1986. Report on Kakapo booming activity on Little Barrier Island: January - April 1986. Unpublished Report, Wildlife Service, New Zealand.

Moorhouse, R.J. 1993. In: Kakapo Recovery Group Meeting 16–17 March 1993. Department of Conservation, Wellington.

Moorhouse, R.J. and Powlesland, R.G. 1991. Aspects of the biology of Kakapo *Strigops habroptilus* liberated on Little Barrier Island (Hauturu), *New Zealand. Biological Conservation* 56, 349–365.

Moorhouse, R.J., Greene, T.C., Lovegrove, T.G., Buckingham, R. 1995. Submission to the International Review Committee of the Kakapo Recovery Programme.

Owen, J. 1994. Kakapo Nest Protection Protocol. Threatened Species Unit, Department of Conservation, Wellington.

Powlesland, R.A. 1989. Kakapo Recovery Plan 1989–1994. Department of Conservation, Wellington.

Powlesland R.A. 1991. Kakapo research 1991–1992. Internal memo. Department of Conservation, Wellington.

Powlesland, R.A., Lloyd, B.D. 1990. Progress report of the supplementary feeding of kakapo on Little Barrier Island, September 1989 – April 1990. *Science & Research Internal Report No. 84*. Department of Conservation, Wellington.

Powlesland, R.A., Lloyd, B.D. 1992. Supplementary feeding of kakapo on Little Barrier Island May 1990–June 1991. *Science & Research Internal Report No. 122*. Department of Conservation, Wellington.

Powlesland, R.G., Lloyd, B.D. 1994. Use of supplementary feeding to induce breeding in free-living kakapo *Strigops habroptilus* in New Zealand. *Biological Conservation* 69, 97–106.

Powlesland, R.G., Lloyd, B.D., Best, H.A., Merton, D.V. 1992. Breeding biology of the kakapo *Strigops habroptilus* on Stewart Island, New Zealand. *Ibis* 134, 361–373.

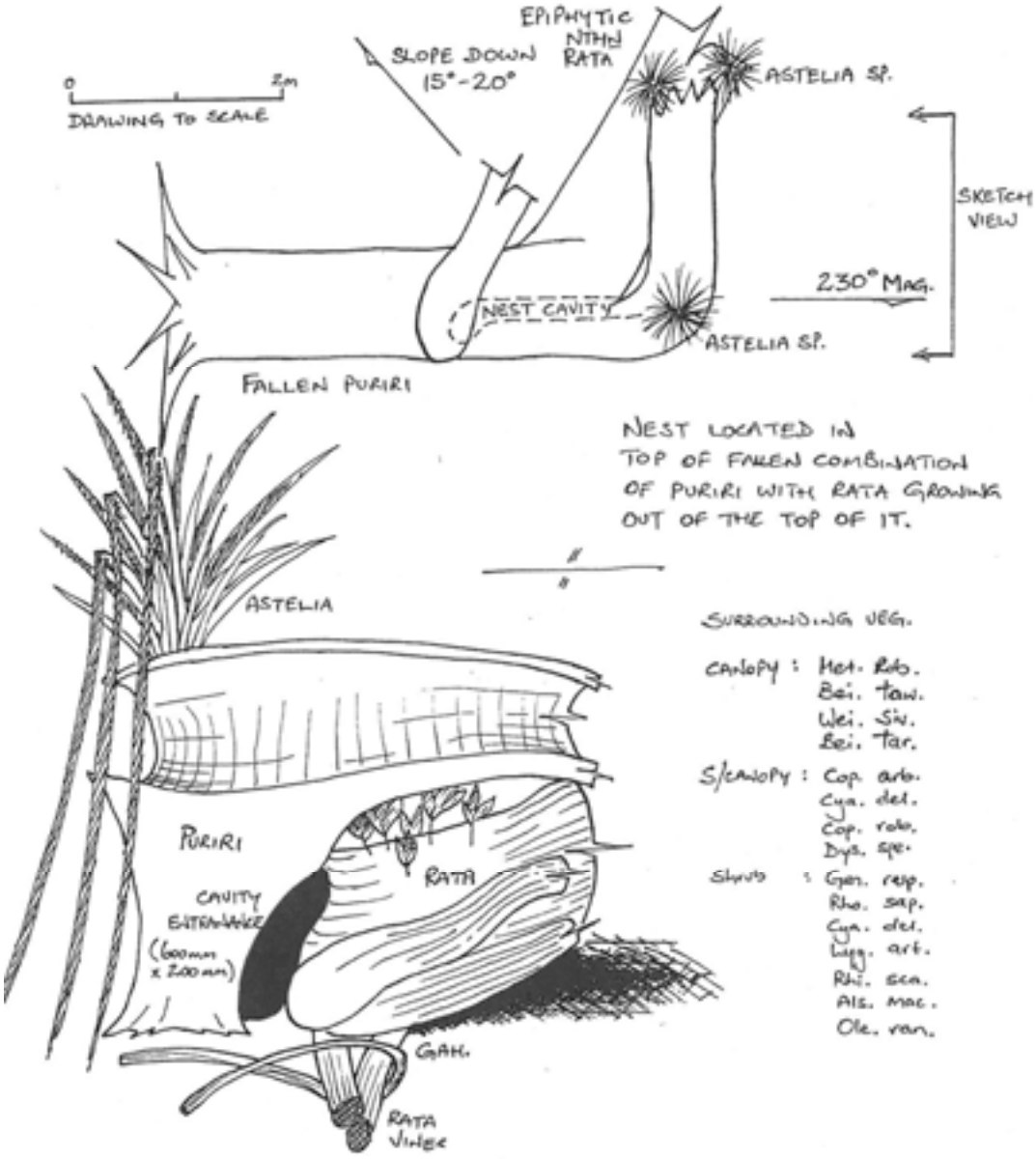
Roudybush, T. 1992. Kakapo information. Paper on kakapo diet. Roudybush, PO Box 331, Davis, California.

Scott, P.W. 1994. Recent thoughts and developments in psittacine nutrition, sexing and disease diagnostics. *International Parrot Convention III*,195–208.

Speed, H. 1986. Demography and diet of kiore (*Rattus exulans*) on Little Barrier Island. Unpublished MSc. Thesis. University of Auckland.

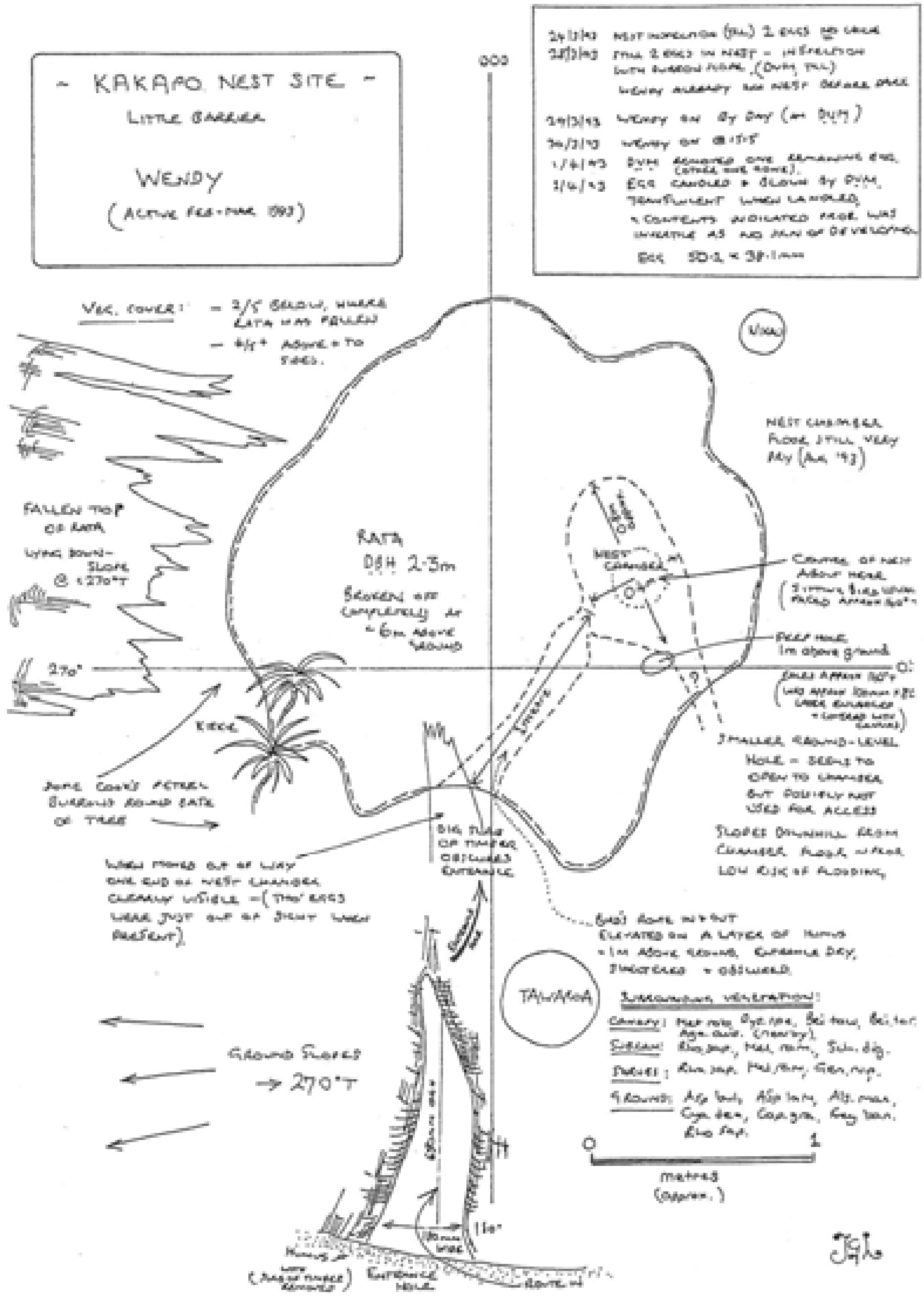
Watson, J.S. 1956. The present distribution of *Rattus exulans* (Peale) in New Zealand. *N.Z. Journal of Science and Technology* 37, 560–570.

Appendix 1



KAKAPO NEST SITE.
LITTLE BARRIER ISLAND.
"HEATHER".
JAN-FEB 1995.

Appendix 2



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(approx.)
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