The Ecology of the Kakerori (Rarotonga Flycatcher) *Pomarea dimidiata*, With Special Reference to Fledged Young.

A thesis presented in partial fulfilment of the requirements for the degree of Master of Science in Ecology at Massey University.

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ABSTRACT

The Kakerori (*Pomarea dimidiata*) is a small flycatcher, endemic to Rarotonga in the Cook Islands. In August 1991 the total world population was estimated at 47 individuals, an increase of 14 birds from the previous year. Kakerori live in the forest canopy of small valleys in the steep, mountainous interior.

This study concentrated on the ecology of young birds and factors affecting the breeding success (the number of fledged young produced) of pairs. Young birds remain in the parental territory for up to four months after fledging, where they are commonly found high in the leafy canopy (mean = 25.7m n=36). After parental care has ceased, young birds move to the high, exposed ridges up to 100m from their natal territories (mean = 87m n=14), and remain on average, 2.4m (n=14) from the ground.

Successful Kakerori territories (those that have produced fledged young) have a relatively lowered canopy (10.3m) and few ferns (28.3%), with many juvenile trees (38.3%) and shrubs (33.4%) making up the shrub layer. These juvenile trees may ensure a continued closed canopy. Successful territories also have few, large trees (mean total basal area = 7.39m^2) and a higher level of moss (16.5%) which may encourage larger populations of insects as well as providing possible nest sites for Kakerori. Unsuccessful territories (those that produced no fledged young) have many, immature trees (mean total basal area = 3.21m^2) and little moss (8.1%).

In general, insect numbers varied little between successful and unsuccessful territories, however during February 1991 successful territories had a large percentage of flies (40.4% n=23) compared to unsuccessful (8.3% n=2). During February when adults are feeding newly fledged young, a greater availability of insects may positively affect breeding success.

Poison baits for rats have been laid in the study area since 1988 and the number of fledged young found has increased from one in 1987/1988 to 14 in

1990/1991. The most effective method of conserving the Kakerori may be to continue indefinitely the rat-baiting campaign throughout the study area and neighbouring valleys. This would depend entirely on the availability of funds and committed personnel.

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INTRODUCTION

1.1 GENERAL BACKGROUND

1.1.1 TAXONOMY

Order : Passeriformes
Sub-Order : Oscines
Family : Muscicapidae
Sub-Family : Muscicapinae / Monarchinae
Genus : *Pomarea*
Species : *dimidiata*

The Kakerori (Rarotongan flycatcher) *Pomarea dimidiata* is a small oscine passerine belonging to the old world Flycatchers - known as Muscipinae (Holyoak, 1980; Bryan, 1987; Mitchell, 1987), but more recently referred to as Monarchinae by Campbell & Lack (1985), Perrins & Middleton (1985), Pratt, Bruner & Berrett (1987), and Gill (1990).

Pomarea flycatchers are found on a number of eastern Polynesian islands, particularly those reaching high altitudes (above 400m). In the Red Data Book of endangered birds, King (1981) describes four species and six sub-species belonging to the genus *Pomarea*, however nine of the ten taxa are listed as extinct, endangered, or rare, including *Pomarea dimidiata* - the Kakerori.

The Tahitian Flycatcher (*Pomarea nigra*) is listed as endangered on Tahiti, while the two sub-species of *P. Nigra* have become extinct: *P. nigra tabensis* from the island of Tongatabu in Tonga, has been extinct since 1773, and *P. n. pomarea* became extinct from Maupiti in French Polynesia in 1823 (King, 1981).

A further three sub-species belonging to *Pomarea mendozae* from the Marquesas Islands in the South Pacific, are extinct or endangered. *P.*

mendozae motonensis was common on the island of Mohatani in 1975, but is now extinct. *P. m. nukuhivae* is probably extinct on Nukuhivae, as is *P. m. mira* on Uapou. Of the three remaining taxa, only one - *Pomarea iphis iphis* from the island Uahuka (Marquesas Group) - is still common. *P. i. fluxa* on Eiao (also in the Marquesas Group) has not been recorded since its discovery in 1922. The Large Flycatcher (*P. whitneyi*) is still common on Fatuhiva in the Marquesas which is free of the ship rat (*Rattus rattus*) (King, 1981).

Pomarea dimidiata (Kakerori or Rarotongan Flycatcher) is the only flycatcher present in the Cook Islands, on Rarotonga. Unlike some species of *Pomarea* flycatchers, there are no sub-species of *P. dimidiata* - geographically, the nearest related forms are the sub-species of *P. mendozae* in the Marquesas Islands.

1.1.2 **MORPHOLOGY**

Like most flycatchers, the Kakerori is a small, compact bird with a high crown, short round wings, and a tail slightly longer than its wings. Fine legs and beak are also characteristic of this family (Campbell & Lack, 1985; Pratt, Bruner & Berrett, 1985), and Kakerori have pronounced whiskers surrounding the base of the beak. An adult Kakerori stands approximately 10 cm high and weighs from 20 grams (small female) to 25 grams (large male). Beak length also varies dimorphically - approximately 13mm for females and 14mm for males (Robertson & Hay, 1989). The plumage is of two distinct colours - grey and orange. Gill (1885) believed that the grey and orange birds belonged to different species, while Hartlaub and Finch (1871) identified the grey birds as male and orange birds as females and juveniles. In 1983, David Todd found two grey birds feeding an orange chick, and described distinct colour phases for maturing Kakerori - bright orange young and dull grey adults (D. Todd, pers. comm.). This has been supported by annual studies of colour-banded individuals over a six year period (Robertson & Hay, 1989; G. McCormack, pers. comm.). For a week after hatching, the chicks carry pale grey down

Dr. Rod Hay

Plate 1.1 Young male Kakerori (first year) on *Macropiper*.

Dr. Rod Hay

Plate 1.2 Adult female Kakerori on nest in Mato.

which is replaced by burnt orange beginning with the head. Juvenile males and females are orange with dark grey/brown tips to the primary wing feathers and in the tail. This plumage persists through the first year, and in the second year the bill changes from blue/grey above with a pale yellow lower mandible to entirely blue/grey (D. Todd, pers. comm.).

In the third year adult plumage begins to show and these birds are referred to as 'mixed'. There are more dark grey/brown feathers throughout the orange, especially along the back and wings. Toward the close of the bird's third year, the plumage is almost entirely grey with a few remaining bright orange feathers in the wings and tail.

At four years of age, Kakerori are entirely grey. The abdomen is a pale silver with darker grey upperparts, however this can differ considerably between individuals. The back, wings and tail can range from battleship grey to a soft, pale grey similar to the abdomen.

The changes in plumage colour may be partly sex-related as well as age-related. Robertson & Hay (1989) noted a female banded as a 'mixed' bird in September 1988, still retained some 'mixed' plumage when re-trapped a year later. They suggested that males gain their full adult plumage a few months earlier than females.

1.1.3 GENERAL BIOLOGY

Kakerori live in densely forested areas on the southern side of Rarotonga, which is wetter than the northern side - especially between November and April. Year-round the climate is usually warm and humid, and the area to which the Kakerori are now restricted is somewhat sheltered from the constant trade winds that blow across the island (Leslie, 1980). Although the usual flycatcher diet consists entirely of insects (Campbell, 1974; Campbell & Lack, 1985; Dupont, 1985; Perrins & Middleton, 1985; Pratt, Bruner & Berrett, 1987;

Erard, 1990), Kakerori sometimes take nectar from the large flowers of the endemic Neinei (*Fitchia speciosa)* which are abundant in higher territories during May and June.

They mostly inhabit the sub-canopy of small, steep-sided valleys and remain very active throughout the day. The breeding season is approximately from September to March and Kakerori are capable of raising two clutches in a season. Breeding pairs actively defend a year-round territory up to 100m in diameter and are usually monogamous. Individuals have been known to live as long as 15 years (Robertson & Hay, 1989; McCormack & Kunzle, 1990).

1.1.4 **STATUS**

Past

The Kakerori is found only in the Cook Islands, on Rarotonga, where it may have been present for hundreds of years (J. Hoskings, pers. comm.). No evidence of the Kakerori has been found on any other island in the Cook Islands group. In the 1800's Gill (1885), noted that Kakerori were very common in Rarotonga and inhabited most parts of the island including large areas of taro swamps, where it appears they ate insects associated with the taro crops. Gill (1885) first noted that Kakerori had declined and by the late 1800's were not apparent in lowland areas.

The status of the Kakerori went unrecorded until 1973 when David Holyoak found two birds in the southern Papua Valley, and heard Kakerori calls in the north-eastern Tupapa Valley (D. Holyoak, pers. comm. to G. McCormack). Although the exact area of the observations were not known, Kakerori have not been found since then in either valley (G. McCormack, pers. comm.). Later, Holyoak & Thibault (1984) described three sightings made in 1973 in the Tupapa area. Eight years after that, in 1981, the New Zealand

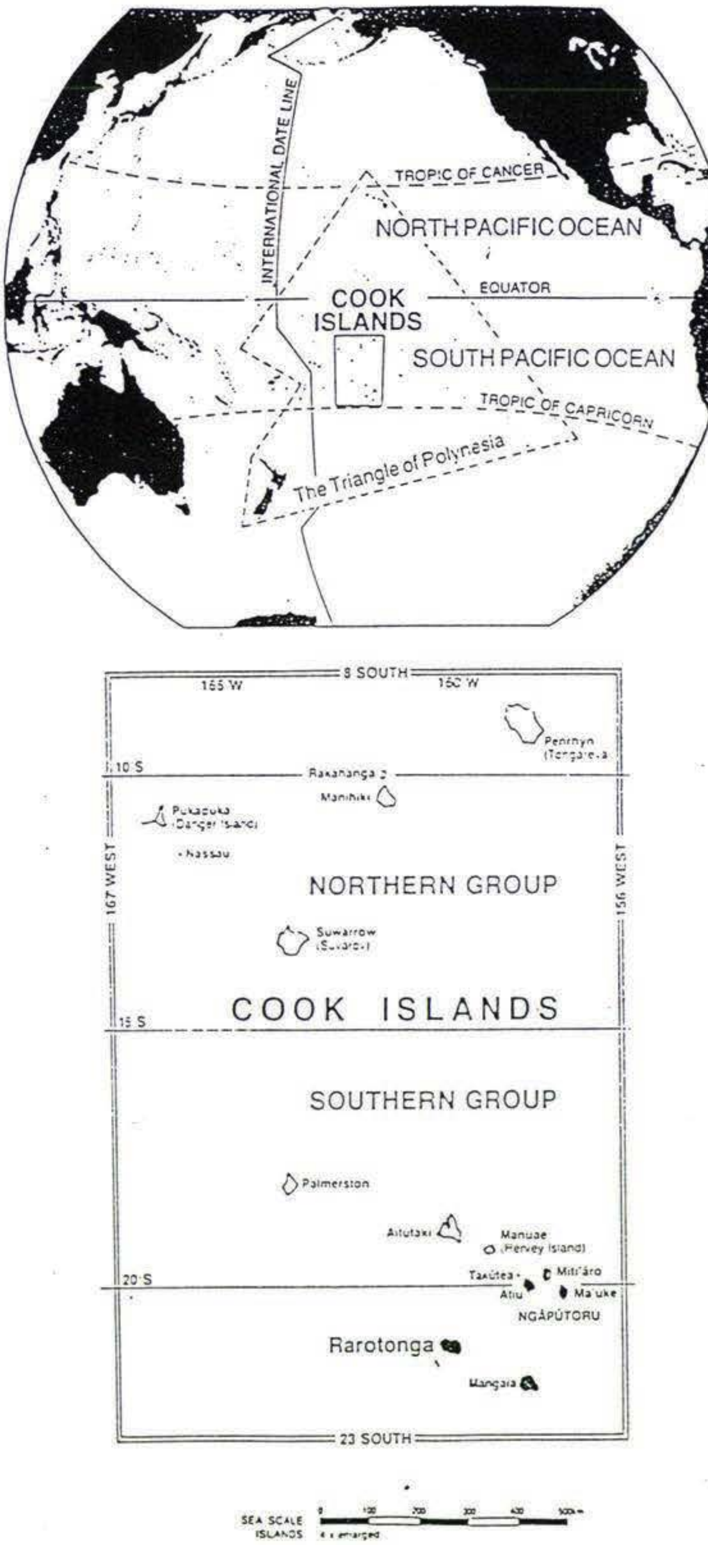

Fig. 1.1 Maps showing the location of the Cook Islands (above) and the position of Rarotonga within the Cooks Group (below). Maps prepared by McCormack & Künzle (1990).

Ornithological Society searched a large area of the island for Kakerori. The search lasted 5-6 weeks but yielded no signs of any birds. Following this extensive effort, there were two sightings of Kakerori in the densely forested Taipara Valley - one in August 1982 by E. Cameron, and another in 1983 by E. Turbott and J. Hosking (Hay & Robertson, 1988).

In December 1983, the first estimate of the Kakerori population was made by David Todd who positively identified 20 Kakerori (and sighted possibly three others) in the upper reaches of three southern catchments. Three orange and six grey birds were recorded in the Totokoitu Valley, four orange birds in the neighbouring Turoa Valley and four grey birds plus one orange individual in the Avana Basin. Todd also located two Kakerori nests, each occupied by a single chick. These nests in the Totokoitu and Turoa Valleys were the first ever recorded (D. Todd, pers. comm.).

In 1984 Rod Hay and Gerald McCormack estimated the Rarotonga population at 24 birds. From these 24 they were able to band eight birds in the Totokoitu Valley (Hay & McCormack, 1984). In 1987, two Cambridge University students found 24 birds - 11 in the Totokoitu Valley and 13 in the Avana Basin (Mitchell, 1987). Since 1984 several visits have been made to valleys near, or similar to, the three populated catchments, including the Papua and Taipara where previous sightings suggested Kakerori may be found. However, no Kakerori have since been found outside of the areas described by Todd in 1983 (G. McCormack, pers. comm.).

Present

At present, the Kakerori is listed as endangered (King, 1981; Johnson & Statterfield, 1990) and a remarkedly small number of birds remain. In August 1991 the total number of Kakerori (including recently fledged young) was 47. Currently, the total known population occupies approximately 2 x 1.5 km of heavily forested land on the southern side of Rarotonga. This $3km^2$ area includes three main catchments - the Totokoitu, the Turoa and the Avana (divided into lower and upper basins).

At the time of this study, approximately 13 Kakerori lived in the Totokoitu Valley, nine in the Turoa Valley, two in the Upper Avana Basin and four in the Lower Avana Basin. In August 1991, five young birds inhabited the ridge between the Totokoitu and Turoa Valleys. The remaining 14 birds (newly fledged young) had no fixed territories and were scattered.

According to Gerald McCormack (pers. comm.), 13 Kakerori specimens are located in museums around the world. In 1869, six specimens - three grey and three orange - were taken by A. Garret for the avifauna collection in the Godeffory Museum in Hamburg and were later described by Harlaub & Finsch (1871). Of these six birds, two are now in the Bremen Museum, Germany. The location of the remaining four is unknown. A pair dated 1850, are kept in the Academy of Natural Sciences in Philadelphia. In 1901 W.E. Gudgeon, the Resident Commissioner, collected a pair of Kakerori for the British Museum (Ogilvie & Grant, 1905). In 1903 three birds were taken by A. Seale for the Bishop Museum in Hawaii where two remain, but the third (a juvenile), was sent to the American Museum of Natural History in New York. Two pairs are also held in the Hamburg Museum, Germany and the Cambridge Museum in England, however it is not known when they were collected, or by whom.

1.2 AIMS

1.2.1 DISPERSAL OF YOUNG

More can be learnt about a crucial point of Kakerori survival by investigating the dispersal and dispersion of newly fledged birds. This includes keeping records of the location of juveniles from when they leave the nest until the following breeding season. From this information the progressive movement of young birds from the parental territory can be followed, and the range of habitats that juvenile birds use during their first year identified.

An estimate of the pairing success of one and two year old birds can also be made, ie: the proportion of juvenile birds that successfully find a territory and/or mate during the following breeding season.

1.2.2 DIURNAL ACTIVITY BUDGET

Very little is known about the daily activities of the Kakerori. An outline of activities of both adults and juveniles will give a clearer indication of their daily requirements and allow comparative analyses to be made. This will help define important variations in requirements for a range of ages.

1.2.3 HABITAT STRUCTURE

By quantifying the components that make up the habitat of each territory, comparisons can be made between the habitat composition in successful (fledged young produced) and unsuccessful territories (no fledged young produced).

Included in this is a break-down of the structure and position of the territory, its vegetation and geographic features. The aim is to pin-point factors causing low breeding success, and achieve a better understanding of the type habitat needed for breeding to be most successful.

1.2.4 INSECT AVAILABILITY

Because food is very important to survival, monitoring the availability of insects in territories will allow a better understanding of the chance for survival of birds in different areas and over different times of the year. This will highlight food as a limiting factor in the Kakerori population.

1.2.5 THE AFFECT OF RAT NUMBERS ON BREEDING SUCCESS

Indices of rat numbers in the study area have been made using the number of rat baits taken from each bait station per week. These records can be used in relation to Kakerori breeding success.

By comparing the nesting success in areas with high rat numbers to those of areas that are low in rats, the level of impact that rats have on breeding Kakerori can be gauged.

Chapter 2

STUDY AREA

2.1 GENERAL AREA

Rarotonga (6724 ha) is one of 15 islands forming the Cook Island Group in the South Pacific. Lying on latitude 21° 21' S and longitude 159° 46' E it is the second southern-most island in the Cooks and is by far the largest, measuring 11.5 km from East to West and 8 km from North to South (Leslie, 1980). The study area comprises approximately 3.5m^2 of steep, forested mountains 1 km inland from the southern side of Rarotonga. It falls within the Takitimu District and incorporates three major catchments - the Totokoitu, Turoa and Avana streams (Fig. 2.1).

Like most of inland Rarotonga, the study area is dissected by many steep slopes that run directly from knife-edge ridges into very narrow valley floors. Although the valleys are forested, the combination of slope, poor soil composition and tropical storms has resulted in erosion with a significant loss of top soil. The soil in the study area is unstable, and being mostly a thin layer of clay on volcanic rock, has a low nutrient value (Leslie, 1980). The recent human history of the Cook Islands is described by D. Scott (1991).

2.2 KAKERORI TERRITORIES

Kakerori are present in at least 10 valleys within the three main catchments. Territories are approximately one hectare in area and often are near or beside other territories and thus have a clumped distribution. Because of the dissected nature of the area, altitudes within a territory may range from 50 to 260 m a.s.l., and the slope of the land is often in excess of 50° from horizontal. Travel between territories for observers is, therefore, much greater than appears on a map.

All the territories incorporate a small, steep-sided, narrow gully, and usually extend up as far as the ridges on either side. Occasionally a territory is situated at the fork of two minor tributaries, and therefore includes a spur.

Plate 2.1 Totokoitu Valley, Rarotonga, showing dissected, forested landform.

Plate 2.2 Ridge dividing the Totokoitu Valley (foreground) from the Upper Avana Basin (background).

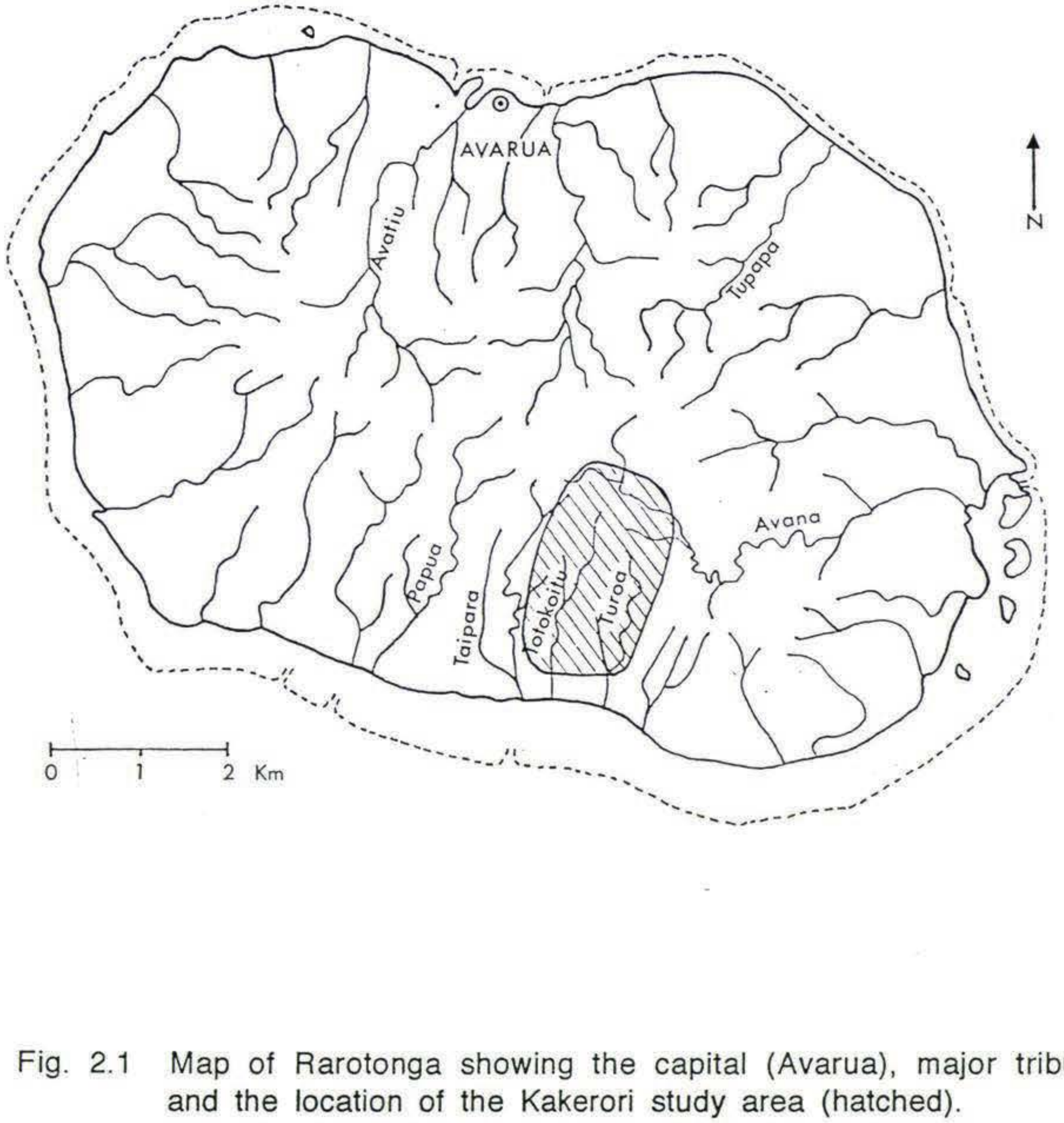

Fig. 2.1 Map of Rarotonga showing the capital (Avarua), major tributaries and the location of the Kakerori study area (hatched).

2.3 VEGETATION

The study area is well forested with a leafy canopy, a noticeable sub-canopy and beneath this, a variable understorey. However, the heights of these components vary with altitude.

The vegetation in valleys with an altitude of up to 400 m a.s.l. is dense and diverse - the canopy height is around 15m with a sub-canopy 5-10m beneath. The forest is dominated by the endemic Mato (*Homalium acuminatum*), a moderately tall (10-15m) tree that is almost entirely responsible for the closed canopy because of profuse foliage and multiple trunks. Scattered among the Mato are several relatively common woody species including *Elaeocarpus tonganus*, an indigenous tree similar in appearance and height to the Mato; *Canthium barbatum*, also indigenous but not a canopy-forming species; and Turina (*Hernandia moerenhoutiana*), a substantial though scattered canopy-forming tree.

Vegetation along streams and narrow valley floors consists commonly of *Hibiscus tiliaceus* and large, scattered Polynesian Chestnut trees (*Inocarpus fagifer*). When mature, Chestnut trees are easily recognisable by their massive size and huge buttress roots. The Hibiscus covers many metres of ground, forming a thick, tangled layer of intertwined branches that is very difficult to penetrate. The origin of this tree is unknown - although some believe it to be indigenous, its main location near formerly cultivated land and along streams may indicate that it was introduced by early Polynesians (Fosberg, 1975; Merlin, 1980).

In most territories, the common King fern (*Angiopteris longifolia*) makes an extensive understorey. These ferns have bases of up to 60cm in diameter and fronds reaching 3m in length. Often the fronds combine to make a false canopy 2-3m from the ground. Beneath the King fern there is usually a profusion of small shrubs and ground covering plants - *Macropiper latifolium*, *Alyxia stellata* and *Ardisia humilis* are notably common. In lowland territories, the introduced Shampoo Ginger (*Zingiber zerumbet*) covers large areas of ground.

Because of the steep slopes and the shallow, unstable soil in areas that exceed an altitude of 400 m a.s.l. the forest is often much reduced. Generally, the canopy is only a few metres high and is sparse and broken. There is little sub-canopy and in places the understorey barely exists and is reduced to scattered King ferns with a few smaller ferns such as *Blechnum orientale* and *Microsorium silvaticum*. Though Mato is still relatively common, near and on the ridges it is mostly replaced by the endemic *Fitchia speciosa*. *Fitchia* grow up to 10m tall but on ridges may be only 2-3m high.

With the exception of a few introduced ground-cover plants and the occasional tree in the lower territories, the vegetation in the study area is in near-original state (Turbott, 1977; Leslie, 1980; Sykes, 1983; Merlin, 1985). The steep slopes and shallow, infertile soil allow little potential for forestry or agriculture, however there is evidence to suggest attempts were made in the lower territories. For instance, a two-strand barbed-wire fence passes through the Totokoitu Valley (particularly the area labelled To3 upr), suggesting cattle may have been run in this area at one time. Throughout the whole interior of the island - including the study area - there are remnants of fire clearances for forestry and crops. These zones are now fern-covered scars scattered over the more accessible hillsides and ridges, consisting mainly of a thick mat of springy *Dicranopteris linearis* (Sykes, 1976; Merlin, 1985).

2.4 WILDLIFE

Although 70% of Rarotonga is uninhabited and largely remains unaltered (Leslie, 1980; Sykes, 1981), there is a surprising lack of wildlife on the island. Rarotonga has a very small land bird fauna comprising five native species - all of which are now restricted to the forested inland - and two introduced species. However, most of these birds are unique, three species - the Cook

Island Fruit Dove (*Ptilinopus rarotongensis*), Rarotongan Starling (*Aplonis inerascens*) and the Kakerori - are endemic to Rarotonga. The Pacific Pigeon (*Ducula pacifica*) and the migratory Long-tailed Cuckoo (*Eudynamis taitensis*) are both indigenous to Rarotonga and are found on other islands in the Cooks also. The Pacific Pigeon is common to Pukapuka, Palmerston, Atiu, Mitiaro and Mauke and also islands in Tahiti, Makata, the Solomon Islands and the Loyalty Islands. The Cuckoo has been recorded on all the islands in the Cooks as well as many other south-eastern Polynesian and Micronesian islands, including New Zealand (Holyoak, 1980).

Although only the Kakerori is listed in the ICPB Red Data Book of Endangered Birds (King, 1981), none of Rarotonga's native land birds appear to be present in large numbers (Turbott, 1977; Holyoak, 1980; Pratt, Bruner & Berrett, 1987). However, all species are found in the Kakerori study area and are often identifiable by their calls rather than by sight.

The Pacific Pigeon is the only large arboreal pigeon in the Cook Islands. It tends to remain in the high reaches of the forest canopy and is often noisy and cumbersome. The Fruit Dove is not commonly seen although its distinctive cooing can be heard up to 500 m a.s.l. A sub-species (*Ptilinopus rarotongensis goodwini*) is found on Atiu and is very similar in appearance to Rarotonga's Fruit Dove (Turbott, 1977; Holyoak, 1980; Pratt, Bruner & Berrett, 1987).

Although the endemic Starling was thought to be "fairly common" in the 1970's (Holyoak, 1980), as with all native land birds on Rarotonga very little is known about its population status, breeding or habitat requirements (Turbott, 1977; Holyoak, 1980; Campbell & Lack, 1985; Perrins & Middleton, 1985).

By comparison, the introduced Common Myna (*Acridotheres tristis*) is abundant in Rarotonga - especially around the populated coastal strand - and is by far the most conspicuous of the land bird species. Mynas are present in the lower reaches of the study area, which in some places are only a few hundred metres from human habitation. The domestic fowl (*Gallus gallus*) is also present in small numbers throughout the study area. Wild populations are present in the mountain areas of many islands in the Cooks (Holyoak, 1980).

The only native land bird which is not entirely restricted to the steep inland areas, is the Long-Tailed Cuckoo. It breeds in New Zealand but migrates to tropical islands in the South Pacific and is commonest on Rarotonga from March to August. It is thought that a few Cuckoos - presumably young birds - remain in Rarotonga instead of returning to New Zealand (Turbott, 1985). These birds are sometimes seen in Kakerori territories from November until January.

With the exception of native skinks and geckos, few other vertebrates are present in the study area. Kiore (*Rattus exulans*) occupy most of the forested areas on Rarotonga and Ship rats (*Rattus rattus*) were numerous in the study area but are now in low numbers because of an efficient poisoning campaign. Feral cats (*Felis catus*) are much less common, and domestic pigs (*Sus scrofa*) occasionally stray into the area from the lowland farms.

2.5 CLIMATE

Geographically, Rarotonga is situated immediately north of the Tropic of Capricorn (23° 27'S lat) and lies within the South-East Trade Wind Belt (Leslie, 1980). It has a tropical climate characterized by high humidity, warm temperatures and wet summers. Figures used throughout this passage have been taken from the records of the Rarotongan Meteorological Office. The figures are averages from data collected from 1930 to 1990, although there are years where entries are missing.

The normal average annual rainfall on Rarotonga is around 2012 mm, and as is the case for most tropical islands, rainfall is markedly higher (939 mm) during the summer months (December to March), than in winter (425 mm) (July to September). Because of the high peaks in the mountainous interior, the northern side of the island is notably dryer, receiving an average of 2048 mm of rain annually compared to southern areas with an annual average of 2728 mm.

The study area lies in the south-east quarter of the island and often receives more than 600 mm of rain per month (this figure is taken from readings at two rain-water gauges in the Totokoitu Valley at elevations of 226 m a.s.l and 102 m a.s.l).

The mean annual temperature in Rarotonga is 24°C, however the temperature within the sheltered inland valleys (up to 400 m a.s.l) is often higher although the temperature varies little throughout the year. The humidity within the study area is usually higher than in more exposed areas because of decreased wind speed, and therefore increased moisture retained in the steep, forested valleys. Inland humidity readings can often exceed 90%, while the average annual humidity for the whole island is only 84% (Leslie, 1980).

Climate observations indicate that levels of moisture, temperature and sunshine (total sunshine averages 2116 hours per annum), are adequate for rapid and sustained plant growth (Leslie, 1980; Sykes, 1981). However, because of the open-ocean location, the island is often hit by tropical storms and cyclones of hurricane intensity and although they generally approach from the north-west, the study area is often affected. Destructive effects are mainly caused by wind and rain and include erosion, flattened vegetation, uprooted trees and minor floods (throughout the lower altitudes).

Chapter 3

DISPERSAL OF FLEDGED YOUNG

3.1 INTRODUCTION

Adult Kakerori are commonly found in sheltered valleys with tall, thick vegetation and spend little time on or near the sparsely vegetated ridges. Young Kakerori remain within their parents' territory only for the first 2-3 months after fledging. In their first year, juveniles stay close to their parents' territories - usually lingering on the periphery (H. Robertson, pers. comm.) which in most cases comprises narrow, exposed ridges. Between breeding seasons (from March to August), juveniles often form small groups of 3-4 individuals (H. Robertson, pers. comm.). Toward the beginning of the breeding season (September) these young birds may drop into the valleys to court and mate. However, some remain on the ridges or travel between valleys, occasionally holding a 'pseudo-territory' alone (H. Robertson, pers. comm.).

Robertson & Hay (1989) noted that shortly after leaving the nest, young birds remained close to the ground. Because the survival rate of adult Kakerori (79%) is much higher than that of juvenile birds (50%) (Robertson & Hay, 1989), conservation of the species would be significantly affected by an improvement in the survival rate of young birds. However, very little is known about the dispersal and dispersion of newly fledged young. The investigation of the dispersal behaviour and spacing of juvenile birds is aimed at better understanding this critical point in Kakerori life history.

3.2 METHODS

Because there are so few birds, the data were collected by following focal individuals for as long as possible. A squeak bottle was often used to attract resident birds, and a tape-recording of Kakerori calls was employed on 12 occasions during the study.

Initially, newly fledged birds were observed with 8 x 30 binoculars within the parents' territories. At this age young birds were usually fed by the adults and could be located by following the movements of the foraging parents. Often the young birds were well concealed high in the leafy canopy, but were visited by the parents every few minutes.

In the absence of parent birds, newly fledged young could sometimes be located by their distinctive calls, however the sounds made by moving foliage, and other birds, often made it very difficult to locate young Kakerori.

Once a bird was pin-pointed, all information was recorded on a hand-held tape-recorder for later transcription. The recorded information included the general location of the bird (including the catchment and valley); the aspect (NESW) and exposure of the position in the valley. Finer details of its location, such as the height of the bird above the ground, and the distance to the nearest viable nest were also noted.

To ensure independence of data, initial observations of individuals only, were used in the following results.

3.3 RESULTS

Fig. 3.1 shows the location of fledged young throughout the study area during the periods January/February, May/June and August 1991. Over the eight months between January and August 1991, the mean distance of young birds from the nearest viable nest increased by a factor of nearly 3.4 (Fig. 3.2). Mean distances (errors in parenthases) were: January/February 25.7m (2.1m), n=36; May/June 52.4m (2.3m), n=15; and August 87.0m (3.2m), n=14.

Fledged young began their independence from the nest high up the canopy, and progressively neared the ground by August (Fig. 3.3). The mean estimated heights (errors in parentheses) of birds above the ground were: January/Feburary 13.5m (1.5m), n=36; May/June 10.6m (1.9m), n=15; and August 7.1m (2.4m), n=15.

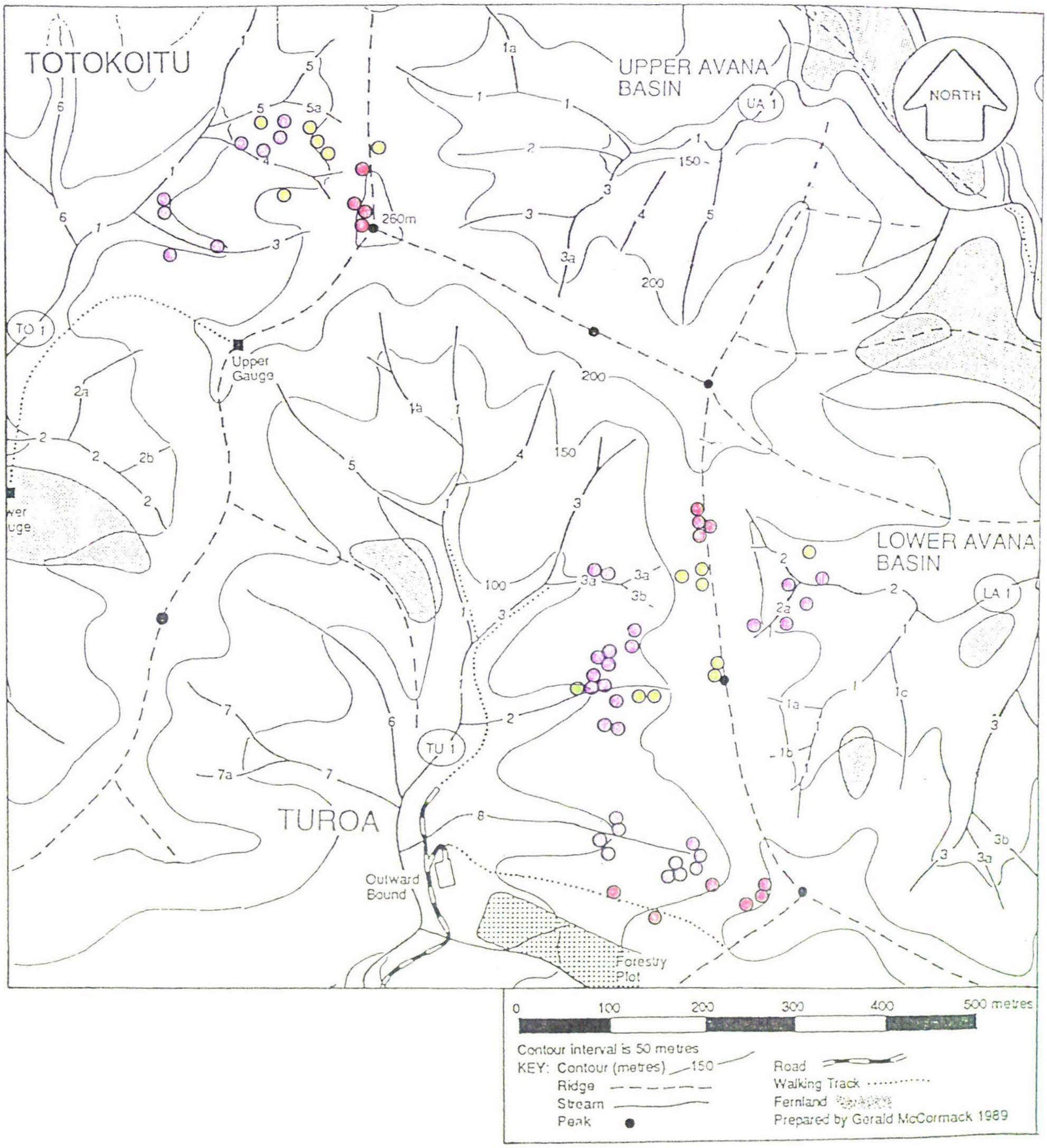

Fig. 3.1 Map of the Kakerori study area showing the distribution of young birds during the periods January/Febuary ○, May/June ○, and August ● 1991.

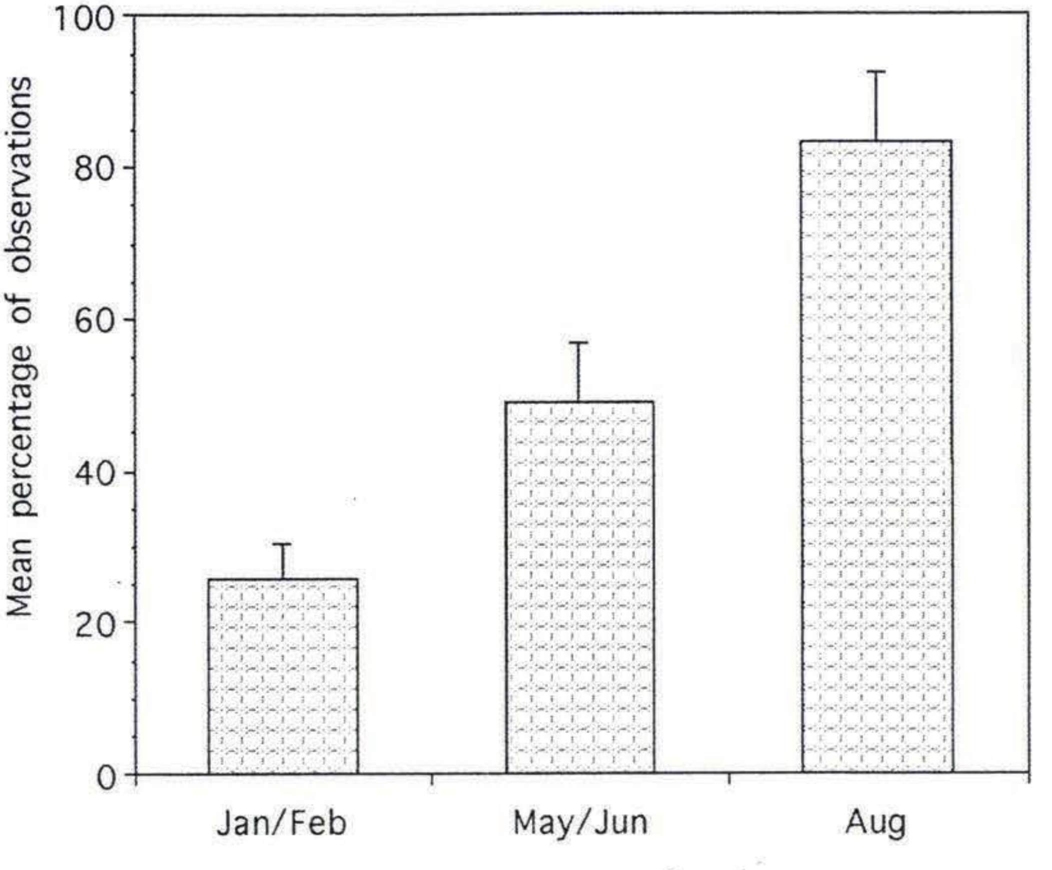

Fig. 3.2 Mean distance of young from the nearest viable nest for the periods January/February, May/June and August 1991. Standard errors and n values are shown.

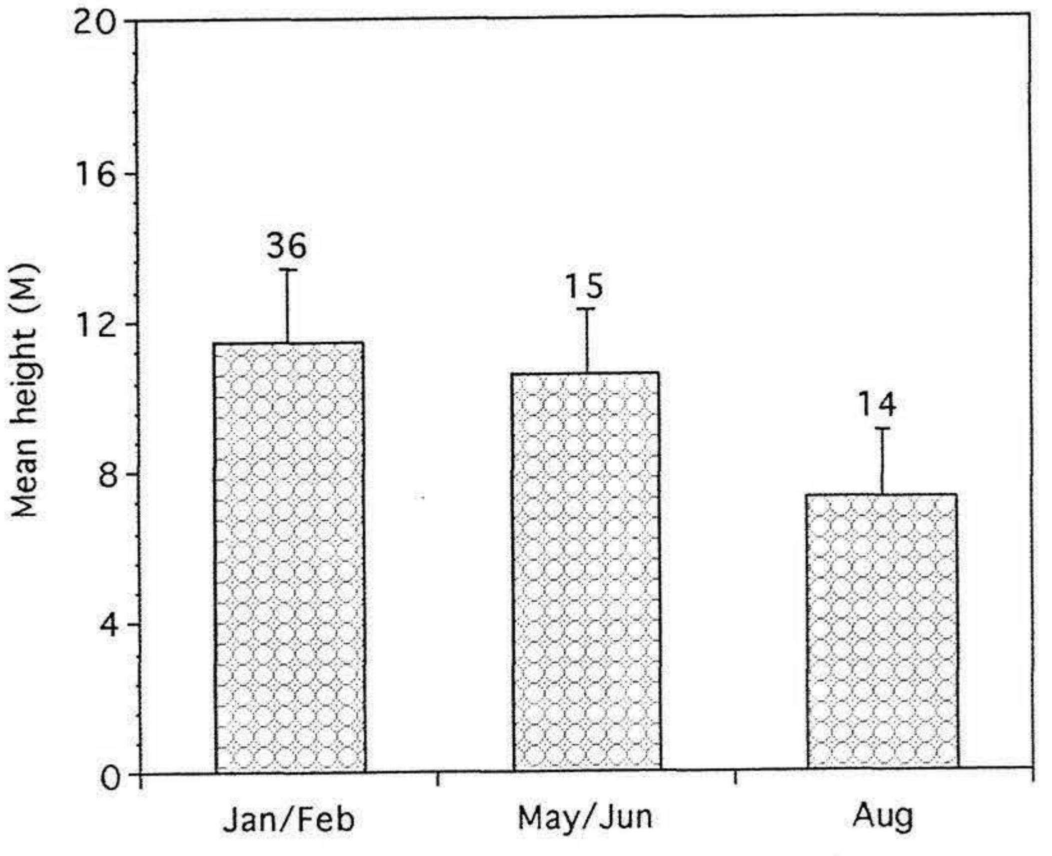

Fig. 3.3 Mean height of young above the ground for the periods January/February, May/June and August 1991. Standard error bars and n values are shown.

3.4 DISCUSSION

Immediately after fledging in January and February, young birds remain near the nest which is usually in the lower reaches of a valley. Seven months later however, they are concentrated along the major ridges dissecting the study area. Robertson & Hay (1989) noted that newly fledged young remained near the ground, however the data presented here shows that during the first 4-6 weeks after fledging, the young are fed by their parents and take positions near the top of the canopy where they are motionless for long periods.

Within four months of the young fledging, parental care was no longer observed, and the young birds fended for themselves. They took up positions near parental territories on neighbouring spurs and surrounding small ridges. During this time, the young birds spent less time in the upper canopy, and by August were most often seen less than 10m above the ground. This is almost entirely due to their occupation of high, windswept ridges which support forest with a relatively low canopy. However, even in areas where the canopy was high, young birds were found mostly low down in the trees. Possibly insects are more available in the sub-canopy foliage that is more protected from the wind.

Although Kakerori are inquisitive and sometimes approach an observer closely, the number of observations is small. The total population of birds in August 1991 was 47, with 14 known first-year birds. Accordingly, sightings of these were always unpredictable and very brief.

A major handicap to the field work was the lack of identifying bands on the juveniles. First-year birds were not colour-banded until the end of August 1991, and therefore it was impossible to identify individuals, or to follow the dispersal of young from any one area. An important gap in understanding the dispersal of fledged young concerns whether patterns of dispersal are peculiar to particular valleys, and if so, whether these patterns are relted to the resourses in the natal valley.

Chapter 4

DIURNAL ACTIVITY BUDGET

4.1 INTRODUCTION

Kakerori are active, agile birds, spending much of the day moving and feeding within the forest canopy (Mitchell, 1987; McCormack & Kunzle, 1990). Since the 're-discovery' of the Kakerori in 1983, there have been several short-term studies of behaviour and breeding, however, very little is known about the birds' daily routine. Mitchell (1987) stated that Kakerori spent a lot of time standing and looking about (38%) and feeding activities were also common (32%). Other activities, such as preening, flying and resting were less common. Although flycatchers are reputed to be acrobatic flyers (Campbell, 1974; Campbell & Lack, 1985; Dupont, 1985; Perrins & Middleton, 1985; Pratt, Bruner & Berrett, 1987; Erard, 1990), Mitchell (1987) concluded that Kakerori spent a comparatively small proportion of time catching insects on the wing (hawking), while taking insects from twigs and leaves (gleaning) and inverted or briefly hovering (hang-gleaning), were more common.

Mitchell's (1987) observations did not include newly fledged young, and no discrimination was made between juvenile and adult behaviour. There has been no break-down of the birds' activities during the day or in different seasons. Previous studies (Mitchell, 1987; Hay & Robertson, 1988; Robertson & Hay, 1989) have concentrated on adult behavior during the breeding season (August-December), and have not dealt with the behavioural development of young Kakerori throughout their first year. Here, the daily activities of newly fledged young are considered, and the behaviour of young and adult birds during the year is compared.

4.2 METHODS

The activities of young and adult Kakerori were observed in January/February, May/June and August, 1991. These periods allowed observation of young Kakerori aged 0-2 months, 4-6 months and 8-10 months respectively. When a bird was located the first activity observed was recorded, and observations repeated at five minute intervals. Information recorded from each observation included behaviour, species of tree used and the position of the bird in the tree (trunks and large branches, small branches and twigs, leaves and flowers). Behaviour was categorized into: Feeding (including hawking, gleaning, hang-gleaning and adult birds feeding chicks); Non-feeding (including flying, standing still/looking, hopping and preening).

Foraging manoevers are those described in detail by Recher *et al* (1985) and Recher (1989).

4.3 RESULTS

Table 1 refers to the number of observations of daily activities for young and adult birds in the morning and afternoon. It shows the number of observations for activities within the Moving and Feeding categories.

In all three periods, adults and young engaged most often in non-feeding activities and adults fed comparatively less than young birds (Table 1), however, the differences were not found significant (Chi-square 2x2 contingency test, n.s.).

Adults call significantly more than young in the afternoon (71% and 55% respectively) (X^2 = 38.5 $p<0.05$)(Figure 2) and within the feeding category, 85% of all gleaning was in the afternoon. However adults flew less (6%) in the afternoon which is consistent with the low level of hawking (6%), whereas young birds showed a low percentage of hawking (9%) but had a higher percent of flying (14%).

Within the moving category, resting has the largest percent for adult and young (60% and 51% respectively) however, young birds flew more and hopped less than adults (young: flying 35%, hopping 15% ; adult: flying 17%, hopping 28%), however there was no significant difference. Although, there

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Plate 4.1 Young bird flying in *Hibiscus* (Turoa Valley).

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Plate 4.2 Young bird looking while perched on *Macropiper* (Totokoitu Valley).

Activity		Young AM	Young PM	Adult AM	Adult PM	Total
Moving	-flying	6	13	3	1	23
	-hopping	3	5	2	6	16
	-resting/looking	8	20	6	11	45
Calling		14	17	7	25	63
Preening		2	6	1	3	12
Feeding	-hawking	6	7	5	1	19
	-gleaning	3	11	0	14	28
	-hang-glean	2	10	1	5	18
	-feeding chick or being fed by adult	2	5	2	5	14
	Total	46	94	27	71	238

Table 4.1 Number of observations for daily activities of adult and young Kakerori.

Species	Tr./LBr.	SBr./Tw.	Le./Fl.	Tr./LBr.	SBr./Tw.	Le./Fl.
Hom. acu.	20	29	9	9	21	15
Her. moe.	1	6	2		4	1
Ang. lon.	1	2		4	19	5
Psi. cat.	2	4		1	10	3
Ale. mol.	2	5			6	2
Ela. ton.		4	1		7	3
Fit. spe.	1	1		2	5	2
Hib. til.	1	4		2	3	
Bis. jav.	1	1		2	2	
Wei. sam.					6	1
Mus. tro.						2
Total (n)	29	57	12	26	82	32

Table 4.2. The total observations (n) of adult and young Kakerori showing the use of, and position in different tree species.

Tr./LBr. = Trunks and large branches
SBr./Tw. = Small branches and twigs
Le./Fl. = Leaves and flowers.

Hom. acu. *Homalium acuminatum*
Her. moe. *Hernandia moerenhoutiana*
Ang. lon. *Angiopteris longifolium*
Psi. cat. *Psidium cattleianum*
Ale. mol. *Aleurites moluccana*
Ela. ton. *Elaeocarpus tonganus*
Fit. spe. *Fitchia speciosa*
Hib. til. *Hibiscus tiliaceus*
Bis. jav. *Bischofia javanica*
Wei. sam. *Weinmannia samoensis*
Mus. tro. *Musa troglodytarum*

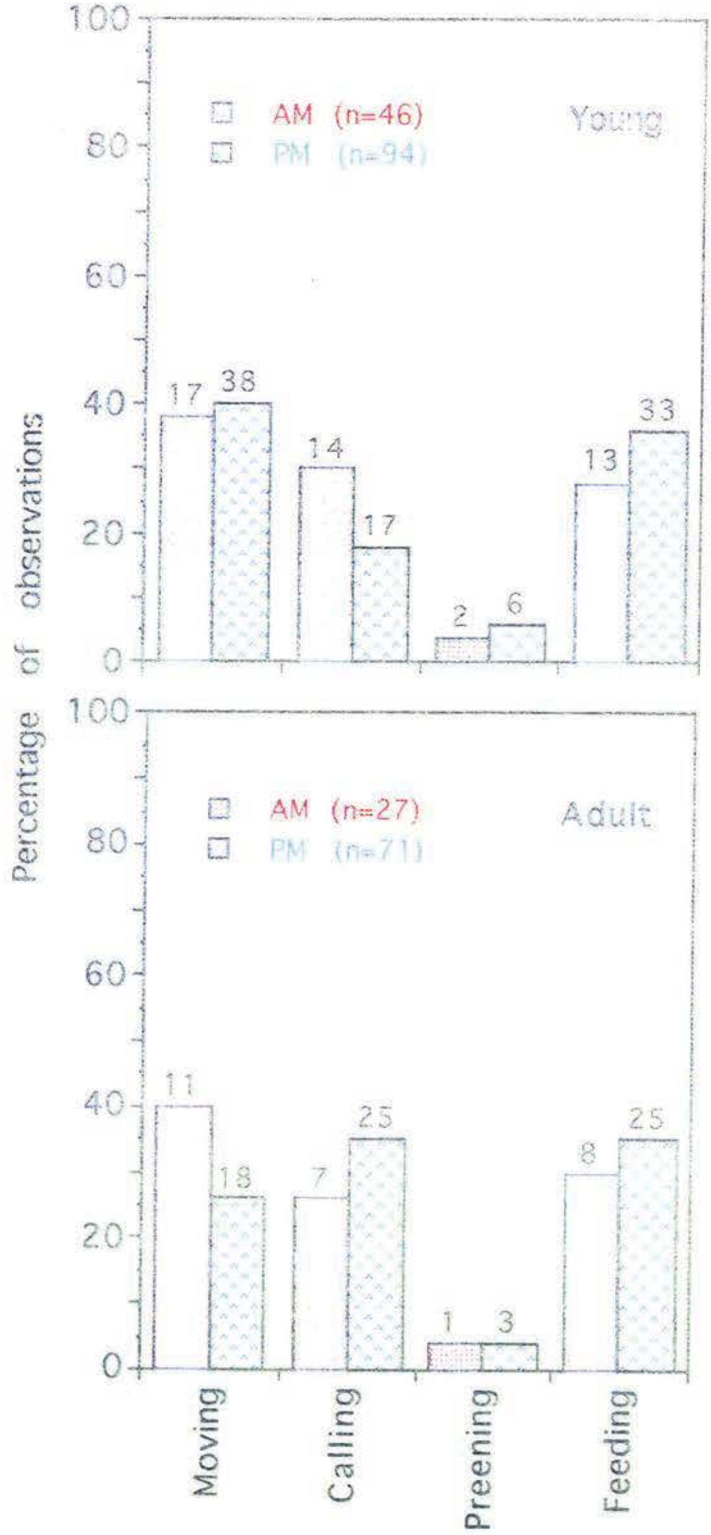

Fig. 4.1 Percentage of activity observations for adult and young Kakerori during morning (AM) and afternoon (PM).

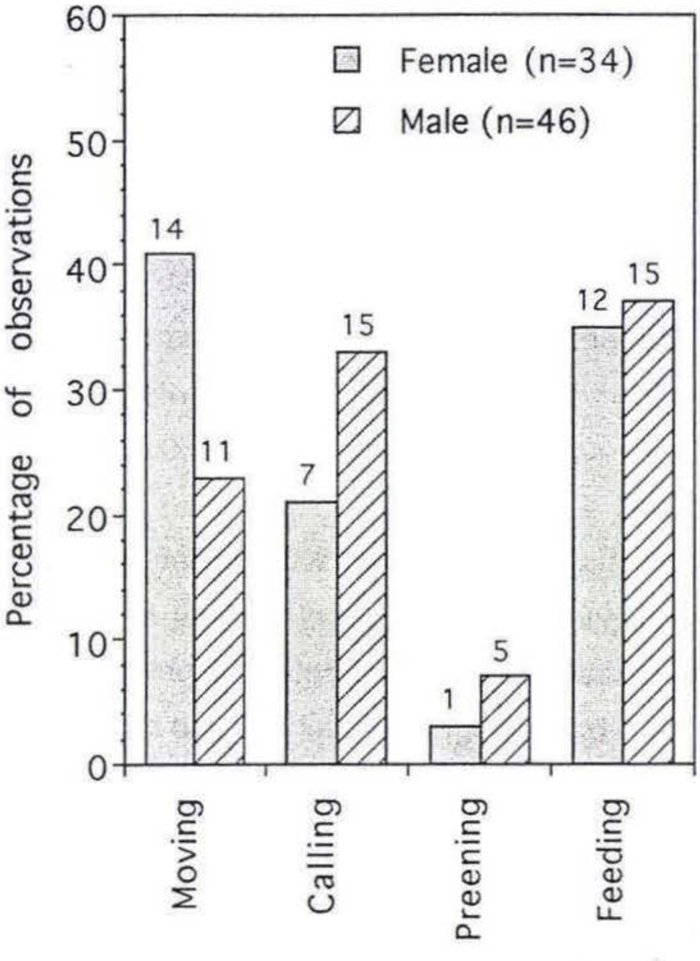

Fig. 4.2 Percentage of activity observations for female and male Kakerori.

was much less calling by young birds throughout the day (young: 22% adults: 33%) it was not significantly different (X^2 2x2 contingency test, n.s.). From all the observations of calling made by young birds, they tended to call more in the morning (30%) as opposed to the afternoon (18%) and adults called less in the morning (26%) than in the afternoon (31%).

There was a significant difference in the amount of time spent calling and moving by females and males. Females move more than males (41% n=14 and 23% n=11 respectively) but called less (21% n=7 and 33% n=15 respectively) (X^2=3.83 $p<0.05$).

In the January/Febuary period, 90% (n=40) of observations were of young birds in the company of adults. In January the young birds were fed by parents approximately every 20 seconds. By Febuary adults fed young about half as frequently, but the data are few. During May and June, the amount of time young spent with adults, decreased to approximately 20% (n=9). Young birds spent a varying amount of time in the presence of adults throughout August, however, no adults were observed feeding young during this period.

Adults and young were found most often on Mato (*Homalium acumatum)* (59%, n=58 and 32%, n=45 respectively) (Fig. 4.3). King fern (*Angiopteris longifolium*) was commonly used by young (20%, n=28) but less by adults (3.1%, n=3). Adults and young were observed most often on small branches and twigs (58%, n=57 and 57%, n=80). Leaves and flowers are used less often by adults (12%, n=12) than by young (23%, n=32), whereas adults use large branches and trunks more often than young (30%, n=29 and 20%, n=26).

4.4 DISCUSSION

The results resemble those of Mitchell (1987) in that the birds spend little time flying, and a lot of time resting or looking. Gleaning is the most common method of feeding (birds gleaned up to 60% of all their food in the afternoon), however Mitchell's data were not independent and similarities between data sets may be coincidence.

It is unclear why feeding activities take up a much smaller percentage of time than non-feeding activities. Considering that flycatchers are small, energetic birds (Campbell & Lack, 1985; Dupont, 1985; Pratt, Bruner & Berrett, 1987; Erard, 1990) it might be expected that feeding would take up a large percentage of available time. The relatively low level of feeding recorded may be partly influenced by the observer distracting the birds. This would also account for the high frequency of resting and looking by the birds.

Because the forest canopy and much of the sub-canopy is formed almost entirely by Mato (Sykes, 1981; McCormack & Kunzle, 1990), it is not unusual that Kakerori are most often found on this species. The common use of small branches and twigs could be for easy access to insects in the foliage, while remaining on a secure perch.

During January and February, fledged young are attended by parents and spend a high percentage of their time with adults. By May and June the young birds have moved from their parental territories, and spend only a small amount of time in the company of adults. However, because the young birds were not colour-banded, it is unknown whether adults seen with young birds were their parents. During August some of the first year individuals begin to court older birds (Mitchell, 1987), and this may explain the great variation between individuals in the range of time spent with adults between individuals.

Chapter 5

HABITAT STRUCTURE

5.1 INTRODUCTION

Although there have been studies on the vegetation of inland Rarotonga (Fosberg, 1975; Merlin, 1988; Sykes, 1983), these reports are brief and do not focus on the habitat of Rarotonga's avifauna. The vegetative composition of the Kakerori breeding area, has only been briefly documented (Mitchell, 1987; Hay & Robertson, 1988; Robertson & Hay, 1989; McCormack & Kunzle, 1990), however, it has been noted that much of the forested inland is in near-original state (Sykes 1976, 1983; Turbott, 1977; Leslie, 1980).

Kakerori territories are typically found in small valleys surrounding the head waters of streams, and generally have a uniform structure with the nest situated at the base of a small, steep-sided valley. Outwardly, the vegetation within the territories varies little. Mato (*Homalium acuminatum*) dominates the forest and scattered *Canthium barbatum* and Turina (*Hernandia moerenhoutiana*) are common. King fern (*Angiopteris longifolia*) creates a dense understorey in most territories, and ground cover often includes shampoo ginger (*Zingiber zerumbet*), *Blechnum orientale* and *Macropiper latifolium*.

Habitat plays a key role in the survival of a species, and although Kakerori territories may initially appear to be constructed on similar foundations, a detailed dissection of the habitat of each breeding pair may pin-point some variations between successful and unsuccessful nesting areas.

5.2 METHODS

Throughout each breeding territory a 60m transect was run. The transect ran perpendicular to the direction of the water course in that territory, with the mid-point (ie; the 30m mark) being at the nest tree. Transect points were every 5m with the nest tree located at the central point (number 7). The length of the transects were floristically representative of the approximate size of the territories.

The following vegetation measurements and environmental factors were collected at each point.

1. **Altitude** (M.A.S.L.)
2. **Canopy height** (M)

   Canopy state (categorized into Open, Broken or Intact receiving a value of 2, 1 or 0 respectively)
3. **Percentage of shrubs present** (defined as standing approximately 1m tall).

   A list of the species found in a 2.5m radius.
4. **Number of coconuts and coconut palms** in a 2.5m radius (listed as Broken, Rooted, Sprouted, or Palm).
5. **Percentage of ground cover** (separated into Bare ground, Vegetation, Leaf-litter, Moss, Dead wood and Other; totalling 100% for each point).
6. **Slope of the ground** (Degrees), elevation above the ground, measured by an Abney level.
7. **Details of nearest tree in each of four quadrants** measured from each transect point (distance from point - less than 2.5m, and diameter greater than $5cm^2$).

For each breeding pair, only the first nesting attempt was used for the following analysis.

5.3 RESULTS

Table 5.1 shows the mean values for all the vegetation characteristics and environmental aspects measured throughout each territory.

Because of the small number of 1990/1991 territories (successful n=9 & unsuccessful n=5), statistical analyses of these data are severely constrained. Accordingly, some apparent differences could not be subjected to rigorous statistical tests.

Mean canopy heights for each territory (Fig. 5.1) suggest that the canopy in successful territories (mean = 10.21m) is lower than that in unsuccessful territories (mean = 13.66m). Densities of the six most common tree species found within each territory are shown in Table 5.2. King fern (*Angiopteris longifolium*) is found in the highest densities in successful (mean = 2491.0 trees/ha) and unsuccessful territories (mean = 2779.7 trees/ha) with Mato (*Homalium acuminatum*) also common (mean = 766.4 and 745.4 trees/ha respectively). *Bischofia javanica* has a density of 313.2 trees/ha in successful territories and 233.1 trees/ha in unsuccessful territories. The "Other" category includes strawberry guava (*Psidium cattleianum)* and Pu'pua (*Fagraea berteriana*) in unsuccessful territories plus candle nut (*Aleurites moluccana*) and *Fitchia speciosa* in successful territories.

Of the three main types of vegetation found in the shrub layer (Fig. 5.2), ferns make up a relatively large percentage (50.6%) in unsuccessful territories, with shrub and young tree species being less common (26.4% and 23.0% respectively). In successful territories, there is no clear difference in the occurence of trees, ferns and shrubs. However, young trees were most common (38.3%) and shrubs and ferns less so (33.4% and 28.3% respectively).

Figs. 5.3, 5.4, and 5.5 show the six most common species in each of the three main vegetative types in the shrub layer. Throughout the successful territories, *Elaeocarpus tonganus* and the endemic *Fitchia speciosa* were the most common juvenile tree species, occuring in 30 of the 117 transect points (25.6%) (Fig. 5.3). In unsuccessful territories, these species were much less common (*E. tonganus* 3.1% and *F. speciosa* 9.2%). Indigenous mato seedlings (*Homalium acuminatum*) were found in 20 of the 65 transect points throughout the unsuccessful territories (30.8%) and are a major contributor to the shrub layer in these territories. *H. acuminatum* is less common in successful territories (19.7%), while the introduced strawberry guava (*Psidium cattleianum*) is found more often in these areas than in unsuccessful territories (23.9% and 15.4% respectively). Young beach hibiscus (*Hibiscus tiliaceus*) and the indigenous lantern tree (*Hernandia moerenhoutiana*) contributed little to the shrub layer in both successful (6.8% and 12.0% respectively) and unsuccessful territories (7.7% and 3.1% respectively). Many of the species grouped in the category labelled "Other" in Fig. 5.3 are present in both successful and unsuccessful territories, however endemic *Meryta paucifora* was found 7 times (6.0%) and *Glochidion ramaflorum* found 4 times (3.4%) throughout the successful transects, and not found in the shrub layer of any unsuccessful territories. Throughout these territories, the recently introduced java plum (*Syzygium cumunii*) was found twice (3.1%) and african tulip (*Spathodia companulata)* once (1.6%). The remaining species were found in both successful and unsuccessful territories: *Aleurites moluccana* (n=2 and n=1 respectively), the polynesian chestnut (*Inocarpus fagifer*) (n=2 and n=1 respectively) and the endemic *Weinmannia samoensis* (n=2).

Among the ferns unsuccessful territories have a large percentage of the indigenous king fern (*Angiopteris longifolium*) compared to successful territories (72.3% and 41.9% respectively) (Fig. 5.4). *Blechnum orientale* also contributes greatly to the shrub layer in unsuccessful territories (38.5%) but is poorly represented in successful territories (4.3%). There is a notable difference in the percentage of *Pneumatopteris glandulifera* found in successful (10.3%) and unsuccessful territories (0%). There are few species included in the "Other" category. *Sphaerostephanous subpectinata* was found in both types of territories (n=1) as was *Pteris comans* (successful n=1 and unsuccessful n=2). *Diplasium harpeodes* was found once in the shrub layer of successful territories but not in unsuccessful territories.

The shrub species making up the shrub layer (Fig. 5.5), included a large contribution of the indigenous *Macropiper latifolium* in all Kakerori territories (successful 54.7% ; unsuccessful 32.8%). Endemic kie kie (*Freycinetia wilderi*) is also common in both successful (22.2%) and unsuccessful territories (23.1%). The recently introduced *Ardisia humilis* is a notably common species in successful territories (17.9%) but not in unsuccessful territories (1.5%), whereas the introduced shampoo ginger (*Zingiber zerumbet*) was more common in unsuccessful areas (13.9%) than successful (6.0%). In the "Other" category for Fig. 5.5 an indigenous ground orchid (*Phaius tancarvilliae*) was found in both types of territory (n=2) as was the endemic *Xylosma sauveolens* (successful n=1 and unsuccessful n=2). The introduced red passionfruit (*Passiflora rubra*) completed the shrub species found in the unsuccessful transects. The remaining shrub species found in the successful transects are the indigenous *Melastoma denticulatum* (n=1) and the bulbil yam (*Dioscoria bulbifera*) (n=2).

There were few major differences between successful and unsuccessful territories in ground cover (Fig. 5.6), the greatest variation showing in the amount of moss with successful territories having more (16.5%) than unsuccessful (8.1%). In both types of territory, leaf-litter was the major component in the ground cover (successful 27.3% ; unsuccessful 32.2%). Bare ground (successful 26.5% and unsuccessful 29.4%) and vegetation (successful 26.5% and unsuccessful 25.8%) also contributed largely to the ground cover. Dead matter was uncommon in all territories (successful 1.8% and unsuccessful 4.0%). The "Other" category comprised water and large areas of surface roots (successful 1.0% and unsuccessful 0.3%).
Fig. 5.7 shows the mean basal area for each territory in the 1990/1991 breeding season. From this it appears that successful territories have a few, large trees (mean area = 7.39m^2) whereas unsuccessful territories have many small trees (mean = 3.21m^2). In successful territories mean total basal areas vary, ranging from 13.99m^2 (To4 upr) to 2.22m^2 (To 2). Basal areas in unsuccessful territories appear more uniform, ranging from 5.91m^2 in Al 3 to 2.00m^2 in Tu8 lwr.

The mean slope in successful territories (26.9° to 39.6°) ranged more widely

Plate 5.1 Turoa territory (Tu3) showing typical Mato canopy and King fern understorey.

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Plate 5.2 'Track' through Totokoitu territory (To5 lwr) showing King fern.

Territory	Altitude (M A.S.L.)	Canopy Height (M)	Canopy State	Shrubs (%)	Ground Cover (%)	Bare Ground (%)	Slope (Deg.)	Basal Area (M^2)
To5 lwr	176.8 (2.0)	8.3 (1.0)	1.0	16.2 (2.0)	61.2 (4.2)	38.8 (2.8)	32.1 (2.2)	6.8 (0.3)
To5 upr	212.8 (2.3)	7.2 (1.1)	0.8	10.1 (1.9)	59.7 (4.4)	40.3 (2.9)	38.7 (2.9)	10.7 (1.0)
To4 upr	203.9 (1.6)	7.1 (1.2)	0.9	8.9 (1.0)	57.7 (3.8)	32.3 (2.3)	31.3 (2.3)	14.0 (0.7)
To3 lwr	146.0 (1.4)	11.1 (0.8)	1.2	13.1 (1.5)	81.1 (3.6)	18.9 (2.5)	29.1 (2.3)	8.5 (0.9)
To2	148.4 (1.6)	12.5 (0.5)	1.5	15.0 (1.5)	66.9 (4.0)	33.1 (2.8)	26.9 (2.6)	2.2 (0.1)
Tu3	100.3 (2.1)	10.5 (0.9)	1.2	24.6 (1.8)	76.1 (4.2)	23.9 (2.8)	39.6 (1.7)	7.4 (0.4)
Tu8 upr	109.7 (2.2)	15.1 (1.3)	1.1	18.8 (1.6)	68.3 (3.4)	31.7 (2.0)	31.8 (1.7)	3.2 (0.1)
Al2	161.2 (2.0)	10.4 (1.8)	1.1	7.1 (1.1)	60.4 (3.2)	39.6 (1.8)	29.2 (2.1)	9.9 (0.4)
Tu2	129.5 (1.5)	9.7 (1.5)	1.1	23.7 (1.4)	77.9 (2.9)	22.1 (1.7)	28.1 (2.5)	3.7 (1.2)
Means	154.3	10.2	1.1	15.3	67.7	31.2	31.9	7.4
To4 lwr	158.8 (1.9)	11.6 (1.8)	1.6	14.0 (1.2)	72.1 (3.0)	27.9 (1.8)	29.0 (1.6)	3.7 (0.1)
To3 upr	165.2 (2.1)	13.4 (1.1)	1.3	15.6 (1.0)	69.3 (3.9)	30.7 (2.9)	34.2 (2.3)	2.4 (0.1)
Tu8 lwr	99.7 (1.7)	14.0 (1.2)	1.2	17.7 (2.1)	73.2 (4.2)	26.8 (2.0)	28.3 (2.3)	2.0 (0.3)
Au5	177.4 (1.7)	13.2 (1.4)	1.2	12.5 (1.8)	63.9 (5.0)	30.1 (3.6)	33.0 (2.0)	2.9 (0.6)
Al3	183.5 (1.6)	16.1 (1.3)	1.5	26.5 (1.7)	71.1 (4.6)	28.9 (2.0)	35.7 (2.2)	5.9 (0.4)
Means	156.9	13.7	1.4	17.3	69.9	28.9	32.0	3.4

Table 5.1 Mean values for the shown habitat components for successful (above) and unsuccessful (below) Kakerori territories in the 1990/1991 breeding season. Standard errors are shown in parentheses.

Territory	Tree species						
	A	B	C	D	E	F	G
To5 lwr	810.1	3567.2					
To5 upr	847.7	2563.5	184.9				1111.1
To4 upr	681.8	2160.5	302.9				
To3 lwr	1388.9	2084.5	71.4			1334.9	
To2	461.9	1758.2	1130.2	150.2	574.9		224.8
Tu3	986.7	1311.6	114.6	423.3			597.2
Tu8 upr	1036.2	3427.0	277.4				1544.2
Al2	390.6	3754.7	244.9	367.6			390.1
Tu2	293.8	1791.8	492.1	900.3			261.9
Means	766.4	2491.0	313.2	204.6	63.9	148.3	458.8
To4 lwr	1032.2	3166.9	555.6		796.8		
To3 upr	285.8	3711.8	56.0				99.6
Tu8 lwr	607.9	998.7	251.9	52.5		617.3	729.6
Au5	906.6	3362.8	241.9	189.1	52.1		
Al3	894.4	2658.4	59.9		957.9		331.5
Means	745.4	2779.7	233.1	48.3	361.4	123.5	232.1

Table 5.2 Densities (no. trees/ha) of the six most common tree species for successful (above) and unsuccessful territories (below) in the 1990/1991 breeding season.

A *Homalium acuminatum*
B *Angiopteris longifolium*
C *Bischofia javanica*
D *Elaeocarpus tonganus*
E *Hernandia moerenhoutiana*
F *Hibiscus tiliaceus*
G Other

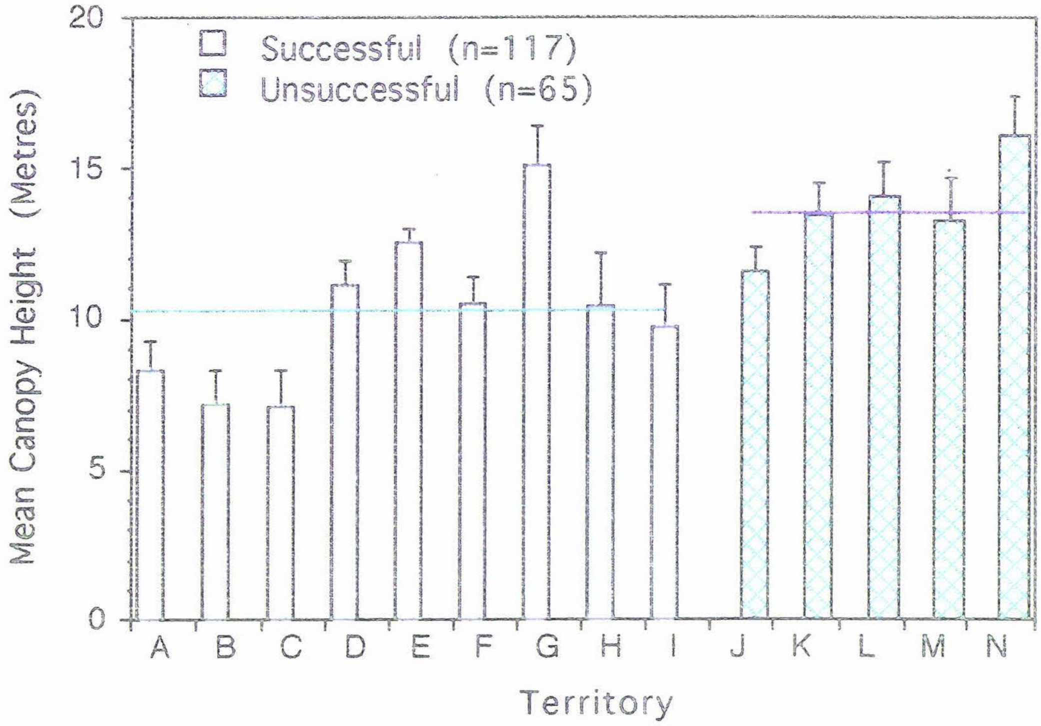

Fig. 5.1 Mean canopy height (m) for Kakerori territories in the 1990/1991 breeding season.

—— Mean (successful) = 10.21

—— Mean (unsuccessful) = 13.66

A	To5 lwr	H	Al2
B	To5 upr	I	Tu 2
C	To4 upr	J	To4 lwr
D	To3 lwr	K	To3 upr
E	To2	L	Tu8 lwr
F	Tu3	M	Au5
G	Tu8 upr	N	Al3

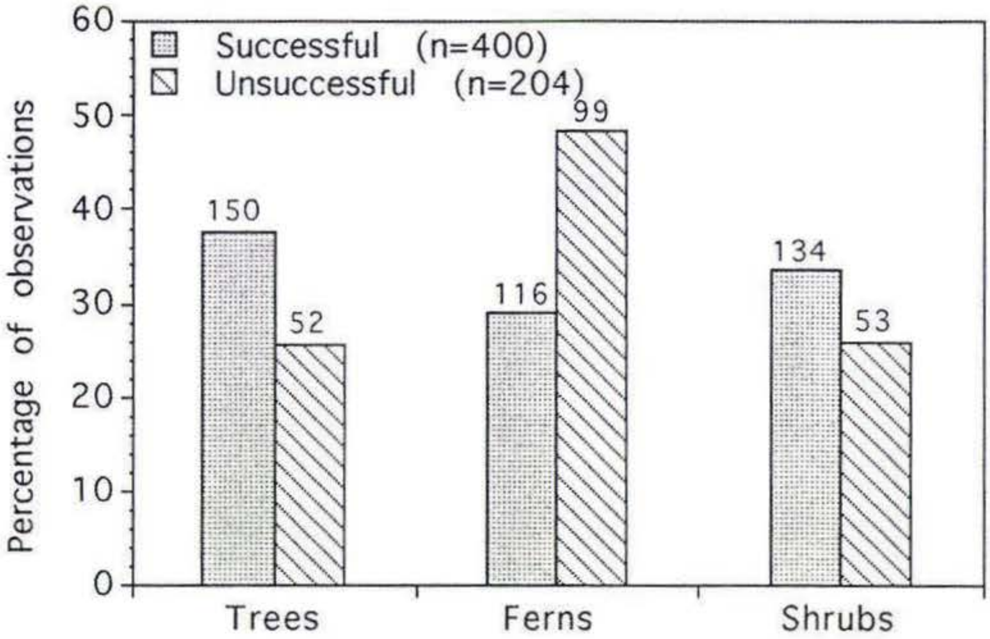

Fig. 5.2 Percentage of juvenile tree, fern and shrub species making up the shrub layer in Kakerori territories.

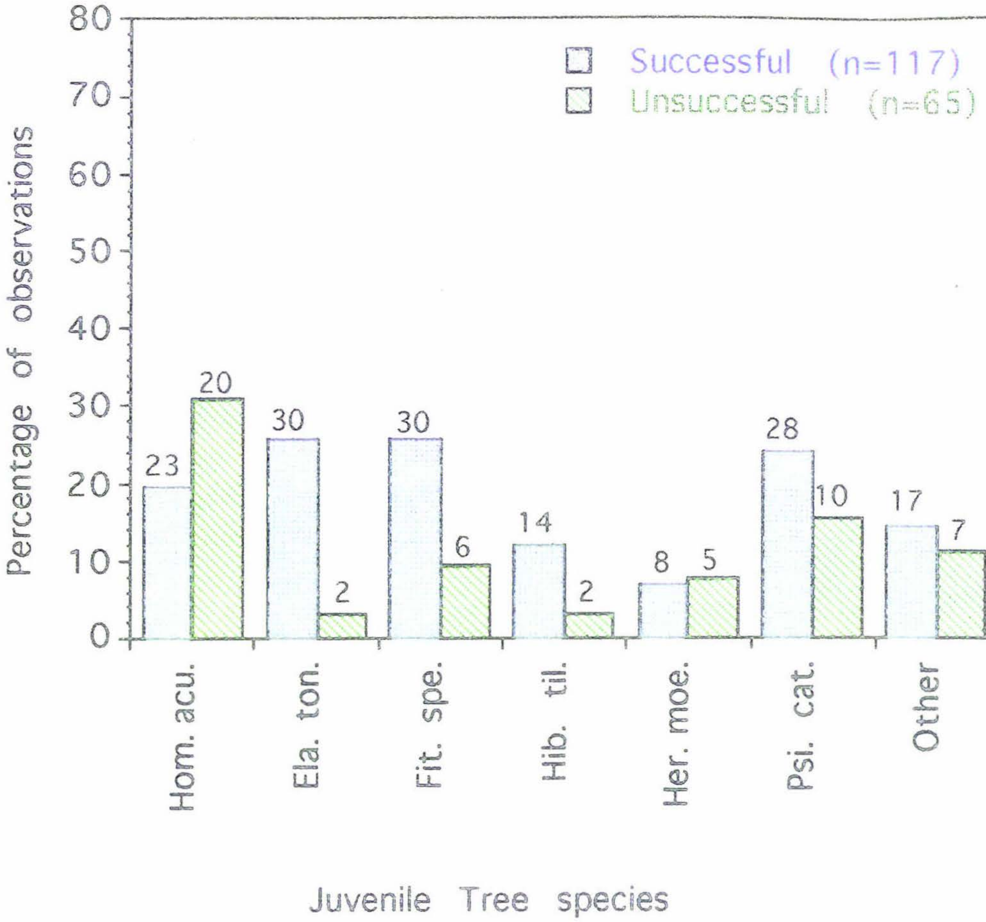

Fig. 5.3 Percentage of juvenile tree species found in the shrub layer of successful and unsuccessful Kakerori territories.

Hom. acu.	*Homalium acuminatum*
Ela. ton.	*Elaeocarpus tonganus*
Fit. spe.	*Fitchia speciosa*
Hib. til.	*Hibiscus tiliaceus*
Her. moe.	*Hernandia moerenhoutiana*
Psi. cat.	*Psidium cattleianum*

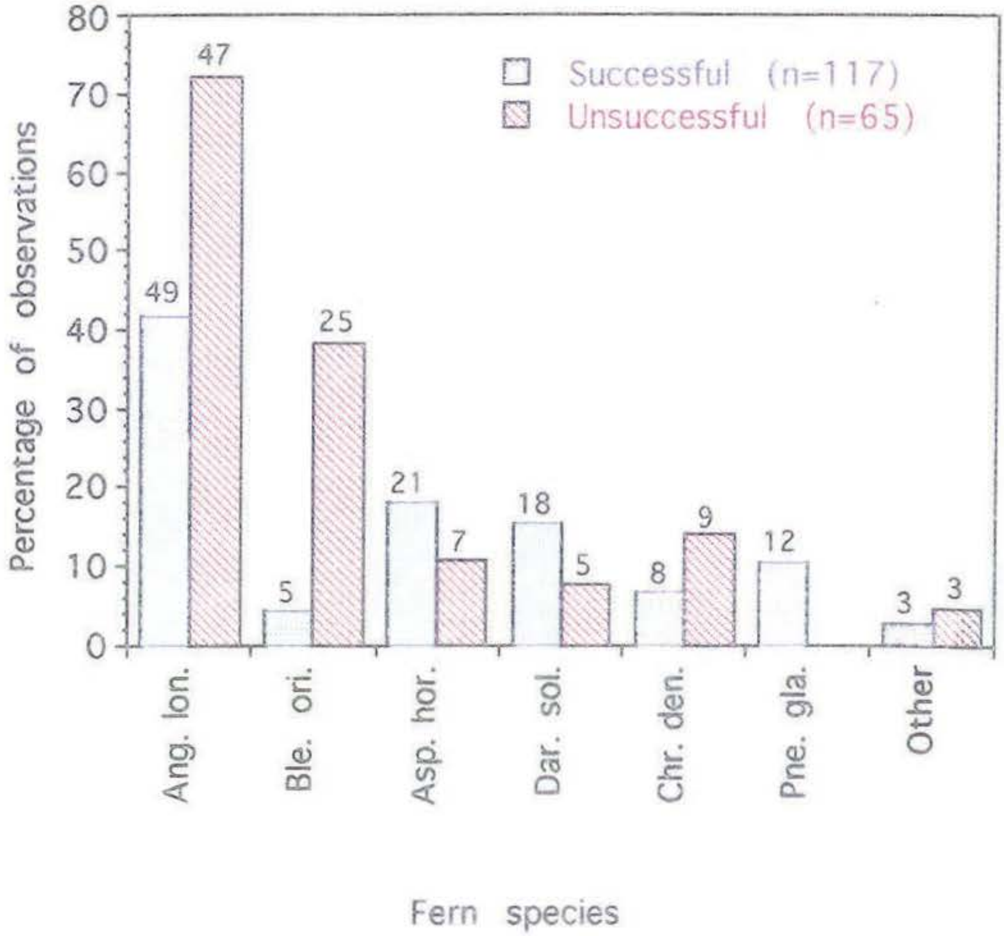

Fig. 5.4 Percentage of fern species found in the shrub layer of successful and unsuccessful Kakerori territories.

Ang. lon.	*Angiopteris longifolium*
Ble. ori.	*Blechnum orientale*
Asp. hor.	*Asplenium horridum*
Dar. sol.	*Darallia solida*
Chr. den.	*Christella dentata*
Pne. gla.	*Pneumatotpteris glandulifera*

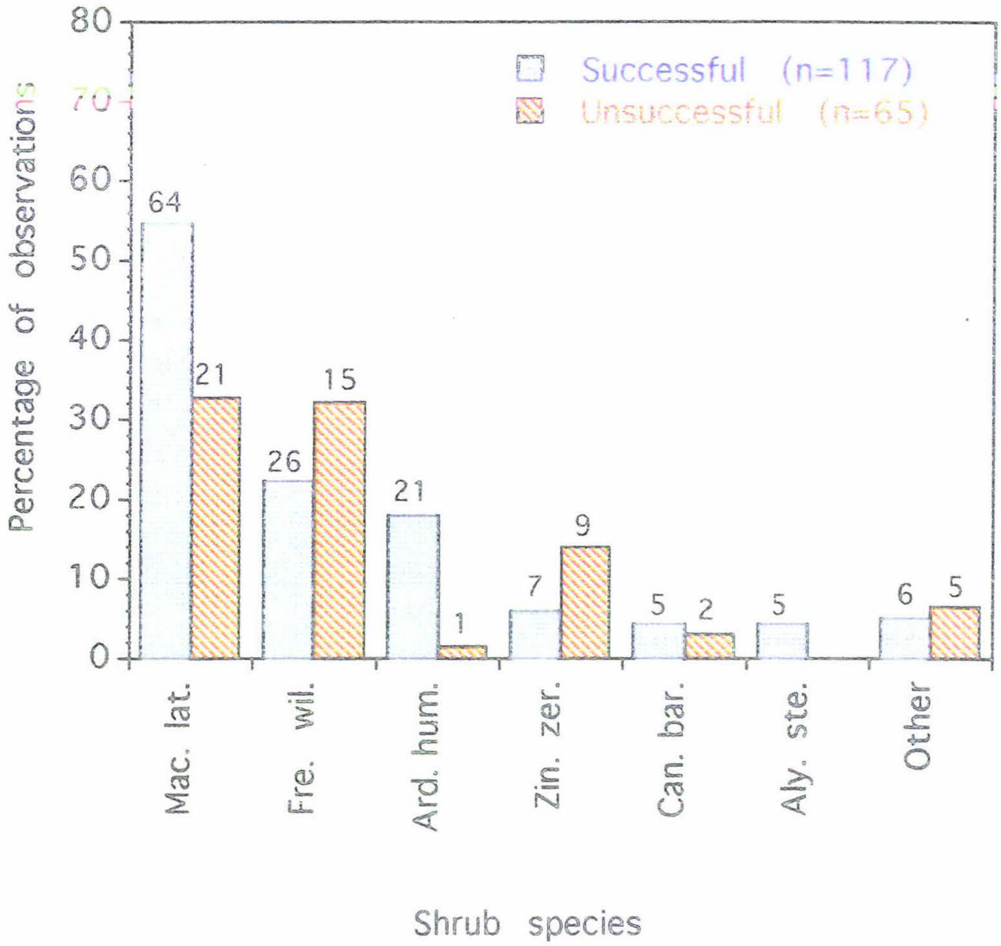

Fig. 5.5 Percentage of shrub species found in the shrub layer of successful and unsuccessful Kakerori territories.

Mac. lat.	*Macropiper latifolium*
Fre. wil.	*Freycinetia wilderi*
Ard. hum.	*Ardisia humilis*
Zin. zer.	*Zingiber zerumbet*
Can. bar.	*Canthium barbatum*
Aly. ste.	*Alyxia stellata*

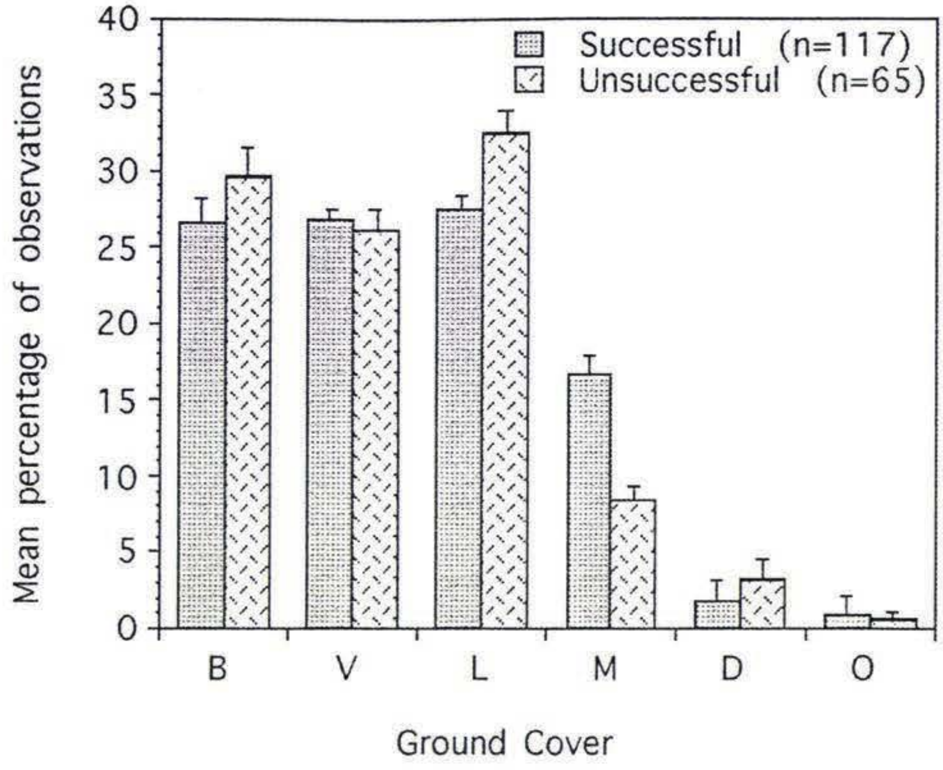

Fig. 5.6 Mean percentage of ground cover for successful and unsuccessful Kakerori territories.
B = bare; V = vegetation; L = leaf-litter;
M = moss; D = dead wood; O = other.
Standard error bars are shown.

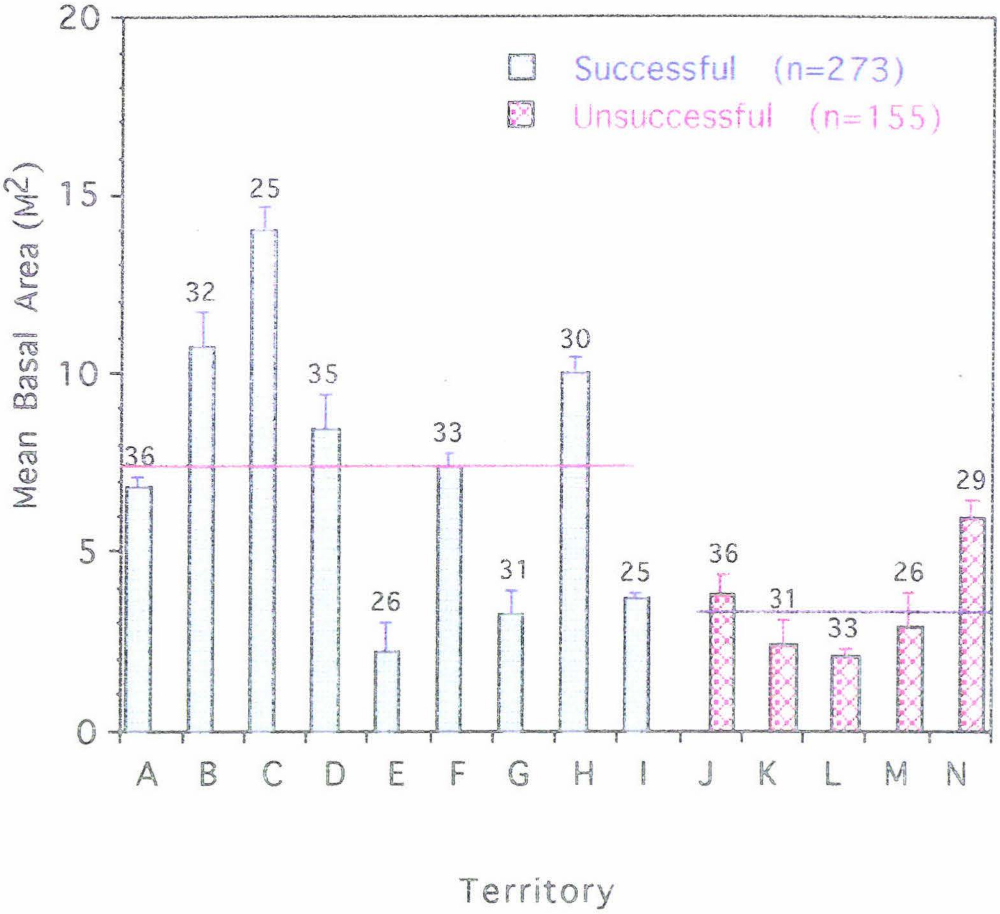

Fig. 5.7 Mean total basal areas of trees in successful and unsuccessful Kakerori territories. Standard error bars and n values are shown.

Mean (successful) = 7.39
Mean (unsuccessful) = 3.21

A	To5 lwr	H	Al2
B	To5 upr	I	Tu2
C	To4 upr	J	To4 lwr
D	To3 lwr	K	To3 upr
E	To2	L	Tu8 lwr
F	Tu3	M	Au5
G	Tu8 upr	N	Al3

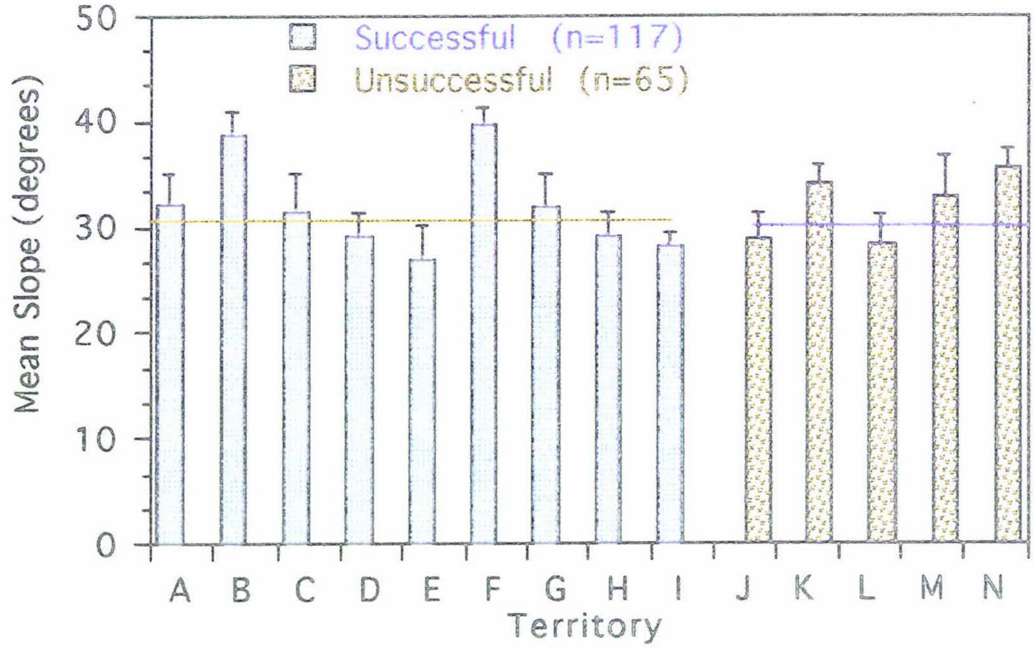

Fig. 5.8 Mean slope of ground in Kakerori territories for the 1990/1991 breeding season.

—— Mean (successful) = 31.9

—— Mean (unsuccessful) = 32.0

A	To5 lwr	H	Al2
B	To5 upr	I	Tu2
C	To4 upr	J	To4 lwr
D	To3 lwr	K	To3 upr
E	To2	L	Tu8 lwr
F	Tu3	M	Au5
G	Tu8 upr	N	Al3

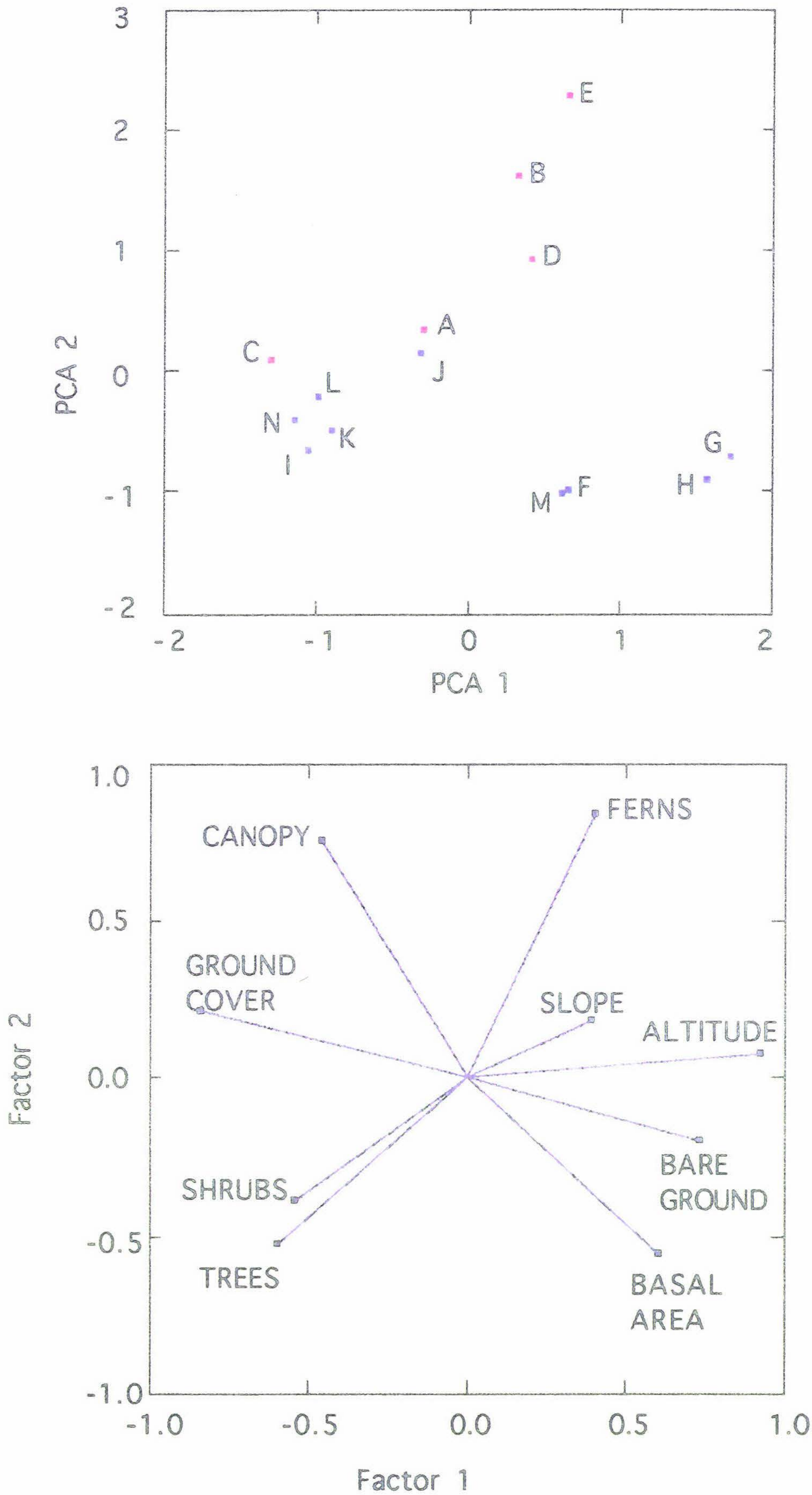

Fig. 5.9 Principal component analyses for successful (F-N) and unsuccessful (A-E) territories.

than those in unsuccessful territories (28.3° to 35.7°) (Fig. 5.8). However, overall the mean slopes of successful and unsuccessful territories were very similar (31.9° and 32.9° respectively).

Table 5.3 shows the number of coconuts palms and coconuts found within territories. Of the transects with nests built in the first breeding attempt, only one had coconuts present - 'Tu8 lwr' had one palm and 79 coconuts throughout the transect. This territory's second nesting attempt (Tu8 lwr b), had one palm and 84 coconuts throughout the transect. Because of the location of these nests (and therefore the position of the transects) within the territory, these results are independent. The only other transect to have coconuts present, was the second nesting attempt in the territory To3 upr. This transect had two palms and 88 coconuts. In all three transects, broken coconuts were notably more common than either rooted or sprouted and palms were rare.

A Principal Component Analysis (Fig. 5.9) using the means of the habitat characteristics from Table 1, and the mean percentage of shrub, fern and juvenile tree species present in the shrub layer of each territory, showed no obvious correlation between habitat and breeding success ie: the successful and unsuccessful territories did not separate clearly into two discrete clumps. However, for the habitat characteristics shown in Fig. 5.9, 40.5% of the total variance is explained by the first principal component (PCA 1) and 24.0% is explained by the second principal component (PCA 2). The best predictors for successful territories appears to be basal area which gives a strong postive correlation, with canopy height showing an expected negative correlation. For unsuccessful territories, the fern component of the shrub layer is the best predictor.

5.4 DISCUSSION

Because of the few data, it is difficult to apply statistical tests to these results. Possibly there are no major differences in overall habitat composition between successful and unsuccessful territories, and the few differences that are evident may not be obvious indicators of breeding success. However, insect availability and protection from the weather may be contributing factors.

The few large trees that make up the lowered canopy (Figs 5.7 & 5.1) in successful territories, may contribute to a more diverse and/or substantial insect fauna in those areas. Larger (and therefore older?) trees often carry many species of epiphytes and moss which can retain moisture and are commonly utilised as breeding grounds for insects (Norris, 1991; Kukalova-Peck, 1991). A low canopy may provide better protection from the weather (especially wind and rain). Insect availability may also be dependent on the plant species present in the shrub layer and ground cover (Figs 5.3, 5.4, 5.5 and 5.6). Although moss does not appear to be an important factor in breeding success, it does indicate that moisure is present. Possibly mossy (and therefore moist) territories may have a more abundant insect fauna bacause many insects require atmospheric moisture or free water.

All territories have high densities of Mato and king fern (Table 5.2), however, in cases where density values determined by distances taken from the point centred quater method have been compared with the actual values, they have been shown to be too high (Mark & Esler, 1990).

Although the mean slope for successful and unsuccessful territories are very similar (31.9° and 32.9° respectively), this does not reflect the great range of slope values found throughout the territories. Slopes often ranged from approximately 0° on the valley floor to above 50°.

The number of coconuts found in each territory gives a general estimate of the gross available food source for rats. However, coconuts appear to be uncommon throughout the higher altitude territories and it is unlikely that coconuts are the staple diet of rats in these areas (G. McCormack, pers. comm.).

Although no strong correlation between habitat composition and breeding success can be found, with respect to the survival of the Kakerori these results are optimistic. Should the results have shown that the Kakerori breeding success was largely dependent upon specific components of the habitat, conserving the species would be made more difficult - for example translocation and captive breeding would no longer be conservation options.

Chapter 6

INSECT AVAILABILITY

6.1 INTRODUCTION

The availability of food is an important factor in the survival of any species. The Kakerori is almost entirely insectivorous, feeding mostly on small flying insects and caterpillars (Mitchell, 1987; Hay & Robertson, 1988; Robertson & Hay, 1989; McCormack & Kunzle, 1990). Taking arachnids, and nectar from the endemic seasonal *Fitchia speciosa* flowers found in the higher territories, are the only exceptions observed in this study.

The insect fauna in Rarotonga is poorly documented. Descriptions are mostly limited to unpublished reports of lowland insects (P. Maddison & G. McCormack, pers. comm.), and there is no published information on the diversity and populations of insects in mountainous inland regions.

With so few references and keys available, it is difficult to study insect diversity in the Kakerori study area, however, food availability is an important factor which may influence the breeding success of adults or affect the survival rate of young. A general overview of insect availability may identify gross variations in insect numbers throughout the year.

6.2 METHODS

Insect sampling began in all territories in February 1991 and was repeated in May/June, and August of the same year.

Samples taken with a fine sweep net (c. 0.4m in diameter) fixed to a 1.5m handle, comprised 5 minutes of active sweep-netting from ground level to the upward extent of the handle, brushing all vegetation and open air. The observer moved freely about the territory, at approximately the same location in each of the three sampling periods.

The identification and classification of the insects was done by Peter

Maddison, John Dugdale (Lepidoptera) and Grace Hall (Arachnids) from Land Care Research NZ Ltd (Auckland).

6.3 **RESULTS**

Table 6.1 shows the representatives of each taxa as far as very limited classification key allows (P. Maddison, pers. comm.). The insect fauna has been grouped into the following Orders: Diptera, Lepidoptera 'a' (juvenile), Lepidoptera 'b' (adult), Orthoptera, Hemiptera, Phasmatodea, Coleoptera and Arachnida; and the families Culicidae, Formicidae and Fulgoroidea. Territories were grouped into successful and unsuccessful. The number of territories n(T) in which individuals were found gives an indication of distribution.

Within Diptera, four Genera were identified - a Muscid fly (*Dichaetomyia sp.*) appearing most often (successful n=13 and unsuccessful n=4), and a Neriid fly (*Mimegralla sp.*) having never previously been reported in the Cook Islands (P. Maddison, pers. comm.). Lepidoptera larvae were separated into five taxa, with specimens from the Family Geometridae-Sterrhinae accounting for 25% of all caterpillars caught (J. Dugdale, pers. comm.). Although Hemiptera appear in large numbers in successful territories (n=15), all the individuals in this Order were caught in one territory, whereas the five taxa of Fulgoroidea (n=10) were well distributed throughout seven territories.

Fig. 6.1 shows the percentage of insects caught during the three periods. Because of low sample sizes, insects in the Orders Coleoptera, Phasmatodea and Fulgoroidea are grouped under "Other". Over the three periods, Arachnids appear to be most common (n=125) with Formicidae, Diptera and Culicidae being well represented (n=108, 69 and 67 respectively). Most taxa appeared least often in February, with larger numbers caught in August, eg: Formicidae, n=15 in February and n=60 in August.

Successful territories showed a very high percentage of Diptera in February

TAXA		Successful		Unsuccessful		Total
		n	n (T)	n	n (T)	
CULICIDAE (Mosquitoes)	Culicidae indet.	43	9	24	4	67
DIPTERA (Flies)	Diptera indet.	32	9	9	5	41
	Dichaetomyia sp.	13	7	4	5	17
	Ornidia obesa	2	2	0	0	2
	Schölastes sp.	4	1	0	0	4
*	*Mimegralla sp.*	1	1	1	1	2
FORMICIDAE (Ants)	Formicidae indet	73	9	35	5	108
LEPIDOPTERA 'a' (Caterpillars)	Noctuidae indet.	4	2	3	1	7
	Pterophoridae indet.	1	1	0	0	1
	G-Sterrhinae indet.	2	1	3	1	5
	G-Geometrinae indet.	1	1	2	1	3
	G-Larentiinae indet.	2	2	2	1	4
LEPIDOPTERA 'b' (Moths)	Yponomeutidae indet.	1	1	0	0	1
	Piletocera signiferalis	3	2	1	1	4
	Labdia sp.	5	3	2	1	7
ORTHOPTERA (Crickets)	Gryllidae indet.	20	8	8	4	28
HEMIPTERA (Bugs)	Lygaeidae indet.	3	1	0	0	3
	Heteroptera indet.	15	1	3	1	18
FULGOROIDEA (Plant hoppers)	Derbidae indet.	1	1	0	0	1
	Delphacidae	1	0	1	0	2
	Colgar peracuta	1	1	1	1	2
	Cicadellidae indet.	1	1	1	1	2
	Swezeyia sp.	2	1	1	1	3
PHASMATODEA (Stick insects)	Phasmida indet.	4	2	2	1	6
COLEOPTERA (Beetles)	Scolytinae indet.	1	1	1	1	2
	Cerampycidae indet.	1	1	1	1	2
ARACHNIDA (Spiders)	Aranae indet.	81	8	39	5	120
	Salticidae indet.	5	1	0	0	5

* New to the Cook Islands list (P, Maddison, pers. comm.).

Table 6.1 Insect and Arachnid fauna found in successful and unsuccessful Kakerori territories during the periods February, May/June, and August 1991.

n = Number of insects/Arachnids

n(T) = Number of territories each taxa were found.

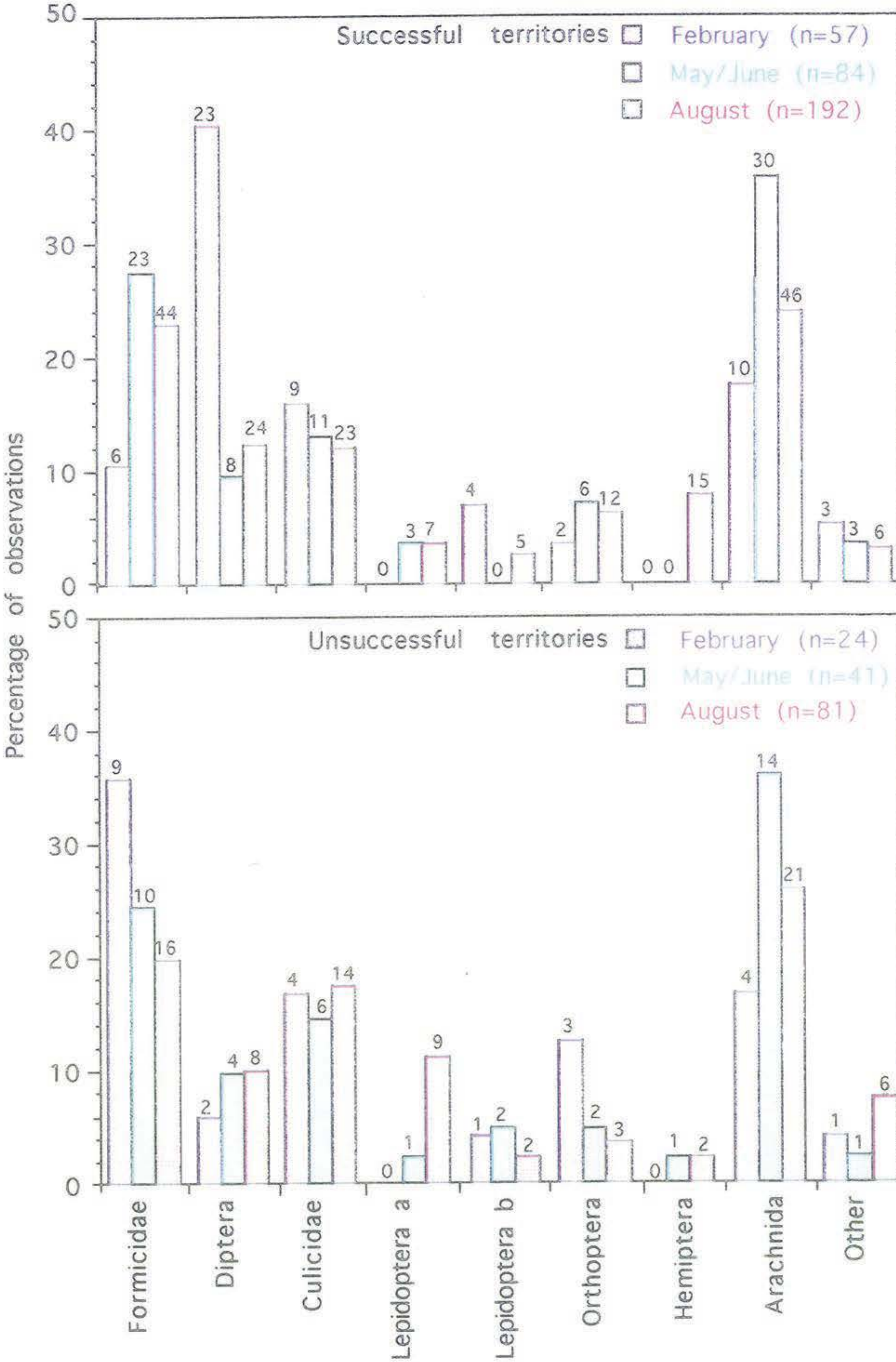

Fig. 6.1 Percentage of insects and Arachnids found in successful and unsuccessful Kakerori territories during 1991.

(40.4%) compared to unsuccessful territories (5.9%), whereas Formicidae specimens were more common in unsuccessful territories during this period (unsuccessful=37.5% and successful=10.5%). During May/June, insect numbers rose with Arachnids being noticeably common in all territories (successful=35.7% and unsuccessful=34.1%). Although insect numbers for most taxa were greater in August, the percentage of observations for each group were similar.

6.4 DISCUSSION

Although it is interesting to note the changes in abundance of taxa throughout the year, the small sample sizes of territories (successful n=9 and unsuccessful n=5) and the capture methods used, limit the conclusions that can be made.

With limited time, equipment, funding, man-power and in very difficult terrain, sweep-netting was the best available capture method. However, it sampled only an approximate 3m belt above the ground. Therefore the diversity of insects caught may have been lessened, by missing easily-disturbed, fast-flying insects higher in the canopy. As a result of the primitive capture methods employed, few conclusions can be made about how insect availability limits the success of Kakerori breeding. However, a general overview of the types of insects available and their distribution throughout the study area is possible.

In general, insect numbers increased from February through to August. This appears unusual, because food is required more during the breeding season which begins in October, and throughout January and February when adults are feeding young. In August, the young birds have fledged and left the parental territories, and no longer require food from within these areas.

To date, no studies have been done on the availability of insects or their relationship to breeding success and juvenile survival. As food is one of the main limiting factors in the survival of a species, this is a topic that needs further study. A greater understanding of the diet of the Kakerori and its changing needs through the seasons, and the needs of growing young, would help conservation decisions in the future.

Chapter 7

BREEDING SUCCESS

7.1 INTRODUCTION

Kakerori are small, fast-moving flycatchers. They tend toward monogamy, actively defending distinct territories year-round (Hay & Robertson, 1988; Robertson & Hay, 1989). Generally, breeding pairs remain in the same territory for successive years, and can raise at least two clutches of 1-2 eggs each season. Repeated nesting attempts are common. Nest building is completed in approximately one week and incubation takes 13-14 days. Chicks are brooded for 12-16 days and remain in the parental territory for about one month following fledging (Mitchell, 1987; Robertson & Hay, 1989; McCormack & Kunzle, 1991; E. Saul and D. Todd, pers. comm.).

Prior to the work by the D.S.I.R. (Wellington), which began in October 1987, very little was known about the breeding of the Kakerori. The first recorded study was in 1987 by Suzanne Mitchell and Mike Bryan. The observed mating and courtship feeding in August 1987 but did not record the first signs of nesting until mid October 1987 (Hay & Robertson, 1988). Although most known pairs had begun nesting by November, two pairs were still building repeat nests and a third pair were incubating in late January 1988.

During the 1988/1989 breeding season, 13 nests were found in 7 territories throughout the Totokoitu Valley only. In this season, one pair was known to have built no fewer than five nests and laid eggs in at least two of them (R. Hay, pers. comm.). Observations of another pair building a second nest in January 1989, while at the same time feeding two fledglings, indicated that Kakerori may be double-brooded (H. Robertson, pers. comm.). This suggestion was strengthened by further observations by Hugh Robertson, Rod Hay, Nigel Langham and Peter Gaze (then at D.S.I.R. in Wellington) in 1989. During the 1989/1990 breeding season, 23 nests were found in 13 territories: 10 nests in 7 territories throughout the Totokoitu Valley; 7 nests in 3 territories in the Turoa Valley, and 6 nests in 3 territories within the Avana Basins (Hay & Robertson, 1988; Robertson & Hay, 1989). Of these nests, five were known to be built by one pair (Tu 3), and another pair successfully raised one chick in late December, 1988, and another in February, 1989.

Robertson & Hay (1989) noted that breeding success in the 1987/1988 season was very poor, with one fledged young from seven known pairs. They also noted that among the limited vertebrate wildlife in the study area, there were two species of rat (*Rattus rattus* and *Rattus exulans*) that are potential predators of Kakerori eggs and nestlings. They considered that a reduction in the local rat numbers could significantly boost the reproductive output of the Kakerori. In September, 1988, the first anti-rat campaign began, in an attempt to reduce the rat populations in nesting areas (Robertson & Hay, 1989). Throughout the Totokoitu Valley poison was laid repeatedly at 56 points (approximately 50m apart), with thirty snap-traps also laid. In addition, metal bands were placed around nest trees. As an apparent result of these efforts, breeding success in 1988/89 was better than the previous season, with at least three pairs producing fledged young (Robertson & Hay, 1989). Rat baiting continued in the Totokoitu and Turoa Valleys during 1989/1990, however nest trees in the Totokoitu Valley were not banded. During this season, a total of 24 nests and 19 fledglings were found (E. Saul, pers. comm.).

Rat-poisoning and tree-banding does therefore appear to have made a considerable impact on the breeding success of the Kakerori. However, to encourage this population increase, rat-poisoning needs to be maintained, and complemented with close observations of breeding and the development of young. Fluctuations in the amount of rat poison removed from an area, may estimate similar oscillations in local rat populations. The removal of poison can be related to the breeding success of birds in that area. Along with rat numbers, factors affecting breeding success such as the species of nest tree and the position of the tree within the territory, may also indicate the expected level of success in an area.

7.2 **METHODS**

7.2.1 Bird Observations

Strenuous efforts were made to follow the breeding of all known Kakerori pairs. Nesting sites located in September 1990 by Ed Saul were observed until the end of August, 1991. The breeding information recorded for each pair included the number of nesting attempts, the number of eggs laid (where possible), the number of chicks hatched (where possible) and whether these fledged.

Characteristics of the nest tree also recorded were; species of tree; diameter (measured 1m above the ground); horizontal and vertical distances of the nest from the nearest water course. In the case of repeated nesting attempts by a pair, the distance and compass direction of the new nest from the original nest was noted.

A mirror fastened to a pole was employed to view the contents of accessible nests. Frequently a squeak-bottle was used to locate parent birds and observations were aided by 10x40 binoculars.

7.2.2 Rat Poisoning

With help from Ed Saul, Gerald McCormack, Hugh Robertson and staff of the Cook Islands Conservation Service, approximately 370 poison bait stations have been placed in and around the Totokoitu and Turoa Valleys (see map of study area Fig. 3.1). The stations comprise numbered plastic tubes, 10cm in diameter and approximately 25cm long). The stations were placed approximately 25m apart and located by coloured plastic markers pinned to near-by trees.

Stations in each valley were visited once a week from September 1990 until December 1991. Intially, all stations were supplied with three pellets of the anti-coagulant Brodifacaum (Talon L50), and were restocked weekly to a total of three pellets per station. The number of pellets missing from each tube was recorded at each visit.

7.3 RESULTS

The changes in the location of each territory from 1989/1990 to 1990/1991 are shown in Figs 7.1 and 7.2. Although the male from To1 (1989/1990) disappeared, in the following year the female formed a new territory with a previously unknown male in To5 upr. The pair in To2 (1989/1990) moved approximately 50m south-east, while the other territories in the Totokoitu Valley remained unaltered. In the Turoa Valley, a new territory formed in 1990/1991 in Tu8 upr, with the female from the downstream 1989/1990 territory and a new male.

The breeding success (number of fledged young) for each pair, is compared for the 1989/1990 and 1990/1991 seasons in Tables 7.1 and 7.2. During the 1989/1990 breeding season, there were 24 observed nests with 13 of these producing 19 fledglings. In comparison, 20 nests were found in the 1990/1991 season, and 12 of these produced 15 fledglings. The percentage of nests producing fledged young therefore increased marginally (1989/1990 = 54% and 1990/1991 = 60%), whereas the number of fledged young from these nests decreased.

Tables 7.1 and 7.2 also shows the location of each nest with respect to the nearest water course and to previously built nests (where applicable). Of the known nest trees, Mato was the most commonly used species. In 1989/1990, 10 nests were found in Mato and 9 in 1990/1991 (Table 7.2). In the case of repeated nesting attempts within a territory, approximately 82% (n=9)were less than 25m from the initial nest. In 1989/1990, one pair (Au5) used the same tree to make a second nest, whereas in 1990/1991, two pairs used previous nest trees. The birds in To4 lwr built three nests before returning to the original tree to build a fourth, while in Au5 the first nest produced at least one fledged young and the second nest in the same tree produced another.

For the 1989/1990 and 1990/1991 seasons, 70% (n=16) of nest trees had a diameter greater than 40cm. The mean diameter of nest trees appeared to increase considerably 1989/1990 (mean = 37.5cm n=4) and 1990/1991 (mean = 60.7cm n=19). However, the few data available for the 1989/1990 season make the results for this season unreliable.

Although observations for the 1989/1990 season were limited (E. Saul, pers. comm.), the available data show there is great variation in the height of nests above ground. Heights range from 6m to 15m in successful territories and 3m to 12m in unsuccessful territories, however the average heights for successful and unsuccessful territories are similar (9.5m and 7.0m respectively). On average, nests in successful territories were found closer to water (mean=1.3m), whereas unsuccessful nests were found up to 14m from water (mean=10.1m). There was less difference in the height of the nests above water (successful mean=13.9m and unsuccessful mean=7.9m).

Table 7.3 shows the number of each tree species that held successful and unsuccessful nests for the 1989/1990 and 1990/1991 seasons. Mato (*Homalium acuminatum*) had a total of 13 successful and 6 unsuccessful nests whereas other tree species were used less often. However, Turina (*Hernandia moerenhoutiana*) held total of 5 successful nests and 1 unsuccessful nest while *Fagraea berteriana*, *Pittosporum arborenscens* and *Fitchia speciosa* all held more unsuccessful nests than successful.

The productivity of each valley is shown in Table 7.3. Although the Totokoitu Valley and the Avana Basins showed a higher percentage of breeding success in 1989/1990 (88% and 100% respectively), than in 1990/1991 (64% and 50% respectively), all valleys produced similar numbers of fledged young in both seasons (Totokoitu=7; Turoa=3; and Avana=3 in 1989/1990 and 2 in 1990/1991).

Plate 7.1 Rat poison-bait station and marker (Turoa Valley).

Territory	Sp.	Dia.	D(n)	H(g)	H(w)	D(w)	#F
Tu 8 lwr (a)	*Psi. cat.*	-	-	3	4	4	0
(b)	*Fit. spe.*	9.6	40m E of a	5	-	20	0
(c)	*Fit. spe.*	-	2m N of a	5	-	5	0
Tu 8 upr (a)	*Fag. ber.*	52.1	-	9	11	-	0
(b)	*Ela. ton.*	-	40m E of a	5	5	2	0
(c)	*Hib. til.*	-	10m W of a	9	-	10	0
Tu 2 (a)	*Hom. acu.*	39.0	-	6	6	0	2
(b)	*Hom. acu.*	-	10m N of a	8	8	0	1
Tu 3 (a)	*Hom. acu.*	-	-	6	12	4	1
(b)	*Ela. ton.*	-	10m S of a	10	13	10	0
(c)	*Hom. acu.*	49.2	20m S of a	12	12	4	0
(d)	*Pit. arb.*	-	5m N of c	3	3	10	0
(e)	*Hom. acu.*	-	3m E of d	9	9	10	0
To 2 lwr	*Hom. acu.*	-	-	6	10	-	2
To1	*Her. moe.*	-	-	11	11	-	2
To 3 upr (a)	*Wei. sam.*	-	-	13	18	5	1
(b)	*Hom. acu.*	-	20m E of a	8	8	-	0
To3 lwr	-	-	-	13	13	-	2+
To 4 lwr	*Pit. arb.*	-	-	10	15	-	1
To 4 upr	*Hom. acu.*	-	-	8	8	0	1+
To 5	*Hom. acu.*	-	-	10	15	-	2
Au 5 (a)	*Her. moe.*	-	-	15	18	0	1+
(b)	*Her. moe.*	-	5m N of a	15	16	0	1
Al 1 *	*Hom. acu.*	-	-	15	30	-	2

Table 7.1 Location of Kakerori nests built in the 1989/1990 breeding season.

Tu = Turoa Valley
To = Totokoitu Valley
Al = Avana Basin (lower)
Au = Avana Basin (upper)
Sp. = Species of tree
Dia. = Diameter of nest tree (cm)
D(n) = Distance of nest from original nesting attempt (m)
H(g) = Height of nest above the ground (m)
H(w) = Height of nest above water (m)
D(w) = horizontal distance of nest from water (m)
#F = Number of fledged young
* = Same tree as used previously
(a) = Initial nest

Fag. ber.	*Fagraea berteriana*
Psi. cat.	*Psidium cattleianum*
Hom. acu.	*Homalium acuminatum*
Fit. spe.	*Fitchia speciosa*
Ela. ton.	*Elaeocarpus tonganus*
Her. moe.	*Hernandia moerenhoutiana*
Wei. sam.	*Weinmannia samoensis*
Hib. til.	*Hibiscus tiliaceus*

Territory	Sp.	Dia.	D(n)	H(g)	H(w)	D(w)	#F
Tu 8 lwr	*Fag. ber.*	52.1	-	9	4	14	0
Tu 8 upr	*Ale. mol.*	52.2	-	6	5	12.5	1
Tu 2	*Hom. acu.*	40.8	-	9	11	3	2
Tu 3	*Fit. spe.*	9.5	-	5	7	5	2
To 2	*Hom. acu.*	41.8	-	5	6.5	3	1
To 3 upr (a)	*Hom. acu.*	100.5	-	12	9	4	0
(b)	*Hom. acu.*	48.0	2 5m W of a	6	9	5	1
To 3 lwr	*Ela. ton.*	20.1	-	6.5	9	5	1
To 4 lwr (a)	*Pit. arb.*	84.7	-	10	15	0	0
(b)	*Fag. ber.*	147.2	7m E of a	3	8	2	1
(c)	*Hom. acu.*	55.8	5 0m E of a	12	16	3.5	0
(d)	*Pit. arb.*	84.7	4m W of a*	10	16	0	1
To 5 lwr	*Hom. acu.*	30.8	-	6	12	2	1
To 5 upr	*Her. moe.*	73.0	-	10	16	1.5	1
Al 2	*Hom. acu.*	32.1	-	2	4	2	1
Al 3 (a)	*Her. moe.*	101.5	-	16	19	2	0
(b)	*Her. moe.*	101.5	1.5m N of a*	16	19	3.5	1
Au 5 (a)	*Hom. acu.*	55.6	-	4	8	4	0
(b)	*Hom. acu.*	21.9	1 5m S of a	8	8	-	?

Table 7.2 Location of Kakerori nests built in the 1990/1991 breeding season.

Tu = Turoa Valley
To = Totokoitu Valley
Al = Avana Basin (lower)
Au = Avana Basin (upper)
Sp. = Species of tree
Dia. = Diameter of nest tree (cm)
D(n) = Distance of nest from original nesting attempt (m)
H(g) = Height of nest above the ground (m)
H(w) = Height of nest above water (m)
D(w) = horizontal distance of nest from water (m)
#F = Number of fledged young
* = Same tree as used previously
(a) = initial nest

Fag. ber. — *Fagraea berteriana*
Ale. mol. — *Aleurites moluccana*
Hom. acu. — *Homalium acuminatum*
Fit. spe. — *Fitchia speciosa*
Ela. ton. — *Elaeocarpus tonganus*
Pit. arb. — *Pitosporum arborensis*
Her. moe. — *Hernandia moerenhoutiana*

	1989/1990		1990/1991		Total	
Sp.	Succ.	Unsucc.	Succ.	Unsucc.	Succ.	Unsucc.
Hom. acu.	7	3	6	3	13	6
Her. moe.	3	0	2	1	5	1
Fag. ber.	0	1	1	1	1	2
Pit. arb.	1	1	0	2	1	3
Fit. spe.	0	2	1	0	1	2
Ela. ton.	0	2	1	0	1	2
Other	2	2	1	0	3	2
n	13	11	12	7	25	18

Table 7.3 Nest tree species used in successful (succ.) and unsuccessful (unsucc.) Kakerori territories during the 1989/1990 and 1990/1991 breeding seasons.

Sp. = Species of tree
n = total number of nest trees

Hom. acu.	*Homalium acuminatum*
Her. moe.	*Hernandia moerenhoutiana*
Fag. ber.	*Fagraea berteriana*
Pit. arb.	*Pittosporum arborenscens*
Fit. spe.	*Fitchia speciosa*
Ela. ton.	*Elaeocarpus tonganus*

	1989/1990			1990/1991			Total		
Valley	#Fl.	#N	% (S)	#Fl.	#N	% (S)	#Fl.	#N	% (S)
Totokoitu	7	8	88	7	11	64	14	19	74
Turoa	3	13	23	3	4	75	6	17	35
Avana	3	3	100	2	4	50	5	7	71

Table 7.4 Total number of nests and fledged young found in the Totokoitu, Turoa and Avana catchments during the 1989/1990 and1990/1991 Kakerori breeding season.

#Fl. = Total number of fledged young
#N = Total number of nests
% (S) = Percentage of breeding success (#Fl./#N)

Territory	#B. St.	#B. Ta.	M(B)	#F
Tu 3	6	96	16	2
Tu 2	3	57	19	2
Tu 8 lwr	4	93	23	0
Tu 8 upr	4	107	27	1
Total	17	353		5
To 2	10	199	20	1
To 3 lwr	8	123	19	1
To 3 upr	7	65	9	1
To 4 lwr	9	95	10	1
To 4 upr	6	103	17	2
To 5 lwr	3	31	17	1
To 5 upr	2	27	13	1
Total	45	643		8

Table 7.5 Number of poison baits removed from stations in Turoa territories (above) and Totokoitu territories (below) during the 1990/1991 Kakerori breeding season.

#B.St = Number of bait stations within each territory
#B.Ta = Total number of baits taken
M(B) = Mean number of baits taken
#F = Number of fledged young found

Date	25 Sept.	2 Oct.	9 Oct.	16 Oct.	23 Oct.	30 Oct.	6 Nov.	13 Nov.	20 Nov.	27 Nov.	4 Dec.	11 Dec.	18 Dec.
#B. St.	118	187	199	199	199	199	199	199	199	199	199	195	199
#B. La.	354	561	597	597	597	597	597	597	597	597	597	578	597
#B. Ta.	247	507	309	462	362	162	134	283	273	263	192	100	57
% B. Ta.	69.9	90.4	51.8	77.5	60.6	27.2	22.4	47.4	45.8	39.5	32.2	17.4	9.5

Date	20 Sept.	28 Oct.	4 Oct.	11 Oct.	18 Oct.	25 Oct.	1 Nov.	8 Nov.	22 Nov.	30 Nov.	7 Dec.	13 Dec.
#B. St.	166	166	166	166	167	168	168	168	168	166	166	166
#B. La.	498	498	498	498	501	504	504	504	504	498	498	504
#B. Ta.	473	485	290	280	231	97	36	13	212	121	35	34
% B. Ta.	95.0	97.4	58.2	56.3	46.1	19.3	7.1	2.6	42.2	24.3	7.0	6.8

Table 7.6 Number of baits laid and later taken by rats from the Turoa Valley (above) and Totokoitu Valley (below) during 1990.

#B.St = Number of bait stations
#B.La = Number of baits layed
#B.Ta = Number of baites taken
% B.Ta = Percentage of baits taken

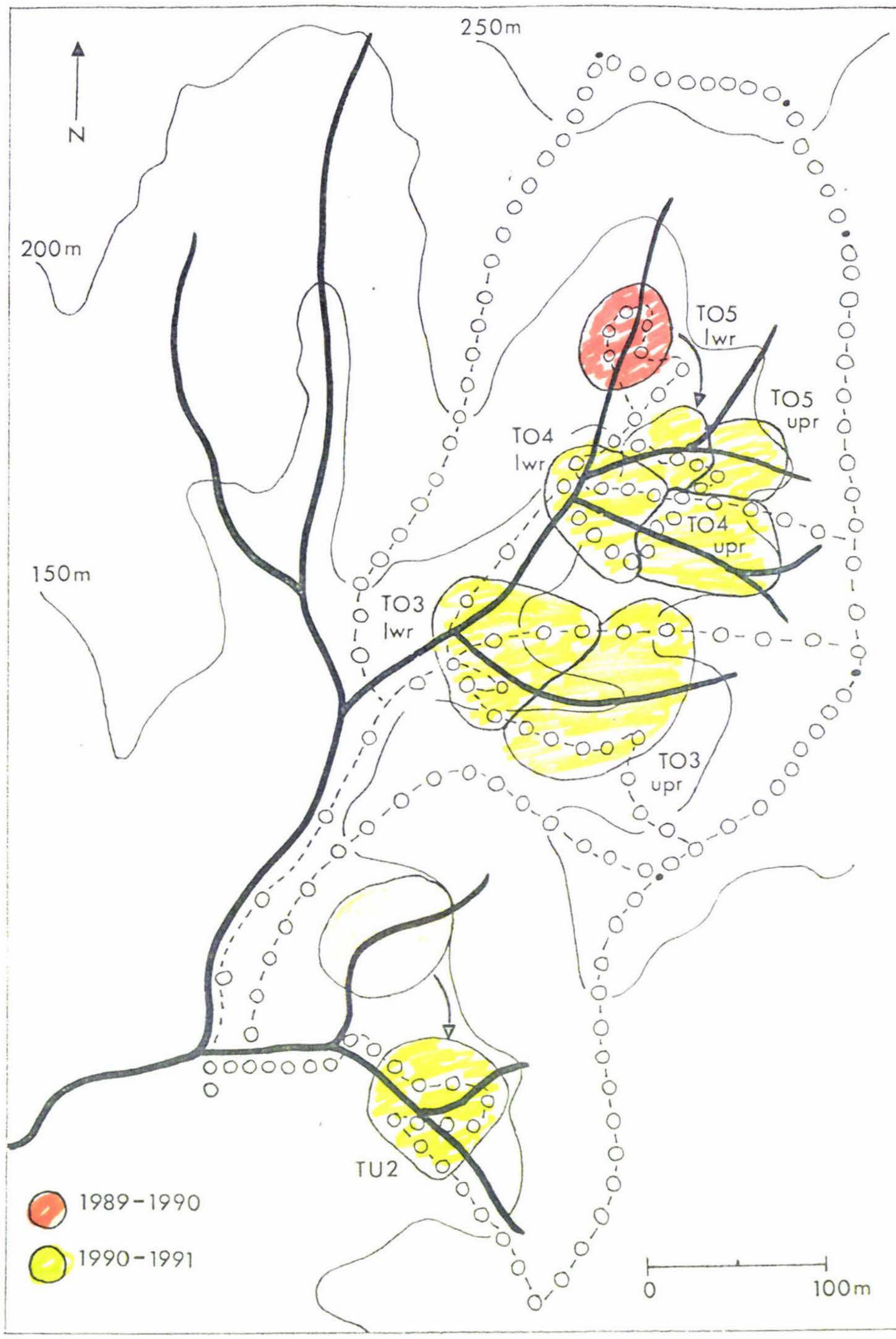

Fig. 7.1 Map of the Totokoitu Valley showing the changes in position of Kakerori territories between 1989/1990 and 1990/1991 seasons. (OOO denotes poison bait stations).

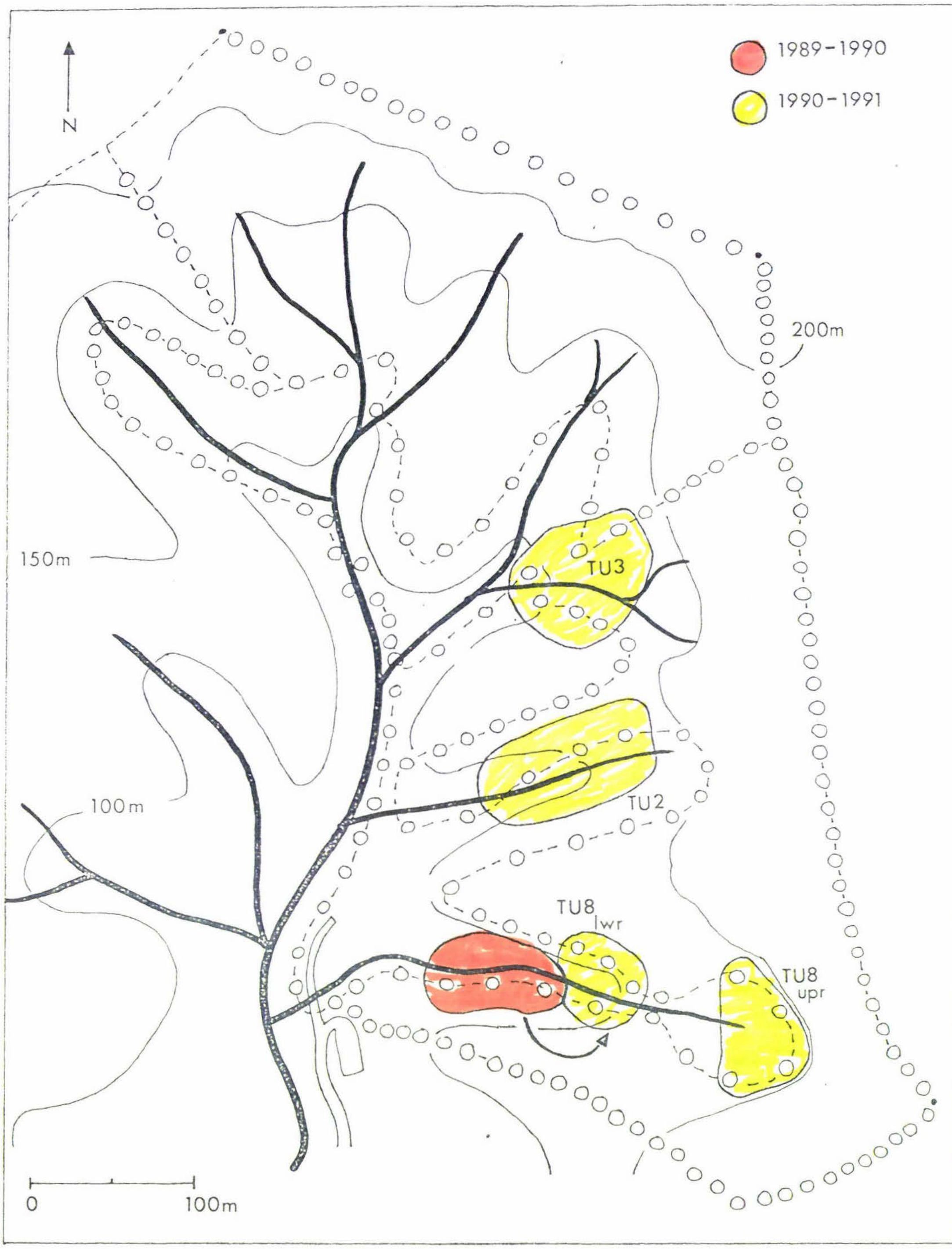

Fig. 7.2 Map of the Turoa Valley showing the changes in the position of Kakerori territories between 1989/1990 and 1990/1991 seasons (OOO denotes poison bait stations).

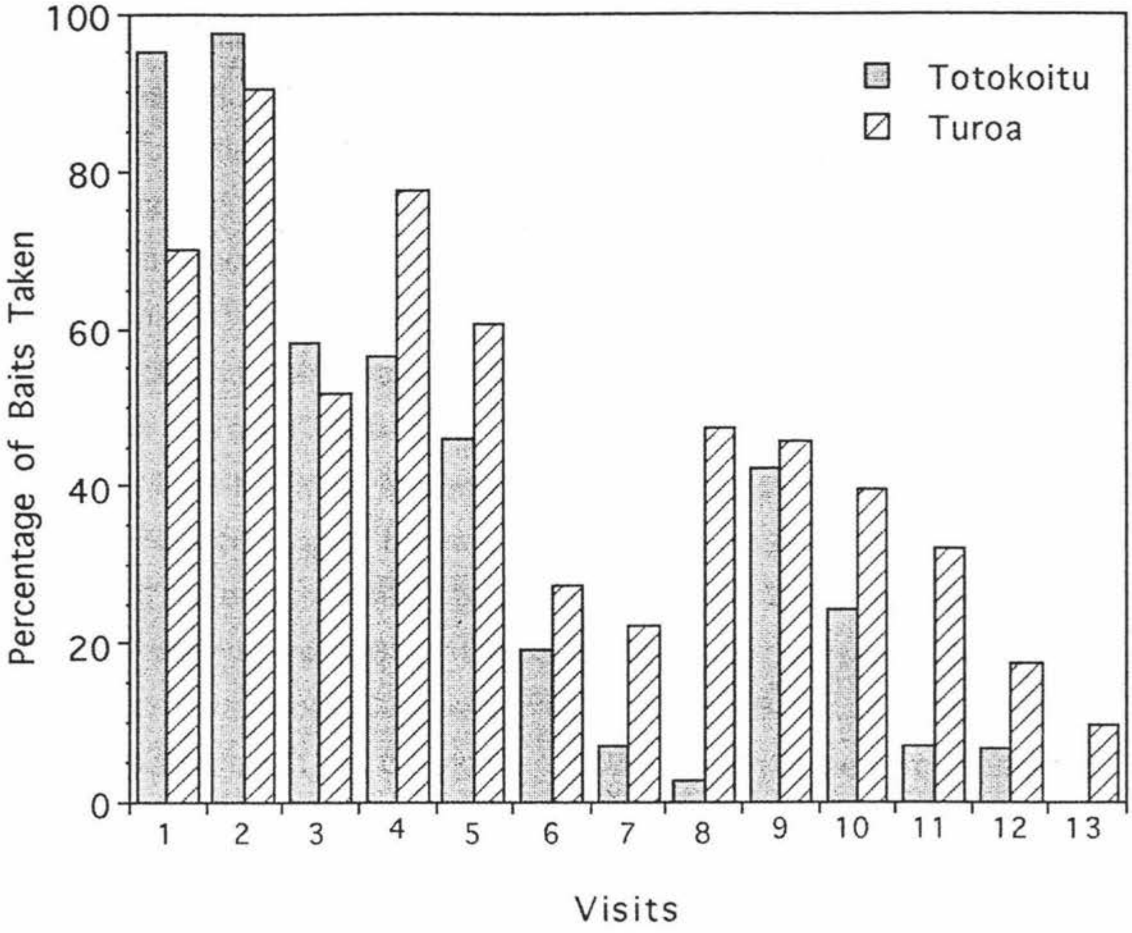

Fig. 7.3 Percentage of poison baits taken by rats in the Totokoitu and Turoa Valleys during 1991. The numbered 'visits' refer to the dates shown in Table 7.6.

The relative sizes of rat populations within the Totokoitu and Turoa Valleys are indexed by the number of poison baits removed from the stations throughout these areas (Fig. 7.5). In September 1990, the percentage of baits taken from 166 stations in the Totokoitu Valley was greater (95.0%) than the percentage taken from 118 stations in the Turoa Valley (69.9%) five days earlier. However, by December 1991, the number of baits taken had fallen to 6.8% in the Totokoitu Valley and 9.5% in the Turoa Valley. The bait stations and corresponding number of baits taken in each territory in the 1990/1991 season are shown in Table 7.5 and Fig 7.3. Table 7.5 also shows the average number of baits taken per station for each territory. Of the 2309 baits taken from the Totokoitu Valley between 20 September 1990 and 13 December 1991, 27.9% were from within Kakerori territories. This contrasts with the Totokoitu valley where 10.6% of the 3326 baits taken between 25 September 1990 and 18 December 1991 were from territories. Both valleys had similar breeding success with only one non-productive territory in the Turoa Valley (Tu 8lwr), and it appears that breeding success is not related directly to the number of baits taken within each territory.

7.4 DISCUSSION

Although the location of Kakerori was assisted by the use of a squeak-bottle, only adult birds responded to simulated calls. Except when being fed, newly fledged young remained still, silent, and generally high in the canopy and therefore were very difficult to locate. Hence the data concerning breeding success (the number of fledged young) is conservative. Only positive identifications have been used in the analyses, with possible sightings being noted. Overall, observations suggest that the actual number of fledged young in the study area was greater than 15.

Although 82% of repeat nests were less than 25m from the original nest, Kakerori territories are small (50-100m in diameter) and this may explain why repeat nests are usually close to the original nest. It is unclear why successful nests were built closer to water. Possibly chicks may benefit from the insects that prefer moist air or require direct access to water.

Although the diameter of nest trees increased from 37.5cm in 1989/1990 to 60.7 in 1990/1991, the few available data for the 1989/1990 season makes comparisons unreliable. However, large, established trees may offer nests increased shelter and stability.

The effects of the anti-rat campaign appear favourable. The number of poison baits removed from the stations throughout the Totokoitu and Turoa Valleys, decreased substantially over a period of approximately three months. However, it is not known to what extent the poison baits actually reduced the rat populations. It is assumed that the poison baits would decrease the numbers of local rats. It is further assumed that any reduction in rat numbers would have a positive impact on the breeding output of the Kakeori (H. Robertson and E. Saul, pers. comm.). It appears that breeding success is not related directly to the number of poison baits taken within each territory. It is possible therefore, that the overall rat population in the study area has an important impact on Kakerori survival. Although no work has been done on rat densities and home ranges in the Cook Islands (G. McCormack, pers. comm.), studies undertaken in New Zealand forests show that *Rattus rattus* densities can be as high as 20 rats per ha (Craig, 1977 *in* Craig, 1983) and individual home ranges in mixed lowland forest are approximately 0.5 - 0.6 ha (Hickson, Moller & Garrick, 1986; Brockie, 1992). If rats on Rarotonga followed this pattern, several Kakerori territories may be visited by the same individuals.

Although the breeding success in the 1990/1991 season was encouraging (15 fledged young), the previous season produced better results (19 fledged young). It is interesting to note that the numbers of fledged young per valley (Table 7.4) were very similar for both seasons, regardless of the variation in the number of nests built. Although the birds are able to build up to 13 nests per valley (Turoa), all valley systems are geographically small and may be able to sustain the development of only a limited number of young.

Apart from *Homalium acuminatum* there is no clear 'best' or 'successful' species of nest tree. *Fagraea berteriana*, *Fitchia speciosa* and *Elaeocarpus tonganus* held unsuccessful nests in 1989/1990 and successful nests in 1990/1991. However, overall *H. acuminatum* and *Hernandia moerenhoutiana* were'successful' nest tree species whereas *F. berteriana*, *F. speciosa* and *E. tonganus* were 'unsuccessful'.

The breeding success of pairs in the Totokoitu Valley was consistantly high for the 1989/1990 and 1990/1991 breeding seasons, whereas pairs holding territories in the Turoa Valley and Avana Basin had variable breeding success over these seasons. However, overall the Totokoitu Valley and Avana Basin have had the highest percentage of breeding success. This may be attributed to the isolated nature of these valleys, whereas the Turoa Valley is in closer proximity to human habitation.

The breeding statistics described in Table 7.2, show that all but one of the existing pairs successfully raised at least one chick during the 1990/1991 season. This suggests that the ability to produce young is not restricted to a few 'high-performing' pairs (as in some endangered bird species), but rather is an attribute of nearly all pairs. It is important, therefore to encourage an increase in the overall number of breeding pairs on Rarotonga as well as repeated nesting in any season. Optimistically this could lead to the invasion of Kakerori into areas adjacent to their natal valleys.

Chapter 8

THE FUTURE OF THE KAKERORI

8.1 CURRENT CONSERVATION EFFORTS

In October 1990, at the start of the 1990/1991 breeding season, the known world population of Kakerori was only 33 individuals. By the close of this study in August 1991, the population had increased to 47 (the additional 14 were young from the previous season). It appears that two years of rat-baiting throughout the study area, along with the addition of metal bands on nest trees, has aided Kakerori survival. Additional bait stations were laid in and around the Avana Basins during 1992 (E. Saul, pers. comm.), in an effort to further protect the birds in these territories from predation by rats. With help from Ed Saul, conservation officers from the Cook Islands Conservation Service in Rarotonga, are maintaining close observations of the Kakerori and local rat populations. Since August 1991, Kakerori numbers have continued to increase steadily (G. McCormack, pers. comm.), although an exact population figure is unknown at the time of writing. Because eradication of rats on the whole of Rarotonga is likely to be impossible with present technologies, rat poisoning in Kakerori areas would have to continue indefinitely, if the present population of Kakerori is to have any prospect of long-term persistence and expansion. The availability of funds and personnel dedicated to the task will determine the long-term effect of this management strategy.

Aside from the continuing anti-rat campaign, other aspects of population maintenance must also be upheld if Kakerori are to survive. The New Zealand Department of Conservation (DoC) will continue to colour-band birds annually for four years following the 1990/1991 season (H. Robertson, pers. comm.) in an attempt to maintain an accurate estimate of population size, age structure, sex ratio and mating pairs. This information is vital to predicting the viability of the population (Robertson & Hay, 1989). Although, the Kakerori was thought to be extinct until the early 1980's (Hay & Robertson, 1988; Robertson & Hay, 1989; D. Todd, pers. comm.), over the previous ten years there have been several unconfirmed sightings in the Taipara and Papua Valleys (G. McCormack, pers. comm.). It is also possible that young from existing territories may disperse into valleys adjoining the present study area, in search of alternative breeding territories. It is important, therefore, that these valleys are checked regularly.

8.2 CONSERVATION AND MANAGEMENT OPTIONS

Although Kakerori numbers are still dangerously low, the rat-baiting campaign appears to be effective, bird numbers are increasing, and it is not immediately necessary to further interfere with the existing population (G. McCormack, pers. comm.). Other conservation options can be considered, but most require considerable effort or funding. In the present economic climate, funding remains a significant problem for all options.

Interfering with, and disturbing the birds should be minimised, thus some techniques found to be successful elsewhere are inappropriate for the Kakerori. For instance, caging nests to prevent predation (I. McLean, pers. comm. in Robertson & Hay, 1989) is particularly disruptive to nestlings and would be extremely difficult to set up around nests at the ends of thin outer branches. Several endangered species of land birds have been transfered to new locations offering broadly similar habitats, but ones free of predators eg; the New Zealand Black Robin from Little Mangere I. to Mangere I. and later to South-east I. (Merton, 1965; Morris, 1977; Flack, 1978). Captive breeding and translocation experiments involving a variety of land bird species in New Zealand indicate that it is preferable to move more than twenty birds at once, and to keep them in captivity for a period before releasing them (Scott & Carpenter, 1987; Conant, 1988; Griffith *et al*, 1989; Craig & Reid, 1991; Wilson *et al*, 1991; Castro, 1992). Apart from the risks involved in transferring Kakerori from an already small population, there are few islands suitable to receive them. Rarotonga is the only island in the Cooks Group over 170m high, and many of the islands in this group have predators common to Rarotonga. Captive breeding and translocation would also further reduce the limited gene pool that exists in the current population.

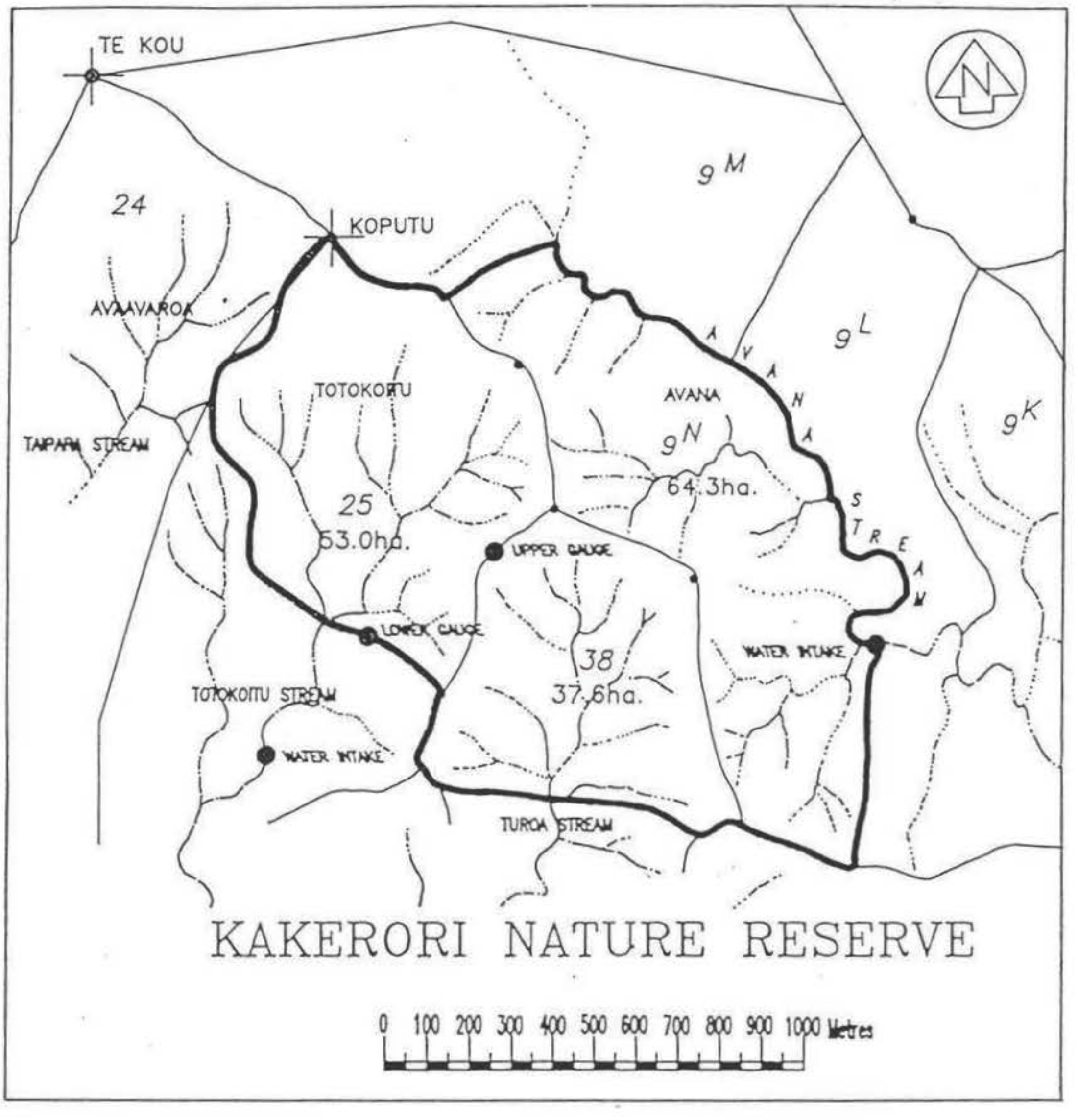

Fig. 8.1 Map showing the layout of the proposed Kakerori nature reserve
Map prepared by Cook Islands Conservation Service (unpublished).

The most practical way to conserve the Kakerori in the short term, may be to ensure continued breeding success within the present range (Robertson & Hay, 1989; McCormack & Kunzle, 1990). This may be largely achieved by continuing to poison rats in the area. But the retention of suitable habitat is also crucial to the survival of any species. While the forest in inland Rarotonga is relatively free from disturbance (Leslie, 1980; Sykes, 1981; Robertson & Hay, 1989), there are some potential hazards arising from fire clearances. Minor land clearances in the Turoa Valley (as part of a forestry trial) was stopped during 1988 and will not be continued. To ensure that the Kakerori breeding area remains intact, a proposal to establish a reserve has been forwarded to the Rarotongan Government (G. McCormack, pers. comm.). The reserve will include the existing study area and surrounding land (Fig. 8.1) in a total area of approximately 155 ha (McCormack & Kunzle, 1990).

Public and political support are important prerequisites to successful species recovery, however local awareness of Kakerori in Rarotonga is not high, and the extent of public access to the Kakerori breeding area is unclear. The Conservation Service in Rarotonga is aware of the gains that may possibly come from increased advertisement and public interest (T. Rongo, pers. comm.). While public access should not necessarily be discouraged, some control may be needed during breeding seasons and rat control operations. It is suggested by Hugh Robertson (pers. comm.) that an easily accessible piece of the Kakerori area could be opened and marked for public access, but that all other territories should remain closed. Public interest and use of the Kakerori areas would need to be closely monitored to ensure that the impact on the birds was not too great (H. Robertson, pers. comm.).

Chapter 9

SUMMARY

9.1 GENERAL SUMMARY

Given that the survival rate of adult Kakerori (79%) is much higher than that of juveniles (50%) (Robertson & Hay, 1989), it appears that birds in their first year are more vulnerable to environmental pressures.

Although parental care continues up to four months after chicks have fledged, the young birds are then pushed up to 100m (mean = 87m n=14) from their natal territory. There they often form small groups, in low foliage approximately 2.5m (n=14) from the ground, on the high ridges. Because adults are found 12-15m from the ground, in the canopy of small, sheltered, heavily forested valleys, the sparsely vegetated and exposed ridges are considered less appropriate habitat for Kakerori.

Successful territories (those that produce fledged young) often have a lower canopy (mean = 10.3m) than unsuccessful territories (mean = 13.7m) with a low percentage of ferns (28.3%) and a high percentage of tree species (38.3%) in the understorey. Juvenile tree species in the shrub layer may help to create a microhabitat near the ground, and ensure the future of the canopy. Territories with a plentiful understorey and a high occurrence of moss (suggesting a moist environment) may also encourage larger insect populations.

All territories had a high density of King fern (*A. longifolium*) and Mato (*H. acuminatum*) with the mean densities for successful territories (2491.0 ferns/ha and 665.4 trees/ha respectively) and unsuccessful territories (2779.7 ferns/ha and 745.4 trees/ha respectively) being very similar. *E. tonganus* was more common in successful territories (204.6 trees/ha) than unsuccessful (48.3 trees/ha), while *H. moerenhoutiana* was found in higher densities throughout unsuccessful territories (361.4 trees/ha) than successful (63.9 trees/ha).

Fewer but larger adult trees occur in successful territories, contributing to a larger total mean basal area (mean = 7.39m^2), whereas unsuccessful territories have many small trees forming the canopy and sub-canopy (mean basal area = $3.21 m^2$). Large, established trees offer niches for a wide variety of insect fauna (Majer *et al*, 1990), and provide many possible nest sites.

During February 1991, successful territories had a considerably higher percentage of flies (Diptera) (40.4% n=23) and a lower percentage of ants (Formicidae) (10.5% n=6) than unsuccessful territories (8.3% n=2 and 37.5% n=9 respectively). As small, flying insects are considered the most common food for flycatchers (Pratt, Bruner & Berrett, 1987; Erard, 1987 and 1990; Sakai & Noon, 1990), it would be beneficial to the birds if flies were abundant during the period when adults are feeding newly fledged young.

Although habitat characteristics and insect availability within territories may have a considerable effect on the survival of the Kakerori, predation of eggs and chicks by rats is likely to have a larger impact on breeding success. Laying poison baits throughout valleys in the study area has coincided with improved reproductive output of pairs in those areas. The number of fledged young increased from one fledged young from seven known pairs in 1987/1988 to 14 young from 13 known pairs in 1990/1991. During the 1990/1991 season, an average of 1.2 fledged young were produced from the six breeding territories throughout the Totokoitu Valley, 1.0 from the five territories in the Turoa Valley, and 0.7 from the three territories in the Avana Basins. Although there are many conservation tactics available including translocation, captive breeding and supplementary feeding, many of these are unsuitable for Kakerori and require extensive man-power and funding.

In summary, the conservation and management of Kakerori will ultimately turn upon the availability of funds and personnel to continue poisoning rats indefinitely. Other measures, such as setting aside a reserve with controlled public access will help draw attention to the plight of the bird, however this should be enhanced by further research concerning its ecology.

9.2 FURTHER RESEARCH

Although the general breeding biology of the Kakerori is now known, many aspects of its ecology remain unclear. Further research on the Kakerori could include dietary analyses and daily food requirements with an estimate of seasonal food availability throughout the study area.

The breeding behaviour of the birds has been rarely observed and there is little knowledge of inter-breeding season relationships between birds. The extent of the movement of birds between territories, and the socio-ecology of territorial and non-territorial birds over the non-breeding period is generally unknown.

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