Status of birds and rodents on Niue following cyclone Heta in January 2004

R.G. Powlesland, D.J. Butler and I.M. Westbrooke

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ABSTRACT

On 6 January 2004, cyclone Heta devastated much of the South Pacific island nation of Niue. Extensive damage was done to forest, particularly of the north-western sector, with many trees up-rooted and others stripped of branches and foliage. This report details our findings from a survey of Niue's birds and rodents during 3–19 September 2004, and compares these with results from a similar survey in September 1994. Five-minute bird count data, an index of conspicuousness, from three transects showed that heahea (Polynesian triller, *Lalage maculosa*) were more abundant in 2004 than in 1994, but miti (Polynesian starling, *Aplonis tabuensis*), kulukulu (purple-crowned fruit dove, *Ptilinopus porphyraceus*) and lupe (Pacific pigeon, *Ducula pacifica*) had declined. The 28–64% decline in the lupe population per transect was probably primarily as a result of hunting, rather than mortality caused by cyclone Heta. Counts of birds seen per kilometre along three sections of road (lower, upper, inland) were also compared with September 1994 data. However, for various reasons we doubt that the results accurately reflect population numbers. The 212 kiu (Pacific golden plover, *Pluvialis fulva*) counted at sites accessible from main roads in September 2004 was similar to the 226 seen in September 1994. Rat trapping results (captures per 100 trap-nights) along the same three transects for December 1994 and September 2004 were not significantly different. Both kuma (Pacific rat, *Rattus exulans*) and ship rats (*R. rattus*) were trapped, but kuma were found only in regenerating scrub, whereas ship rats were present in both scrub and forest. Recommendations for future work are made mainly in relation to the long-term conservation of lupe, a toaga (treasured) species of Niueans.

Keywords: Niue, Pacific, cyclone Heta, five-minute bird counts, kiu survey, rat-trapping, conservation

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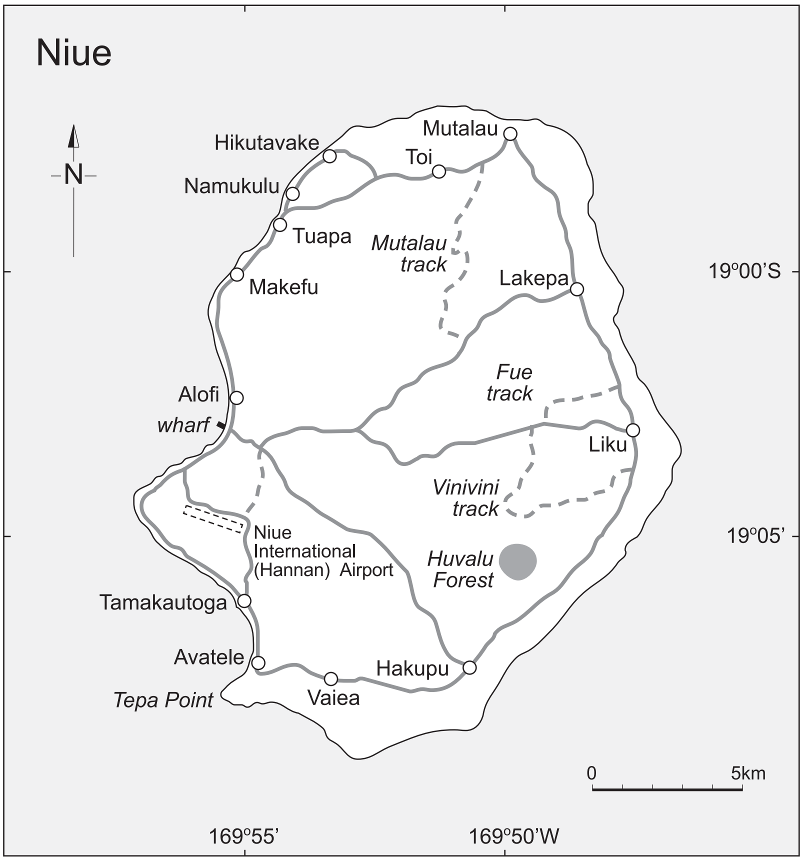
1. Introduction

On 6 January 2004, cyclone Heta, a category 5 hurricane, devastated Niue Island. Winds in excess of 270 km per hour ravaged the island for about 5 hours, and a mountainous storm surge battered the west coast. Alofi and the villages of Makefu, Tuapa, Namukulu and Hikutavake (Fig. 1) were all badly affected. The combination of a high spring tide, directional travel, wind velocity, spiral direction, and a sloping seabed combined to maximum effect in producing a sea surge estimated at 50 m. This overtopped the cliffs and in places pushed 100 m inland devastating all in its path. In addition to the loss of human life and property that resulted, serious damage was done to the forest, particularly on the northern and western sides of the island. If not blown over, most trees and shrubs were stripped of leaves, flowers, fruit, and thin branches, and subjected to salt spray. The cyclone was followed by several days of intense heat, with no rain. After the cyclone some fires started to clear patches of forest for gardens destroyed forest when they got out of control because of the considerable volume of flammable material on the ground (Space et al. 2004).

DJB visited Niue Island about three weeks after the cyclone, and found that the impact of the cyclone on the forests was highly variable, with estimates of the proportion of trees up-rooted varying from 2% to 30% in different parts of the island. The coastal forest on the western side was almost entirely defoliated from the canopy to the ground. While there were more trees standing than uprooted in this area, many had branches snapped off. Heading inland from Alofi (Fig. 1), the ground cover and shrub layer were the first to have retained some foliage. Near the centre of the island (5–6 km inland), some trees had leaves and there were occasional groups with crowns largely intact. In comparison, some patches of forest on the eastern side of the island looked untouched. S. Togatule, Director of Department of Environment (DOE), Niue, observed during a reconnaissance flight on 27 January that the eastern coastal forest on the island's lower terrace was largely intact from the coast off Liku village to almost Tepa Point, and that the forest on the next terrace up showed perhaps only 5–10% damage.

While the cyclone and the subsequent drought killed some wildlife, of more concern was the survival of forest-dwelling species during the period of several months when few flowers and fruit were available. Such species included the peka (flying fox fruit bat, *Pteropus tonganus*), lupe (Pacific pigeon, *Ducula pacifica*), kulukulu (purple-crowned fruit dove, *Ptilinopus porphyraceus*), miti (Polynesian starling, *Aplonis tabuensis*) and hega (blue-crowned lory, *Vini australis*). In late January, sprouting of foliage on defoliated trees was evident, and reasonable numbers of most forest bird species were seen in less affected forest areas. This allayed initial concerns for bird population survival. However, many peka, lupe, and kulukulu on the eastern side of the island entered villages in search of food and water—a very atypical behaviour. In response to this crisis the Government of Niue provided funds for a programme to provide food and water at feeding stations under the co-ordination of Misa Kulatea. Because bats and birds entering villages were vulnerable to predation by dogs, cats, and people, some peka and lupe were taken into captivity, with the intention of

Figure 1. Niue Island, showing the locations of villages, roads, and the three tracks along which the five-minute bird counts and rat trapping were carried out.



releasing them once natural food sources were readily available again. A flock of lupe (consisting of a few hundred birds) fed in low scrub about the airport following the cyclone. They had not been seen feeding at this location just before the cyclone or in previous years. Although no specimens were submitted for testing, several were found dead in the area. Because the lupe were thought to have been feeding on green berries of lantana (*Lantana camara*), which are known to be toxic to mammals (Shepherd 2004), it was suggested by locals that the lupe may have been poisoned by toxin in the berries.

Following Butler's assessment of the impacts of cyclone Heta in late January 2004 (Butler 2004), he urged more in-depth surveys on the flora and fauna of Niue be carried out within a few months. The surveys were duly agreed to by the Government of Niue and by the United Nations Development Programme (UNDP), which contributed to the funding through the 'Enabling Activity on Biodiversity' project. This report details our findings from the survey of Niue's birds and rodents during 3–19 September 2004, and includes a comparison with the results from a similar survey conducted in September 1994 (Powlesland et al. 2000).

1.1 TERMS OF REFERENCE

The objectives of the study were:

- To assess and provide a written report on the changes in bird populations since the previous surveys in 1994, (including comment on the likely role of cyclone Heta in these changes)

- To provide recommendations on any management work needed to secure the recovery of any bird species
- To assess rat densities along the bird transect lines in forest and scrub habitats, and compare with the 1994 findings
- To determine whether management of rodent populations is necessary for forest bird conservation
- To make recommendations for future monitoring that could be carried out by local staff to assess future changes in bird and rat populations
- To share skills on bird identification, assessment, and management options with any Department of Environment and Department of Agriculture staff accompanying the team

2. Study area

Niue is an isolated single raised coral atoll in the south-central Pacific (19º 03′S, 169º 55′W). It is approximately 480 km east of Tonga, 930 km west of Rarotonga, and 660 km south-east of Samoa. Niue is roughly circular (18 × 21 km, see Fig. 1), 261 square kilometres in area, and formed of two terraces. There is a prominent terrace at 18–24 m a.s.l. which encircles much of the island. Above the lower terrace is a steep rise to a ridge crest at about 55 m a.s.l. in the east and 60–65 m a.s.l. in the west. This ridge is generally about 1 km inland. From the ridge, the land initially slopes down towards the island's centre, but is essentially flat across most of the interior, and is about 30 m a.s.l. Some parts of the coastline, particularly to the west and north, are fringed by a narrow wave-cut platform close to the shore.

Niue may have been inhabited by Polynesians for about 2000 years (Walter & Anderson 1995), and the population was estimated at 1769 people in 2001 (Richmond-Rex et al. 2001). Alofi, on the western coast, is the administrative centre and port (Fig. 1). In addition, there are 12 villages near the coast, connected by 64 km of perimeter road.

Niue is of recent geological origin (Schofield 1959), and formed in isolation from other land masses. All but one species of bird, the introduced moa (feral fowl, *Gallus gallus*), must have flown to the island, even if assisted by storm-force winds. All the species presently breeding on Niue are of western Polynesian origin, and most have originated from Tonga or Samoa. Although the heahea (Polynesian triller, *Lalage maculosa*) and miti have evolved into distinct subspecies on Niue, all other species are found elsewhere in the Indo-Pacific region. A notable feature of Niuean birdlife is its lack of introduced species, except for the moa. This is in contrast to other Pacific island groups, such as Fiji and Samoa, where several species have been introduced, sometimes to the detriment of the native fauna and agricultural crops (Watling 2001).

The soils of Niue are generally fertile, but shallow (Lane 1994). As a result they are suitable only for the traditional 'slash and burn' cropping techniques whereby garden areas are left fallow for up to ten years before being reused for one year. As a result of this continuing practice of shifting agriculture, much of the island is now a mosaic of varying stages of regeneration, interspersed with cultivated gardens. There are also scattered coconut plantations and three experimental farms with some pasture.

The long-term conservation of Niue's flora and fauna depends, in part, on the continued presence of habitats that existed before people colonised the island (Richmond-Rex et al. 2001). The natural vegetation consists of limited areas of rainforest, with a 20 m-high canopy, but much of it has been modified to some degree. Open habitat, covering 30.1% of the island in 1994, included bush gardens under cultivation, and areas dominated by fou (*Hibiscus tiliaceus*) and fernlands, mostly *Nephrolepis hirsutula* (Martell et al. 1997). A further 8.7% was covered by coastal forest, which included areas c. 50–1000 m from the coast, with generally good cover, but where the trees were stunted by salt spray and strong winds. This coastal forest on the eastern side of the island and on the encircling terrace at c. 60 m a.s.l. was mainly on makatea (rocky ground with many sharp coralline limestone pinnacles up to 5 m tall, and deep holes). Of the total land area, 48.6% was previously in cultivation and is now under regenerating scrub and forest. Just 12.6% of the island in 1994 was covered by remnants of mature tropical rainforest (Martell et al. 1997), concentrated in the triangular area delimited by the villages of Alofi, Lakepa and Hakupu (Fig. 1). The largest block is the Huvalu Forest (Fig. 1) containing a 'tapu' area which people are forbidden to enter.

Niue has a variety of introduced mammals. Two species of rat are ubiquitous; the kuma or Pacific rat (*Rattus exulans*), introduced by the early Polynesian settlers, and the ship rat (*R. rattus*), which arrived between 1902 and 1925 (Smith 1902; Wodzicki 1971). Mice (*Mus musculus*), dogs (*Canis familiaris*) and cats (*Felis catus*) are common about villages, and feral cats are widespread over the island. Escaped pigs (*Sus scrofa*) are present in some areas of forest.

3. Methods

3.1 FIVE-MINUTE BIRD COUNTS

In both 1994 and 2004, index counts of forest birds were made using the five-minute count technique (Dawson & Bull 1975), an index of 'conspicuousness'. Transects (non-randomly selected), were along vehicle tracks through mature forest, regenerating scrub, and gardens under cultivation (mainly for taro). At the start of each field trip, the 200 m distance between successive count stations was measured with a tape-measure, and the locations marked with flagging tape. At each station all birds seen or heard within a 100 m radius of the observer were noted during a five-minute period. The transects were at three places (see Fig. 1). The Mutalau transect (20 count stations) ran north–south through the middle of the northern end of the island. It traversed small areas of taro gardens and remnant forest, and extensive areas of regenerating scrub. Because many trees along the Fue and Vinivini transects had been up-rooted during cyclone Heta and not cleared by September 2004, fewer count stations were available along these transects than in 1994. The Fue (14 stations) and Vinivini transects (16 stations), both situated near Liku village, were mainly through mature forest and regenerating forest, few garden plots being worked. Table 1 summarises the number of counts undertaken along each transect in September 1994 and 2004.

3.2 BIRDS PER KILOMETRE

Whenever travelling along main roads by day, a record was kept of: (a) the number of each species seen; (b) the kilometres travelled along each section of road, categorised as **lower** terrace (Avatele–Hikutavake, along the western side of the island, Fig. 1), **upper** terrace (Hikutavake–Avatele, along the eastern side), or **inland** (inland roads between Alofi and Tamakautoga, Hakupu, Liku, or Lakepa); and (c) the time of day. Observations were made during dry weather, and usually the speed was 30–50 km per hour. Observations were made from a car in 2004, but a motor-bike in 1994. Table 2 (see below in section

TABLE 1. A COMPARISON OF FIVE-MINUTE COUNTS OF HEAHEA (*Lalage maculosa*), MITI (*Aplonis tabuensis*), KULUKULU (*Ptilinopus porphyraceus*), AND LUPE (*Ducula pacifica*) IN 1994 AND 2004 FOR EACH TRANSECT, NIUE ISLAND. Only stations counted in both years are included, although 20 stations were counted on each transect in 1994. The standard error (SE), t-statistic and *P*-value are based on a two-sided paired *t*-test for difference between the two years, based on the average station counts in each year.

	MUTALAU		FUE		VINIVINI	
	1994	2004	1994	2004	1994	2004
No. of stations	20		14		16	
No. of counts	139	160	117	160	128	154
Heahea						
Mean no.*	3.4	3.6	2.5	3.3	2.8	4.1
SE	0.145		0.214		0.180	
t-statistic	1.367		3.776		7.288	
P value	P = 0.188		P = 0.002		P < 0.001	
Miti						
Mean no. *	2.6	2.0	2.3	2.3	2.6	2.2
SE	0.298		0.225		0.283	
t-statistic	2.093		0.047		1.271	
P value	P = 0.050		P = 0.963		P = 0.223	
Kulukulu						
Mean no. *	3.1	1.3	1.1	1.3	1.1	1.9
SE	0.241		0.164		0.182	
t-statistic	7.407		1.290		4.305	
P value	P < 0.001		P = 0.219		P < 0.001	
Lupe						
Mean no. *	1.5	0.9	2.0	1.5	2.4	0.9
SE	0.178		0.196		0.232	
t-statistic	3.391		2.709		6.637	
P value	*P* = 0.003		*P* = 0.018		*P* < 0.001	

* Mean number of birds per five-minute count.

4.3) summarises the number of kilometres travelled along the three sections of road in September 1994 and 2004.

3.3 KIU SURVEY

On 19 September 2004, all sites where kiu (Pacific golden plover, *Pluvialis fulva*) were likely to occur were visited between 08:20 am and 10:45 am, and kiu were counted. Sites chosen were readily accessible from the main roads, such as village greens, house lawns, school grounds, Niue golf course, and Hanan International Airport runway.

3.4 RODENT INDEX TRAPPING

In September 2004, Victor Professional® rat traps, similar in design and mechanism to the Ezeset® rat traps used in December 1994, were set along each of the three transects. The aim was to determine the species present and habitat selection, and to provide an index of each specie's abundance. Traps were set in vegetation 1–5 m off the vehicle track near each of the bird count stations and, therefore, were 200 m apart. One trap was set per site with no cover over the trap unless it was in thick undergrowth. The traps, baited with cheese, were set for three fine nights. They were checked daily, and all intact rats were weighed and, if possible, identified to species and sexed. The habitat at each trap site was determined as either regenerating scrub or forest. None were set in gardens. The index of abundance (captures per 100 trap-nights) was calculated, as indicated in Cunningham & Moors (1996), taking into account sprung empty traps, and non-target captures, e.g. crabs.

3.5 STATISTICAL ANALYSES

3.5.1 Five-minute bird counts

When determining the difference in the counts for a species, for a particular transect the difference between 1994 and 2004 means at each station was taken. Only stations where counts were taken in both 1994 and 2004 were included. A *t*-test on the station differences for each transect was used to establish whether the mean difference was significantly different from zero. This is equivalent to a two-sided paired *t*-test for a difference between the means for 1994 and 2004. Based on Johnson (1995), a *t*-test approach was seen as more appropriate for comparing means, in particular means of these station means, than a Mann-Whitney U test. For each transect, the mean of the included stations means was calculated.

3.5.2 Rodent index trapping

The chi-square test was used to compare total rat captures between transects and in total for 1994 and 2004, and kuma and ship rat captures between habitat types.

4. Results

4.1 FIVE-MINUTE BIRD COUNTS

4.1.1 Heahea (Polynesian triller, *Lalage maculosa*)

During the September 2004 visit, heahea were vocal and territorial. Territorial disputes were frequent, involving much chasing and loud song. Many pairs were breeding, with adults regularly seen carrying invertebrate prey. One nest was found at which the adults were feeding large chicks, and many pairs were seen feeding one or two fledglings. Most heahea were seen foraging for invertebrates through the foliage in the scrub and forest canopies. In addition, a few birds were seen foraging on roads and lawns, presumably taking mainly invertebrates, but on one occasion a heahea was observed subduing a small skink.

A comparison of the index of abundance (conspicuousness) for heahea in September 1994 and September 2004 (Table 1), as determined by the five-minute count technique, indicates that there was little difference in abundance along the Mutalau transect. However, there were significantly more heahea in 2004 than in 1994 along the Fue transect ($P < 0.05$), and Vinivini transect ($P < 0.01$).

4.1.2 Miti (Polynesian starling, *Aplonis tabuensis*)

As in 1994, miti in 2004 were widespread over Niue wherever forest was present. Occasional miti were seen visiting nest cavities, but it was not obvious whether incubation or brood-rearing was occurring. However, several pairs were accompanied by food-begging fledglings.

As determined by the five-minute count technique, there were significantly fewer miti along the Mutalau transect in 2004 than in 1994 ($P < 0.05$) (Table 1). However, the mean number of miti detected per count was not significantly different for the Fue and Vinivini transects between the two years.

4.1.3 Kulukulu (purple-crowned fruit dove, *Ptilinopus porphyraceus*)

Kulukulu were widespread in forested areas of Niue in September 2004, mainly evident by their distinctive and loud calls. While the regular, loud calling of kulukulu (males calling to attract mates and to indicate territory occupancy to other males; Gibbs et al. 2001) suggested that breeding was underway, no nests were found, and only one recent fledgling was seen.

A comparison of the results from the 1994 and 2004 five-minute counts for kulukulu along the three transects were quite variable (Table 1). There was no significant difference for the Fue transect, significantly more kulukulu were detected along the Vinivini transect in 2004 ($P < 0.001$), and significantly fewer were detected along the Mutalau transect in 2004 ($P < 0.001$).

4.1.4 Lupe (Pacific pigeon, *Ducula pacifica*)

In September 2004, lupe were seen and/or heard wherever tall, diverse forest was present on Niue. No occupied nests were found, nor were recent fledglings seen. However, it is probable at least some lupe were nesting, given the frequent calling by both sexes (especially males), the occasional display flight, and the fruiting of a variety of tree species.

The mean number of lupe detected along each of the transects was significantly fewer in 2004 than in 1994 (Table 1). The decline varied from 28% for the Fue transect to 64% for the Vinivini transect.

4.2 OBSERVATIONS OF OTHER BIRD SPECIES

4.2.1 Hega (blue-crowned lory, *Vini australis*)

There were nine sightings of hega (all birds in flight), one of a singleton, the others of pairs. Four sightings were of birds along the Fue track, mainly within a kilometre of the Alofi–Liku Road (Fig. 1), one sighting from the Alofi–Liku road between the Fue and Vinivini tracks, three sightings along the Vinivini track within 300 m of the Alofi–Liku road, and one sighting about 3 km along the Mutalau track from the Alofi–Lakepa road. The concentration of hega sightings along the Vinivini and Fue tracks near the Alofi–Liku road, was much the same as in 1994 (Powlesland et al. 2000).

Introduced pests, such as ship rats and feral cats, can cause serious declines in populations of forest bird species on islands through predation and/or competition for food (Atkinson 1985; Powlesland et al. 2000). Decline of a species to the point that it becomes rare makes it much more vulnerable to extinction from a catastrophic event, such as a cyclone. There was concern for the continued existence of the hega on Niue because it was infrequently seen before cyclone Heta. However, the sightings of hega during the September 2004 visit suggest that the population remains as scarce as it was previously.

4.2.2 Veka (banded rail, *Rallus philippensis*)

Butler (2004) saw just four veka when travelling about the island during 26–29 January 2004. During our two-week trip in September 2004, veka were seen regularly on roads, adjacent to all habitat types (forest, regenerating scrub, and gardens). However, the rate of sightings (birds per kilometre) in September 2004 was about half that of September 1994 for each section of road (lower terrace: 0.07 in 1994, 0.03 in 2004; upper terrace: 0.44 in 1994, 0.18 in 2004; inland: 0.21 in 1994, 0.10 in 2004). Whether this decline in veka sightings relates to mortality associated with cyclone Heta, an increased incidence of deaths from collisions with faster-moving vehicles following the tar-sealing of most main roads during 2000, or some other factor is unknown. During September 2004, adult veka were occasionally seen with young 1–3 weeks old.

4.2.3 Lulu (barn owl, *Tyto alba*)

Lulu were frequently seen during dusk counts of peka at various sites about the island (Brooke 2005). Single lulu were seen flying over gardens and scrub-covered areas as they searched for prey. Sightings indicated the species was widely distributed, from coastal to inland locations.

4.2.4 Kale (purple swamphen, *Porphyrio porphyrio*)

Three sightings of kale were made during this visit, two at the roadside near Vaiea, and one at Vaipapahi Farm near Toi. In addition, the distinctive call of a kale was heard along the Vinivini track adjacent to a bush garden. Thus, the kale continues to be a rare inhabitant of Niue.

4.2.5 Kalue (long-tailed cuckoo, *Eudynamys taitensis*)

Kalue were recorded on nine occasions during the September 2004 visit, all but one being of birds calling. Most kalue were detected in forest while we were involved in counts along the Mutalau, Fue, and Vinivini tracks. Since most adult kalue would have been in New Zealand when cyclone Heta occurred, there would have been little, if any, direct impact of the cyclone on the Niuean population of kalue.

4.2.6 Kiu vouvou (bristle-thighed curlew, *Numenius tahitiensis*)

There are few published records of kiu vouvou on Niue (Powlesland et al. 2000) so the sighting of a single bird on 19 September foraging on a patch of roadside lawn south of Alofi is worthy of note.

4.2.7 Motuku (reef heron, *Egretta sacra*)

Although motuku have occasionally been seen on Niue (Powlesland et al. 2000), even a small population has not persisted there during the past 30 years. This may be about to change with an influx of motuku in early 2003 (H. Talagi pers. comm.). During September 2004, a minimum of five motuku were seen, three white and two grey birds. Motuku were regularly seen feeding along the reef adjacent to Tamakautoga at low tide, one bird regularly foraged along the roadside at Kings Lookout, near Tamakautoga, and two birds were seen in flight over Alofi township. After cyclone Heta, motuku were seen taking the chicks of moa vao (feral fowl, *Gallus gallus*) near villages (H. Talagi pers. comm.). Presumably this indicates that usual prey of motuku was scarce at the time, because usually the species is quite wary and does not forage in or near villages. I. Mamaia (pers. comm.) found nests he thought were those of motuku in sparse vegetation along the coast near Liku, but it is not known whether chicks were fledged.

4.2.8 Tuaki (white-tailed tropicbird, *Phaeton lepturus*), taketake (white tern, *Gygis alba*), and gogo (common noddy, *Anous stolidus*)

Good numbers of all three of these seabird species were regularly seen foraging just offshore and in flight above central forested areas, so it did not seem that cyclone Heta had caused a major decline in any of these species. Athough two tuaki briefly landed at likely nest sites, and a few pairs of taketake were seen perched in the forest, neither species seemed to be nesting at the time. A few pairs of gogo were nest-building in the tops of canopy trees along the Fue track.

4.3 BIRDS PER KILOMETRE

In total, more kilometres were travelled while recording the numbers of birds seen in 2004 (830.3 km) than in 1994 (518.6 km). However, fewer kilometres were travelled along the upper terrace section of road in 2004 than in 1994 (Table 2).

For each of the five land bird species that mainly occupy forest and scrub habitats (heahea, miti, kulukulu, lupe, and veka), fewer were seen along each section of road in 2004 than in 1994 (Table 2). The only exception to this trend was that more miti were seen along the upper terrace road in 2004 than in 1994. Fewer pekapeka (white-rumped swiftlet, *Collocalia spodiopygia*) per kilometre were evident along the lower and upper terrace roads in 2004 than in 1994, but the reverse was the case along inland roads (Table 2). More kiu were seen along all sections of road in 2004 than in 1994. Of the three pelagic seabirds (tuaki, taketake, and gogo) that come ashore by day to nest in forest on Niue, the difference in numbers seen per kilometre in September 1994 and 2004 varied according to species and section of road (Table 2). Similar numbers of tuaki were seen both years along the lower terrace road, but more were evident from inland and upper terrace roads in 2004. More taketake were seen along the lower terrace road in 2004, but fewer along the other two sections. Similar numbers of gogo were seen per kilometre each year for each section of road.

4.4 KIU SURVEY

There were 6% fewer kiu counted in 2004 (212) than in 1994 (226) (Table 3). Numbers at each site were similar for the two counts, except for more in 2004 on the airport runway and the lawn areas of Alofi south, and fewer on the Avatele and Lakepa village greens and lawns of homes (Table 3).

TABLE 2. A COMPARISON OF THE NUMBER OF BIRDS SEEN PER KILOMETRE FOR 10 SPECIES ALONG THREE SECTIONS OF ROAD (LOWER, INLAND, UPPER) OF NIUE ISLAND IN SEPTEMBER 1994 AND SEPTEMBER 2004.

SPECIES	LOWER		INLAND		UPPER	
	BIRDS/km 1994	BIRDS/km 2004	BIRDS/km 1994	BIRDS/km 2004	BIRDS/km 1994	BIRDS/km 2004
Kilometres travelled	117.4	243.1	194.3	490.3	206.9	96.9
Heahea	0.33	0.09	0.28	0.17	0.23	0.07
Miti	0.16	0.07	0.30	0.13	0.15	0.24
Kulukulu	0.04	0.00	0.07	0.01	0.19	0.00
Lupe	0.01	0.00	0.40	0.07	0.48	0.09
Pekapeka	0.97	0.43	0.37	0.56	0.42	0.11
Veka	0.07	0.03	0.21	0.10	0.44	0.18
Kiu	0.37	0.69	0.10	0.15	0.34	0.68
Tuaki	0.06	0.07	0.06	0.15	0.12	0.22
Taketake	0.20	0.25	0.24	0.10	0.15	0.09
Gogo	0.04	0.02	0.00	0.04	0.03	0.08

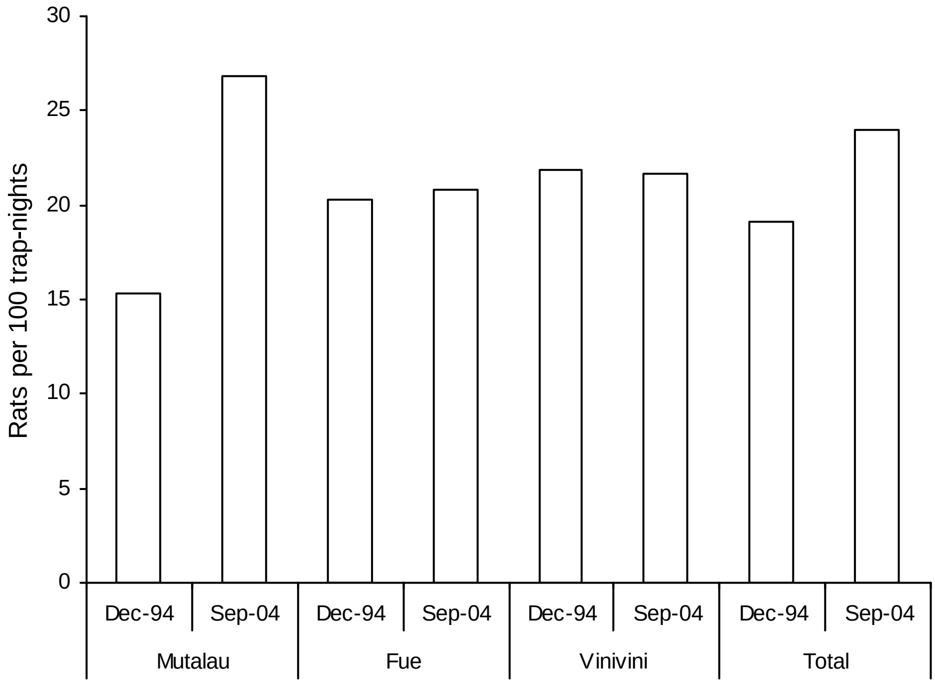
TABLE 3. COMPARISON OF KIU (*Pluvialis fulva*) NUMBERS AT VARIOUS SITES OF NIUE ISLAND ON 25 SEPTEMBER 1994 AND 19 SEPTEMBER 2004.

SITES	1994	2004
Alofi south to airport	1	6
Niue Sports Ground & Golf Course	42	45
Airport lawns	9	9
Airport runway	9	20
Alofi south, including museum and hospital, lawns	0	10
Tamakautoga to Alofi south	4	2
Avatele	16	5
Niumaga (Island style)	2	1
Vaiea and farm paddocks from road	14	14
Hakupu	6	6
Hakupu to Liku	1	0
Liku	30	27
Lakepa	26	6
Mutalau	4	5
Toi to Makauga	8	6
Vaipapahi Farm	8	4
Hikutavake	2	4
Namukulu	3	4
Tuapa	4	9
Avaiki	0	1
Makefu	5	4
Alofi north lawns and road	16	5
Paliati High School	15	12
Alofi central	0	1
Alofi primary school	0	0
Total	226	212

TABLE 4. HABITAT USED BY SHIP RATS (*Rattus rattus*) AND KUMA (*R. exulans*) TRAPPED IN SEPTEMBER 2004, NIUE ISLAND.

HABITAT TYPE	TRAP-NIGHTS	CAPTURES		
		SHIP RAT	KUMA	TOTAL
Fue				
Regenerating scrub	18	3	3	6
Forest	24	2	–	2
Mutalau				
Regenerating scrub	42	3	5	8
Forest	18	5	–	5
Vinivini				
Regenerating scrub	24	1	3	4
Forest	24	5	–	5
Total				
Regenerating scrub	84	7	11	18
Forest	66	12	–	12

Figure 2. Rat trapping results for each of three transects on Niue Island in December 1994 and September 2004.



4.5 RODENT INDEX TRAPPING

There was no significant difference in the rodent trapping index result for the three transects combined for December 1994 and September 2004 (Fig. 2) (χ^2 with Yates' correction = 0.345, df = 1, P = 0.557). Similarly, there was no significant difference between the results for each transect for December 1994 and September 2004 (Mutalau: χ^2 with Yates' correction = 1.103, df = 1, P = 0.293; Fue: χ^2 with Yates' correction = 0.012, df = 1, P = 0.914; Vinivini: χ^2 with Yates' correction = 0.002, df = 1, P = 0.969).

During 2004, rats were trapped at a similar rate in regenerating scrub (25.9 rat captures/100 trap-nights) and forest (21.6) (χ^2 with Yates' correction = 0.075, df = 1, P = 0.784). However, while ship rats were present in both regenerating scrub and forest, kuma were restricted to regenerating scrub; this result held true for each transect (Table 4).

5. Discussion

5.1 SURVIVAL OF FOREST BIRDS ON ISLANDS HIT BY CYCLONES

Cyclones are natural catastrophes that the native bird populations of Niue have survived and adapted to over thousands of years. Cyclones can cause massive canopy damage to forests, often defoliating or uprooting trees, and snapping of stems and branches (Burslem et al. 2000). No doubt, most forest birds have behavioural mechanisms to avoid being blown off an island during a cyclone, such as avoiding flight and seeking shelter on or near the ground (Wiley & Wunderle 1993). While such adaptations would not prevent the mortality of some individuals, presumably they would enable sufficient to survive to enable the population to recover to its pre-cyclone abundance and distribution. The greatest threat of a cyclone to most forest bird populations is not the level of mortality during the cyclone, but the loss of food supplies or foraging sites, increased vulnerability to predation, and increased conflict with people afterwards (Wiley & Wunderle 1993). The most vulnerable forest bird populations have a diet of nectar (hega), fruit (miti, kulukulu, and lupe) or seeds. These foods are often entirely removed from trees during very strong cyclones, such as Heta.

Adaptations to avoid mortality during a cyclone would only be useful if an island was of sufficient size and variety of landforms (such as terraces or sheltered valleys), to preserve some reasonably-sized patches of forest as food sources following the most destructive cyclone. This would enable at least small populations of each forest bird species to survive and eventually to re-colonise the defoliated areas once the forest recovered.

Other factors that need to be considered in this context are the impact of people on the extent of forest cover, and the impact of introduced pests on native bird populations. Survival of small populations in habitat fragments will be more precarious if the frequency and destructive potential of catastrophes increases, as predicted with global warming (Emanuel 1987). For example, on Niue, if a large proportion of forest is removed, or it is broken up into small patches, then a cyclone may cause so much damage to the remaining forest that insufficient patches remain unscathed to enable the birds to survive the subsequent critical weeks when there is little food available. The minimum area of forest needed to ensure the survival of each bird species on Niue is not known, but having at least one large patch that extends over a variety of landforms seems important given that trees were more often up-rooted at edges of forest behind cleared areas than in areas of forest away from the edge (Butler 2004).

Fruit-eating birds, such as lupe, kulukulu, and miti, and fruit bats (peka) are important seed dispersers, and so are important in the ecology of forests (Cox et al. 1991; Lee et al. 1991). Thus birds and fruit bats play a role in forest regeneration after cyclones. To ensure successful regeneration of the full complement of the Niuean forest flora about the island it is essential that fruit-eating birds and bats are fairly common and visit all forest patches. If these fruitdispersing species become scarce then the forests' ability to recover after cyclones and fires is likely to be compromised.

One way of assisting these species immediately after a cyclone when fruit sources are scarce is 'life-lining' (Lovegrove et al. 1992). Life-lining is the provision of food supplements to birds and bats at food stations in the wild for a few weeks or months while water and/or natural foods are scarce. Life-lining eliminates the need to catch and handle essentially healthy wild birds and bats, build captive facilities, settle them into captivity, and then ensure they are fit enough later to be released back into the wild. By his efforts in providing food to peka and lupe (see 1. Introduction), Misa Kulatea showed that these species readily found and took advantage of the supply. Once natural food sources again became available in the forest, several months after the cyclone, they no longer visited the food stations, preferring instead to feed in the forests. While life-lining concentrates birds and bats in a small area, exposing them to possible shooting or predation by dogs and cats, these problems can be overcome. Certainly life-lining is preferable to maintaining lupe and peka in captivity, because the latter is invariably quite expensive, and much time spent in captivity can compromise their ability to cope with release back into the wild.

5.2 HEAHEA

The five-minute counts indicated that heahea were more abundant in September 2004 than in September 1994 along the Fue and Vinivini transects, but not the Mutalau transect. Either cyclone Heta had little impact on the heahea population of Niue Island, or the surviving birds bred well after the cyclone and more than made up for any losses. Given the strength of the winds that tore most foliage and twigs from forest trees over more than 50% of the island, it is likely that some heahea were killed during the storm and others blown out to sea. Following the cyclone, several weeks would have elapsed before invertebrate prey populations would have begun to recover, especially the arboreal species that heahea mainly feeds upon in forest and regenerating scrub habitats. Whether the heahea population declined further during this time is not known, but from observations three weeks after the cyclone, Butler (2004) considered that the heahea population had declined significantly as a result of the cyclone. The rapid population recovery within eight months seems quite plausible given that it is a habitat generalist throughout its range (Steadman & Freifeld 1998; Steadman & Franklin 2000; Watling 2001), it has varied foraging habits (arboreally in forest and scrub habitats, on the ground in open habitats), and it has a varied diet (invertebrates, small reptiles, and fruit) (Watling 2001).

The re-sprouting of the defoliated forest trees, already evident within three weeks of the cyclone (Butler 2004), would have stimulated some invertebrate species to breed. As an indication that this did occur, by day butterflies were particularly evident along forest tracks and in coastal areas during our 2004 visit, and at night, moths and beetles were attracted to lights in their hundreds. Such aggregations were not seen during RGP's visits in 1994. Given that heahea feed extensively on arboreal invertebrates, especially caterpillars (Watling 2001; RGP pers. obs.), and have a long breeding season (at least March to

November (Powlesland et al. 2000; Watling 2001)), some pairs of heahea may have reared two or even three broods (one or two chicks per brood) during February–August 2004 as foliage of forest and scrub regenerated. Similarly, Lovegrove et al. (1992), using the five-minute count method, found that the Polynesian triller in Western Samoa (*Lalage m. maculosa*) had increased at 3 of 11 sites within three months of the very destructive cyclone Val, but it was not known whether this was due to dispersal or breeding.

5.3 MITI

Fewer miti were evident along the Mutalau transect in September 2004 than in September 1994, but there were similar numbers along the other two transects for the two surveys. Likewise, Lovegrove et al. (1992) found that the same species on Western Samoa had declined at 4 of 11 sites re-surveyed 3 months after cyclone Val. The result for miti on Niue may relate to the prominence of fruit in the miti's diet, and the lesser impact of the cyclone on forest of the eastern side of the island. The Polynesian starling elsewhere in the Pacific tends to be a habitat generalist, and increases in relative abundance with increasing maturity of forest (Steadman & Franklin 2000). It feeds mainly on fruit, and eats some insects (Feare & Craig 1999; Watling 2001). How important fruit are in the diet of miti on Niue is not known. If they are important, especially for breeding, then the miti population would be much slower to recover from any decline associated with the cyclone than the heahea. Firstly, there would be intense competition for any fruit remaining after a cyclone given that kulukulu, lupe, and peka all feed mainly on fruit. Secondly, while trees and shrubs start sprouting foliage within a few weeks of being defoliated by a cyclone, the availability of flowers, and later fruit, would be several weeks, or perhaps months, later.

The geographical change in numbers of miti between the two surveys probably related to the variable impact of the cyclone on the forest from west to east (Butler 2004). Almost all foliage was stripped from forest on the north-western section of Niue, reflecting the dominant NW wind direction during the cyclone. About the middle of the island (Mutalau track area), the foliage of some trees remained intact. Even further east (Fue and Vinivini track areas) small patches of forest appeared untouched. The miti population is expected to recover readily from the decline evident along the Mutalau transect once conditions in the adjacent forests return to normal.

5.4 KULUKULU

As its Palangi (English) name implies (purple-capped fruit dove), the kulukulu feeds predominantly on small fruit (Gibbs et al. 2001; Steadman & Freifeld 1999; Watling 2001). However, there would have been few fruit available for kulukulu after the cyclone, particularly in the north-western forests of Niue. After the cyclone, kulukulu were desperate for food as evidenced by doves searching for food and water in villages—places where they are rarely seen foraging normally (M. Kulatea pers. comm.; Freifeld 1999). Although kulukulu are not usually hunted by people these days, no doubt some doves would have fallen prey to cats and dogs while weakened by hunger and thirst in or near villages. Presumably many kulukulu moved to the eastern side of the island (where food would have still been available in patches of intact forest), or subsisted on leaf shoots and flower buds until fruit became available.

These observations help to explain the findings from the comparison of the 1994 and 2004 five-minute count results for particular transects. Significantly fewer kulukulu were evident along the Mutalau transect in 2004. This was probably because there was little fruit available in the adjacent forest, and little would have developed in the subsequent eight months. Also, kulukulu from this area may have moved further east. Along the Vinivini transect the species was significantly more evident in September 2004 than 10 years previously, perhaps because of a shift of doves from the cyclone-affected forests in the west to those less affected in the east.

Although the results indicate there were significantly fewer kulukulu present along the Mutalau transect in 2004 than 1994, there were ample kulukulu still surviving for the population to recover. As the forest recovers, fruit production will return to normal, enabling kulukulu to breed. In addition, given the declining number of people on Niue in recent years (Richmond-Rex et al. 2001), the area of bush gardens being left to regenerate is increasing, which may gradually result in an increased area of suitable habitat for forest-inhabiting birds such as kulukulu.

5.5 LUPE

Lupe were significantly less conspicuous along all three transects in September 2004 than in September 1994 (Table 1)—the decline per transect varied from 28% to 64%. Like kulukulu, lupe were seen in villages along the western side of Niue after cyclone Heta searching for food and water. Because they are hunted, lupe are usually very wary of people and avoid foraging in or near villages. This phenomenon of 'acquired' shyness in hunted bird species has been observed on other Pacific islands (Barrett & Freeman 1986). A flock of several hundred lupe on Niue foraged in low scrub near the airport (M. Kulatea pers. obs.), apparently feeding on lantana seeds. Lupe were not usually seen foraging in such habitat, generally inhabiting diverse and relatively undisturbed native forest, as they do on other islands (Freifeld 1999). Some birds were so weakened by lack of food that they were able to be caught by hand and taken into captivity (M. Kulatea and B. Pasisi, pers. comm.). We expect that people took advantage of this situation and harvested some lupe, and others were preyed upon by cats and dogs. Lupe numbers declined markedly in Samoa and American Samoa following cyclones in the early 1990s (Lovegrove et al. 1992; Watling 2001). However, we believe it is unlikely that the lupe mortality directly or indirectly caused by cyclone Heta on Niue, would have brought about the dramatic population decline evident from the five-minute count results.

Lupe feed mainly on fruit (Gibbs et al. 2001; Steadman & Freifeld 1999; Watling 2001), although they can probably subsist on leaf buds and shoots, and flower buds and flowers when their preferred foods are in short supply (Watling 2001). Given that the lupe's diet is similar to that of the kulukulu, it is noteworthy that the lupe population had declined by about 50% since 1994 (28-64% per transect), whereas the transect results for the kulukulu were contradictory. A major difference is that the lupe is subject to cultural harvest (by shooting) and the kulukulu is not. There is a keen interest in hunting lupe, both during the legal season (December–January annually, March in recent years too) and outside of it. We suspect that this is the main cause of the decline in the lupe population. From interviews carried out by Anne Brooke and John Talagi with 13 hunters in September 2004, it transpired that these hunters had shot an average of 85 lupe each during December 2003. There were 425 shot guns registered in December 2003, and each hunter was entitled to 100 cartridges per gun for the shooting season (M. Tongatule, Acting Police Chief, pers. comm.). Although some cartridges would have been fired at peka, a reasonable proportion would have been fired at lupe. Even if there were only 60 active, the hunter interviews suggest they shot about 5000 lupe in December 2003 (A. Brooke, pers. comm.).

To estimate the impact of such a harvest on the lupe population of Niue, we have made the following assumptions in calculating the lupe population:

- About 33.5% or 8755 ha of Niue's 26 173 ha was habitat suitable for lupe: coastal forest, mature tropical forest, and late stage regenerating forest (Martell et al. 1997).
- There were 2.55 lupe per hectare in September 2004 as determined from the figure of 1.1 per five-minute count area of 3.14 ha (radius 100 m), but with only 50% of the area being of suitable habitat, and that only 25% of lupe were seen or heard.

This gives an estimated total of 22 325 lupe on Niue in September 2004. Thus a harvest of about 5000 lupe from a population of about 30 000 in December 2003 is 16.7%, a large proportion for a species to replace before the next hunting season, given that it lays just one egg per nest (Watling 2001). If our assumption of the proportion detected during the five-minute counts is too conservative (more than 25% are detected during counts), this would reduce the total population estimate and so indicate the population is under greater threat from hunting than suggested here. Even if the hunters exaggerated their tallies of lupe harvested, say by as much as 50%, then the proportion harvested would reduce to about 10%. This is still a sizeable proportion of the population, given its low breeding rate, and the likely severe predation of eggs and chicks by ship rats on Niue (James & Clout 1996).

5.6 BIRDS PER KILOMETRE

We doubt that our comparisons between years of counts of birds seen along roads and converted to numbers per kilometre reflect true changes in population status (declining, static, increasing) because we did not count along the same section of road to determine variance, and did not control for time of day or weather conditions, other than not counting while it was raining. Two observations indicate that time of day and/or weather can influence the number of certain species seen. Tuaki, taketake, and gogo were commonly seen flying over inland forested areas of Niue each day during our trip in September 2004.

However, no seabirds were seen inland during a day of windy weather following a wet and windy day. Similarly, M. Kulatea (pers. comm.) reported that no seabirds were seen over Niue for several days following cyclone Heta. Secondly, time of day had quite an influence on sightings of pekapeka along roads. Pekapeka (white-rumped swiftlet, *Collocalia spodiopygia*) were regularly seen at specific locations, particularly where the road went through tall closed forest. Generally, in the morning and early afternoon pekapeka fed while moving through an area mainly above the forest or scrub canopy. However, by mid-afternoon numbers began to build up along roads, with highest counts occurring during the two hours before dark, when 2–10 birds constantly flew back and forth along a stretch of c. 100 m, generally within a couple of metres of the ground. Similarly, time of day influenced the number of lupe seen from roads during trips in 1994 (Powlesland et al. 2000), with flocks flying to coastal forest in the early morning, and returning inland during the evening. A territorial species such as the heahea seems the most suitable for this methodology. However, fewer heahea were counted along all three sections of road (lower, upper, inland) in 2004 than in 1994 (Table 2), while the five-minute count results from transects indicated the reverse (Table 1).

5.7 KIU SURVEY

This survey detected little difference (6%) in the number of kiu on Niue in September of 1994 (226) and 2004 (212). Each August, kiu numbers start to increase as adults and juveniles arrive from the breeding grounds in Siberia and western Alaska (Heather & Robertson 2000) to spend the non-breeding season (August–March) on Niue. Thus the 6% difference between the two counts may reflect that the 1994 count was carried out later in September than that in 2004. Whatever the reason for the slight difference in the two counts, it is evident that there had been no obvious impact of cyclone Heta on the kiu population.

5.8 RODENT INDEX TRAPPING

There was no statistical difference in the rodent capture rates (numbers per 100 trap-nights) between December 1994 and September 2004 for each transect, and in total (Table 4). This was to be expected because elsewhere in the Pacific kuma breed during most or all months, and population numbers remain fairly constant year round (Koeppl et al. 1979). The population dynamics of the ship rat on Niue are probably similar, given that it has a 10–12 month breeding season on tropical islands (Innes 1990).

Ship rats dominate kuma in enclosures (McCartney & Marks 1973), and in the wild kuma are restricted to grassland or thick ground cover in the presence of ship rats (Taylor 1978, 1984). Thus the finding that kuma on Niue were restricted to habitats containing thick ground cover (regenerating scrub) in the presence of ship rats, is in line with findings from elsewhere. During the trapping session on Niue in September 2004, kuma were trapped in areas of thick ground cover, mainly dominated by the fern *Nephrolepis hirsutula* in the regenerating gardens. Most heahea, miti, kulukulu, and lupe probably nest in mature forest (Watling 2001), so any rodent control to reduce predation at their nests should be carried out in mature forest and take into account that just ship rats would initially be exposed to control measures. When ship rat numbers are controlled to low levels this would probably allow kuma to invade from adjacent scrub.

6. Recommendations

From these observations the authors make the following recommendations in relation to work needed to secure the recovery of bird species on Niue.

1. Encourage (by all appropriate means) a ban on the hunting of lupe and the critically scarce peka (Brooke 2005), for several years to enable their populations to recover.
2. Investigate ways to support the Niuean Government's ban on the hunting of lupe and peka (both toaga species for Niueans).
3. Facilitate the re-survey of the lupe population in September prior to any planned hunting season using the five-minute count methodology and the same transects as used in 1994 and 2004 to determine whether the population has recovered to 1994 levels. The lupe and peka populations may take several years to recover.
4. Ensure relevant staff are fully involved in re-surveying the lupe population with a view to them receiving sufficient training to enable them to carry out such surveys independently in the future.
5. Prepare a poster of the key findings from the five-minute count study of heahea, miti, kulukulu, and lupe populations in September of 1994 and 2004 with the aim of increasing awareness among the Niuean community of the need for a ban on hunting of lupe and peka until re-surveys show that their populations have recovered to 1994 levels.
6. Any future hunting season on lupe (and peka) should take account of the need to ensure that the level of harvest is sustainable in the long term. To achieve sustainable harvesting, the following actions/information are needed:

- Survey the lupe population in September using the five-minute count method along the Mutalau, Vinivini, and Fue tracks.
- Request hunters to provide a record of number of shells fired at lupe (and peka), and how many of each species were killed. (Provide a record sheet/booklet for data entry = hunter diary.)
- Accompany some hunters to record hunting success, and age ratio of prey.
- At the end of the shooting season, obtain information from the Police Department of the number of registered shot guns, or preferably the number of hunters, and the number of shells sold for the season.

- Re-survey the lupe population in February using the five-minute count method along the three transects to determine whether the impact of the hunting season can be detected.
- Model the likely impact of the hunting harvest on lupe/peka populations, and its likely implications for the next hunting season.
- Develop a cyclone contingency plan to manage injured and starving wildlife after a cyclone, particularly kulukulu, lupe, and peka.
- Develop wildlife conservation education materials suitable for school children, and also for distribution to villages.
- Encourage appropriate training for staff with responsibilities in the areas of wildlife monitoring and predator control on Niue.

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