THE STATUS OF THE *PEKA* ON NIUE, POPULATION SURVEY OF THE FLYING FOX, *PTEROPUS TONGANUS*.

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Summary

During September 1998 field surveys were conducted to estimate the population of *Pteropus tonganus* and three Huvalu Forest conservation officers were trained to monitor bats by evening dispersal counts. The island-wide population was estimated at 1,900-3,800 bats from dispersal counts of colonies, while at the 22 stations established to monitor the long-term changes in the bat population, 447 bats were sighted. Only one colony was identified in the Huvalu Forest, in or near the Liku tapu area, while the two largest colonies were found northeast of the Huvalu Forest.

We interviewed or had written questionnaire responses from 27 hunters who shot ca 574 bats (21.3 bats/hunter) during the 1997-1998 season. As these responses were inflated by a small number of 'good' hunters, it is likely that a total of 1,000 – 1,500 bats were shot. A small but constant amount of hunting occurs throughout the year and an unknown number of bats are shot outside of the legal hunting season. There is little pressure, legal or social, for hunters to comply with the two month limit on hunting. Most bats are shot in flight at dusk or at dawn but when hunters locate a colony, many bats can be shot at one time.

Based on the current population estimate of 1,900-3,800 animals, a maximum of 750 bats can be sustainably harvested. If the current level of hunting continues the population will become increasingly smaller and risk extinction from overhunting, cyclones, or disease introduced by people. A population of at least 8,000 bats is recommended to maintain an annual sustainable hunt of 1,500 and to be resistant to other perturbations, such as cyclones and disease. A temporary ban on hunting for two years will allow the population to increase to this number.

Recommendations

1) Temporarily ban hunting for two years to allow the population to increase to ca. 8,000 animals, a size that can sustain the current rate of hunting. A temporary hunting ban will be an unpopular measure and will be difficult to enforce. Monitoring the bat population will be critical to determine when the population has increased sufficiently for hunting to resume.

2) Monitor the number of bats shot each year during hunting season. Two possible methods to determine the hunter take are: 1) survey a random sample of hunters at the close of hunt 2) require hunters to report how many bats they shot in the first month of the hunt when they purchase the second months' ammunition.

3) Close the Huvalu Forest to hunting: specifically Vinivini track, Pago Pago track, and the Alofi-Liku road where it passes through the Conservation area. This would provide an area of protection as most bats are shot flying across or near roads. Closing the Forest to hunting would be appropriate step toward making the Huvalu Forest a true conservation area.

4) The mature forest north of Alofi-Lakepa road is a prime roost and foraging area for wildlife. This area should be protected from cutting and included in the Huvalu Forest Conservation Area if possible.

5) Act to end out-of-season hunting by enforcement of the law and through social pressure on hunters. The number of bats shot throughout the year cannot be monitored and these hunters may take a significant number of bats each year.

6) Discourage hunters from shooting bats they find roosting during the day.

7) Public attention should be drawn to the small number of bats and what will happen if action is not taken to ensure the future of the bat population. As many people hunt, public support and community agreement will be very important in order for hunters to agree to limit the number of bats shot.

8) The profit made from the sale of ammunition would be appropriate to put into wildlife management and conservation, helping to fund bat and Pacific pigeon monitoring programs.

9) Development of Niue will benefit by retaining the existing mature forest in uninterrupted blocks. Limiting further development and clearing so new roads do not bisect the forest and limiting the introduction of electricity and water into areas within the forest will help to maintain wildlife habitat.

10) Plant native tree species rather than foreign species such as mahogany. *Kafika* (*Syzygium inophylloides*), *tualie* (*S. dealatum*), and *kanumea* (*Planchonella samoensis*) are native species that are desirable for local timber needs, grow well in Niue, and provide foods for Pacific pigeons, coconut crabs, and flying foxes.

11) After cyclones stop all hunting including taking bats from tapu areas to let the population recover.

SPREP TOR

Objectives of Survey

- determine the status of bat population estimates, distribution and, to the extent possible, other aspects of bats population dynamics in Huvalu specifically and Niue generally (the information is necessary for setting baselines for subsequent monitoring and population and bat habitat management purposes.);
- train selected number of Environment Unit staff in methods for bat surveys
- design and set up a system of observation stations for regular counting and
- develop and initiate a bat (*peka*) monitoring programme to be implemented by local staff of the Environment Unit and the Huvalu Forest Conservation Area Project community.

Methodology

The methodology used by John Engbring in his 1989 study and refined by Craig, Trail and Morrell in their Samoan study of 1994 (*Biological Conservation* 69 (1994) 261 - 266) is to be used in this survey.

The data collected should be both quantitative (field counts and estimates of total population covering all suitable habitat areas of Niue) and user-survey data to determine the impact of hunting and usage trends. Some of the specific outputs expected include: estimate of suitable habitat area; assessment of status of suitable habitat; population distribution and total population estimates for all suitable habitat areas.

Expected Outputs

- A report detailing the methodology used for data collection and analysis, statistical and socio-economic (usage trends and users etc.) data collected and analysed, findings from analysis, conclusions and recommendations for population conservation including recommended sustainable levels of harvesting of *peka* in CAP/Niue based on findings.
- the report should also assess the potential for ecotourism and implications for ecotourism development and management purposes.
- a minimum of 3 trained Niueans in bat surveying methods and in implementing and maintaining a bat monitoring programme.
- a system of observation stations already established
- bat monitoring and reporting programme to monitor bat population levels and the rate of harvesting by locals.

Introduction

Flying fox fruit bats are the only indigenous mammals on Niue. They are a key part of the forest ecology, pollinating forest trees and dispersing seeds, as well as an important part of Niuean culture as bats are a popular delicacy. In recent years, the flying fox population has apparently declined according to local residents. This report is the first quantification of the status of fruit bats on Niue.

Flying foxes are of crucial importance in maintaining the native forests on Niue by pollinating flowers and dispersing seeds. The role of flying foxes in forest ecology may be greater on Niue than on other Pacific islands. Bats are apparently the only native species that pollinate indigenous forest trees, such as *kafika* (*Syzygium inophylloides*) and *futu* (*Barringtonia asiatica*) since there are no birds that visit flowers (Cox et al 1992, Rainey et al 1995).

In the early part of this century, flying foxes were reported to be numerous (Loeb 1926). After the cyclone of 1960, the bat population declined substantially and in 1968, Wodzicki and Felten (1975) reported that the population was still quite low. Since that time, there has been no monitoring of the number of bats or estimation of the number of bats killed during hunting season.

Literature review

Accounts by European visitors to Niue in the 1800's and early 1900's reported that bats were numerous. In 1873, Brenchley observed "...a great number flying at considerable height during daylight". The New Zealand Government Resident in 1901, S. Percy Smith, lived on Niue for four months and wrote an account of how people lived at that time Niue Island and Its People (1902). He reported that bats were "... common, and large flocks of them are sometimes seen flying overhead."

During a seven month stay in 1923-24, Loeb (1926) described how bats were caught from permanent platforms built in the tops of *kafika* (*S. inophylloides*) trees, reached by a ladder. "Late in the afternoon or in the early morning the native would go to his *fata* and place a snare, which almost surely a few hours later brought a *peka* which was used as a decoy. Attracted by the animal's cry, other *peka* came near enough to be caught in a net. Natives say that one night's catch amounted to as many as fifty, seventy, and even a hundred and fifty. An expert, Takopo of Alofi, caught two hundred in one night". Although the hunters were using nets, the number of bats they were able to catch in one night indicates that the population was quite large.

Wodzicki and Felten (1975) did the first study of bats in 1968. They taxonomically identified the species present as *Pteropus tonganus tonganus* and gave the only existing ecological information on diet, roost sites, and behavior of Niuean bats. By 1968 the population had declined severely from the earlier abundance and the authors saw no flying bats. Information on roosting habits was obtained from a local inhabitant, Mr. Tohilima, rather than from the authors' observations. Mr. Tohilima considered the Hakupu tapu area in Huvalu forest as the main roosting area on the island and any roosts outside the tapu area were considered temporary. Most roosting bats that he had seen were single individuals or pairs; colonies of 20-100 were rare and found only within the tapu area, he reported having seen one roost of 200 bats. A list of 15 plant species that bats eat was provided and divided into preference categories from observations made by Mr. Tohilima and his brother. The authors considered that the bat population was at a very low level. They report that in June 1972 the General Assembly of Niue passed a Wildlife Ordinance that prohibited shooting of bats.

Grant published an account of two brief visits to Niue in 1993 and 1994 (1994). He saw few *P. tonganus* and found little evidence of bats from partially eaten fruit but he smelled bats at several locations. Grant interviewed Wayne Tagelagi, Environmental Officer, who thought that 300-500 bats were shot during the month-long hunting season in each of ten districts for a take of 3,000-5,000 animals. A hunter estimated that about 60 hunters shoot around 20 bats each season, for a take of ca 1,200 bats (Grant 1994).

Powlesland and Hay (1995) recorded few bats during three visits to Niue in 1994 to assess the status of bird populations. During their fieldwork they saw a total of 33 bats, most were seen flying overhead in the afternoon, one bat seen eating *le* fruit (*Macaranga seemannii).* Most of their observations were made during the day within mature forest from Vinivini track and Fue track.

Natural History
Flying foxes are bats in the family Pteropodidae, the largest group of old world fruit bats. In the genus *Pteropus*, 48 of 64 species are found on islands (Pierson and Rainey 1992). Approximately half of these species (23) have ranges that are confined to land areas of <10,000 km^2 (Pierson and Rainey 1992).

The *peka* or flying fox found on Niue, *Pteropus tonganus tonganus*, is a medium sized bat. It is also known as the white-collared flying fox, the Tongan flying fox, or the insular flying fox. Bats are a dark brown color with longer white or yellow fur on the back of the neck and shoulders (Fig.1). A systematic review gave the mean forearm size of nine bats collected on Rarotonga and Niue as 139 mm, (range 132-148 mm) although only one of these individuals was from Niue (Wodzicki and Felten 1980). Wodzicki and Felten were uncertain whether the population on Niue and Rarotonga should be considered *P. tonganus tonganus* or a new subspecies because the bats appear to be smaller than those from other islands.

Pteropus tonganus is common throughout the South Pacific and has the largest geographic range of any pteropodid species in Oceania (reviewed by Koopman and Steadman 1995). The range extends from the Schouten Islands and Karkar Island off the northern coast of Papua New Guinea, eastward to the southern Cook Islands, including the Solomon Islands, Vanuatu, New Caledonia, Wallis and *Futu*na, Fiji, Tonga, Samoa, and Niue (Wodzicki and Felten 1975; Nowak 1991; Rainey and Pierson 1992; Flannery 1995). *Pteropus tonganus* is found on the outlying islands on the Solomon Island chain but not on the larger islands. Small populations on Rarotonga and Mangia in the Cook Islands are the easternmost limit of flying foxes (Wodzicki and Felten 1975; Tiraa 1992). Archeological records from Mangaia, Cook Islands, show that *P. tonganus* was hunted and eaten for at least the last 1,000 years (Steadman and Kirch 1990).

Three subspecies of *P. tonganus* are recognized. *Pteropus tonganus tonganus*, the subspecies present on Niue, is found in the Cook Islands, Samoa, Fiji, Tonga, Wallis and *Futuna*. *Pteropus tonganus geddiei* is from New Caledonia, the Solomon Islands, and Vanuatu. *Pteropus tonganus basiliscus* is restricted to the islands off the coast of New Guinea (Mickleburgh et al. 1992).

Pteropus tonganus is highly colonial (Pierson and Rainey 1992). During the day, large groups of bats hang from the same tree or group of trees, known as a roost (Fig.1). Colonies of *P. tonganus* range in size from a few individuals to 4,000 or more (Brooke et al, in press). Traditional roost sites are in areas where bats are secure from disturbance but bats may move to other sites for a variety of reasons such as human disturbance or to be close to an abundance of fruit (Brooke et al, in press). Ectoparasites (ticks and mites) can accumulate at well used roost locations and moving to other locations may help limit infestations (Marshall 1982).

Within the roost, bats hang together in "harem" groups consisting of a single dominant adult male with several adult females and their young (Grant and Banack 1995). Young bats that are old enough to fly typically hang near their mother and look similar to adults, while young that are too small to fly hang on the mother beneath her wings. Groups of "bachelor" males, young males or bats that do not have a roost territory to defend, are separated from the female groups, often in a separate tree (Grant and Banack 1995). In American Samoa *P. tonganus* bear young throughout the year. Young bats are carried by the mother until they are able to fly at 2-3 months of age (Brooke 1997).

Study Area and Methods

Niue is an uplifted coral atoll in the South Pacific Ocean at 19° S latitude and 169° W longitude. The island is roughly oval shaped with an area of 260 km^2 and maximum elevation of 69 m. The interior of the island is relatively flat with a series of marine terraces that grade to sea level. Niue is isolated from neighboring islands, lying ca 480 km east of Tonga, 930 km west of Rarotonga, and 660 km southeast of Samoa. The tropical climate has two seasons, a warmer and wetter period from December-March, and a drier and cooler period, April-November. The mean annual temperature is 25 ° C with a daily variation of ±8 ° C; the mean annual rainfall is 204 cm. (Whistler and Atherton 1997).

Field surveys for this study were conducted between Sept. 4 and Sept. 27, 1998 at 67 sites distributed around the island with an emphasis on the Huvalu Forest Conservation Area (Fig 2 and Appendix 1). Field surveys were done by Anne Brooke, Marco Tschapka and three Huvalu Forest Conservation Officers who had been trained in survey techniques. Dr. Marco Tschapka from the University of Erlangen, Germany, is an experienced bat biologist and was hired to ensure that the field surveys would be completed in the limited time permitted. Dr. Tschapka worked exclusively for the project conducting surveys, looking for roost sites and did not undertake personal research during this project.

Training of conservation officers for conducting bat surveys
Three Conservation Officers, Logopati Seumanu, Masani Togiamanu, and Ioane Mamaia were trained in conducting bat surveys. Following a discussion of the methods and goals of the survey program, an evening of field training was carried out on Sept. 3, 1998 prior to the start of the actual surveys. After each evening's survey we discussed what had been seen, the implications of the sightings, and potential problems with survey site. The Conservation Officers have a working knowledge of the survey process and are fully capable of conducting surveys in the future. Care should be taken to follow the instructions handed out in the final briefing and to have enough people participating in the surveys that a large area, not only the Huvalu Forest, can be covered in as short a time as possible. A number of other people attended the final briefing who may participate in future surveys. Anyone who will work on the bat surveys should accompany one of the Conservation Officers for a night when a number of bats are seen for training.

Long-term Monitoring
Evening dispersal counts were made as bats left roost sites and flew to foraging areas using the methodology of Ebring (1989) and Craig et al. (1994) as specified in the TOR. 40 stations designated for monitoring population changes were selected to be at least 1 km apart to minimize repeat counts of the same individuals (Fig 3). All surveys were conducted in the early evening between ca 1800-1900 h from ca 30 minutes before dark until it was too dark to see clearly with the unaided eye. During each count we recorded the number of bats observed in five-minute intervals and the flight direction of each bat. Care was taken to avoid counting the same individual twice within each session and most bats flew directly through the survey areas and only rarely milled about or reversed direction. We did not conduct surveys on extremely windy and rainy evenings although most of the nights had strong winds. We observed flyways at two survey sites in darkness with a night vision scope to determine if the roost exodus continued beyond the time that we were able to watch bats in flight.

Observations were made from roads and clearings of taro plantations that had an unobstructed view of the forest. Observers watched for bats flying above the nearby forest and directly overhead both with and without binoculars. Sites were chosen that had mature or tall secondary growth forest adjacent to the clearings. Many of the survey stations were hunting stands with accumulated shotgun shells from several years lying on the ground. Because of the lack of hills viewing range was limited to cleared land and the immediate forest edge. At one location, the observer climbed a tree for a better view. During most counts one person watched from a station although at three stations two people watched in different directions.

Figure 1 Photograph of a *Pteropus tonganus* roost in American Samoa.

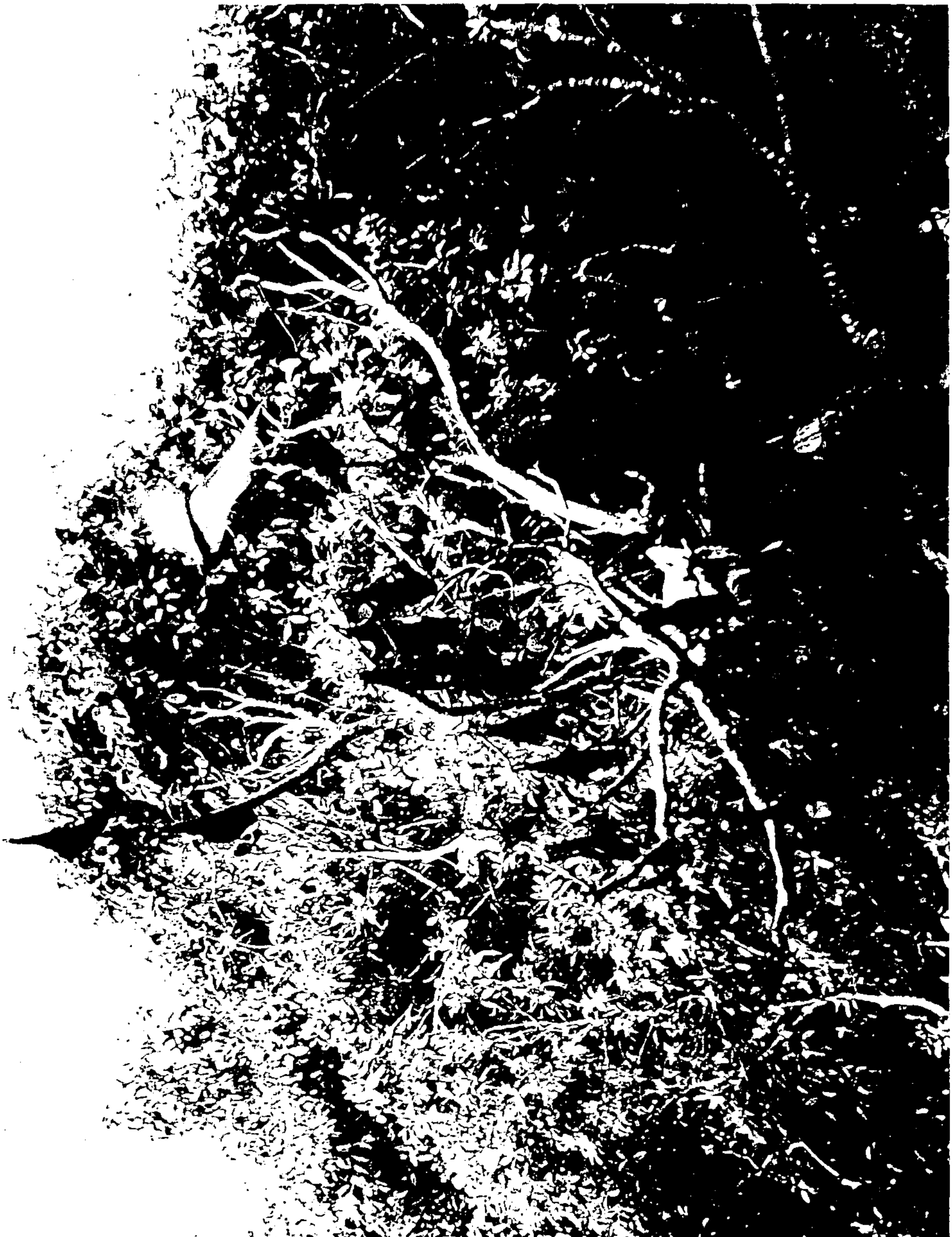


Fig 2 All survey stations
Dark lines represent paved roads, thin lines bush tracks

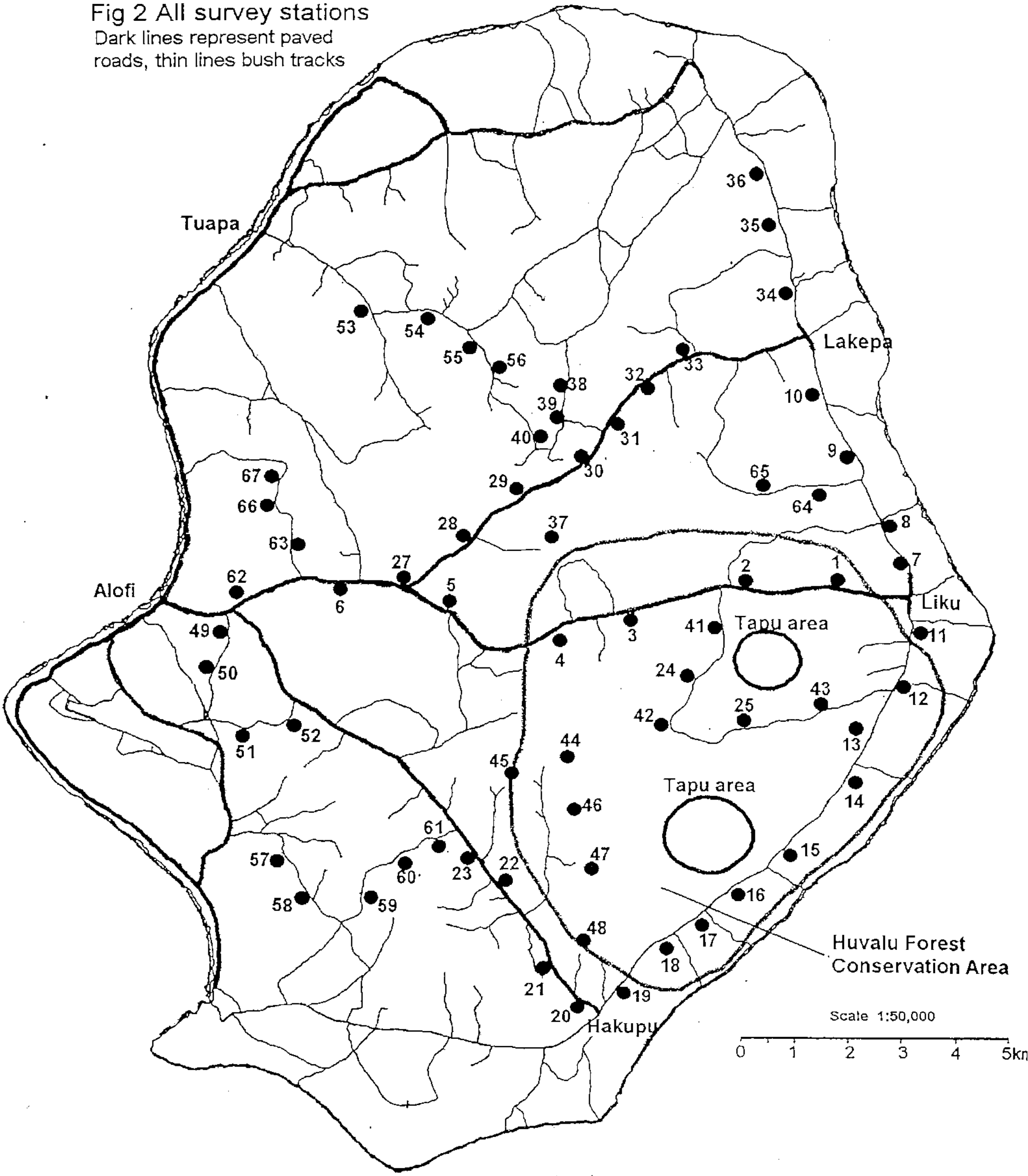
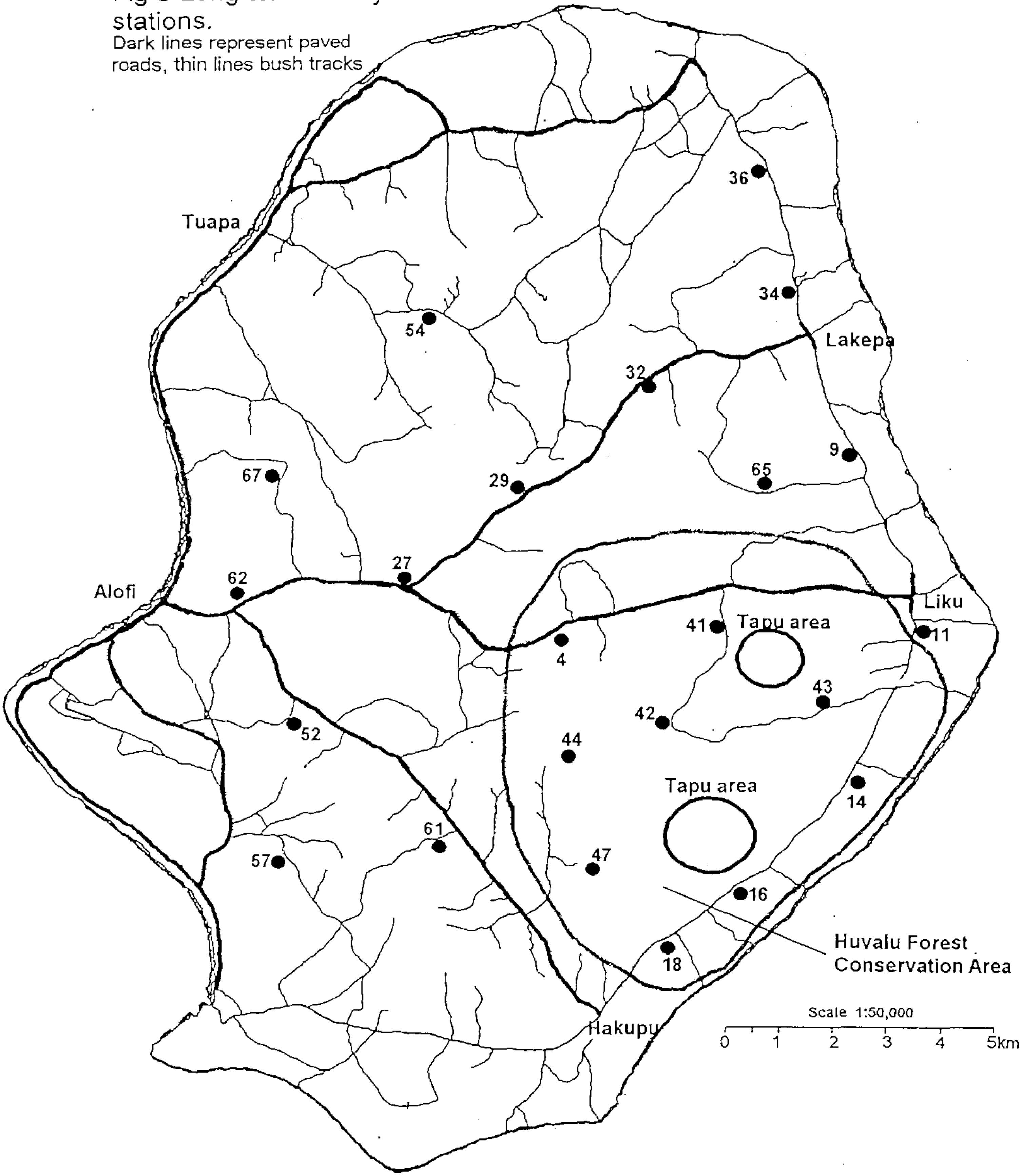


Fig 3 Long-term survey stations.
Dark lines represent paved roads, thin lines bush tracks



Population estimation

The total bat population was estimated from the number of individuals dispersing from colonies at dusk. The general location of colonial roosts were determined from the combined data of the 67 survey stations (Fig 2). An actual count of roosting bats would have provided a more accurate population estimate than the dispersal counts. We spent several days searching for three colonies after ascertaining the general roost area from the evening surveys but were unable to find them.

Hunter information

Prior to the field work for this study, I requested that the Conservation Officers distribute questionnaires asking the number of bats shot the previous year to as many hunters as possible. Twelve of 21 people returned questionnaires that had been given to hunters in Liku and Hakupu villages. We conducted verbal interviews with an additional 15 hunters who worked at the Department of Land, Surveys and the Environment, the Department of Community Affairs, and at a business in Alofi.

The Chief of Police, Andrew Lovelock, and Deputy Chief of Police, Maria Tongatule, provided information on the number of guns registered, the amount of ammunition sold, and enforcement practices of wildlife hunting regulations. The number of registered shotguns from 1984-1997 was collected from Annual Police Reports in the Library Archives. No reports prior to 1984 were available.

Sustainability estimate

The number of animals that can be sustainably harvested depends on the populations' growth rate. How fast a population grows depends on several factors: the age females reach sexual maturity, the number of young born to a female per year, how frequently females bear young, the sex ratio of the population, and the longevity of animals in a non-hunted population (Birch 1948). As none of this information is known from the Niue population data from other populations and species were used.

There are a number of methods used to determine whether a population is being over-harvested. The method most applicable to tropical mammals is Robinson and Bodmer's (1999) production model that derives the population's rate of increase according to Cole's formula (Cole 1954):

$$1=e^{-r} + be^{-r(a)} - be^{-r(w+1)}$$

where r is the maximum intrinsic rate of increase of a population not limited by food, space, resource competition, or predation; a is the age at first reproduction; w is the age at last reproduction; and b is the annual birth rate of female offspring, assuming an equal sex ratio of males to females. As there are no data on the sex ratio of the population in Niue, an equal number of males and females were assumed to reach sexual maturity. This information could easily be collected from bats shot during hunting season.

There are no data on the longevity of *P. tonganus* in Niue or elsewhere. Data from four species were used as an indication of the likely lifespan of *P. tonganus. Pteropus alecto* live for 3.5 to 4 years although the high mortality during this study may be atypical (Vardon pers. comm.). The estimated longevity for *Cynopterus brachyotis* and *Pteropnochirus jagori* are four to five years, with a maximum lifespan of six to eight years. The lifespan of *Haplonycteris fischeri* may exceed ten years (Heideman and Heaney 1989). From these data it seems reasonable that in an unhunted *P. tonganus* population, the average longevity would be between 5-10 years. Lifespan was used to estimate the number of animals born each year as there is no information on how frequently *P. tonganus* give birth (Robinson and Bodmer 1999).

The available bat habitat on Niue was estimated at 182 km^2 : 30 km^2 coastal forest, 120 km^2 light and scattered forest, and 32 km^2 of merchantable forest (Foresty Section, 1990).

The finite rate of population increase was calculated as

$e^r = 1.4918 = I_{max}$

using the growth rate = 0.4 as derived by for *P. giganteus* (Dolbeer et al. 1988) and *P. alecto.* (Vardon pers. comm.)

Two methods were used to estimate sustainable yeild. The first method uses the population growth rate to determine the percentage of the population that can be harvested.

Maximum % harvestable = $(Y_{rr}-1) * 100$ / habitat area

The second method assumes that *K*, the population density, is taken from an unhunted population that is not limited by foods or resource competition. The model assumes that production is density dependant and peaks when population density is 0.6*K* (Robinson and Redford 1991). The estimated population size on Niue has been used for these calculations even though it is heavily hunted and is not at its greatest natural size.

Maximum production, P_{max}, was calculated by multiplying the density at the point of maximum production by the maximum multiplication rate of the population. This holds the population stable through time (Robinson and Bodmer 1999).

$P_{max} = (0.6K * I_{max}) - (0.6K)$

Effective rate of population growth: $Y_{rr} = 1.1967$
was calculated $Y_{rr} = 1 + (I_{max}-1) fr r$ where $frr = 0.4$ for species with an estimated longevity of 5-10 years.

Maximum production that can be sustainably harvested: $Prr = (Y_{rr}-1)\ 0.6K$

The maximum possible production available for harvest was calculated by multiplying the density at the point of maximal production by the maximum multiplication rate of the population thus holding the population stable through time.

$P_{rr} = (Y_{rr}-1)\ 0.6K$

Habitat

The relative importance of mature, secondary, coastal, and littoral forest as foraging habitat was estimated for the Huvalu Forest using data from 21 botanical survey plots (Whistler and Atherton 1997). The relative dominance of nine tree species, identified as highly preferred flying fox foods (Banack 1999) was determined for each forest type.

Results

Long-term Monitoring: base-line population index

We observed 447 bats at the 22 long-term monitoring stations (Fig. 3, Appendix 2). As the data are non-normally distributed, (Kolmogorov-Smirnov distribution = 0.335, $P<0.001$) the mean number of bats per survey cannot be computed. At most stations few bats were counted: less than 25 bats were seen at 17 stations, less than 50 at 21 stations. Figure 4 depicts the uneven distribution of bat sightings resulting from concentrations of bats at colonial roosts. The greatest concentration of bats was in the central part of the island, including the northern part of the Huvalu Forest (Fig 5). The roost sites of flying foxes are not permanent and colonies move periodically as food resources change and people disturb roosting bats during the day. The areas of high bat density found in this study will not remain constant through time. The number of bats observed in this initial survey can be used as the baseline for comparisons in the future to monitor changes. Raw data from all surveys, the date, location, and observer, are given in Appendix 1

Figure 4 Frequency of bats seen at long-term monitoring surveys

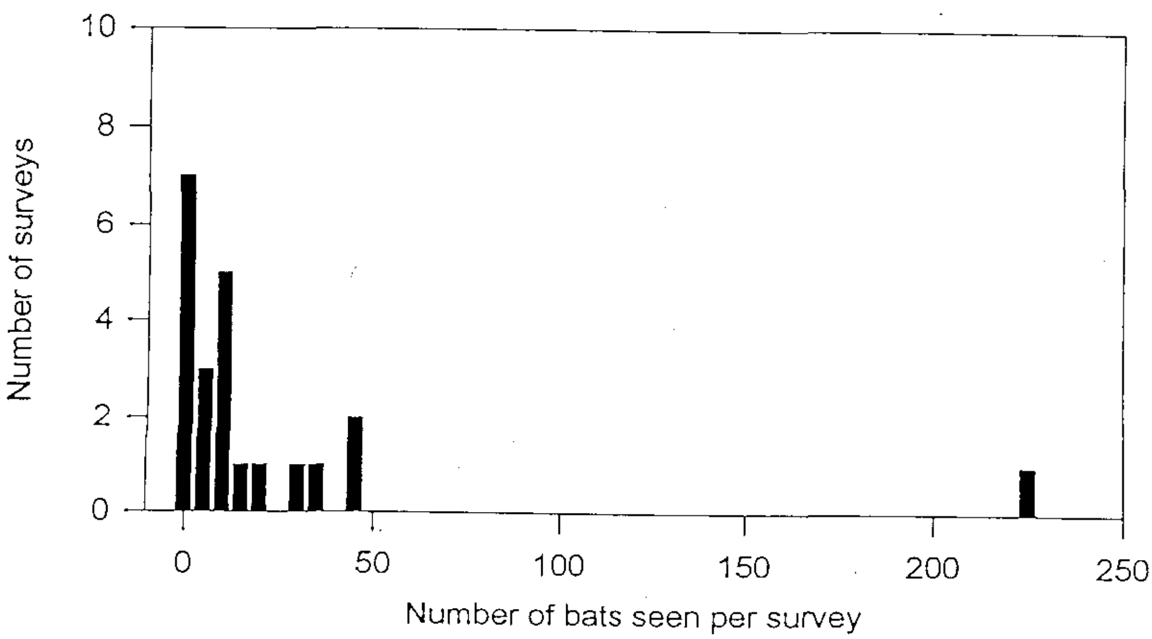
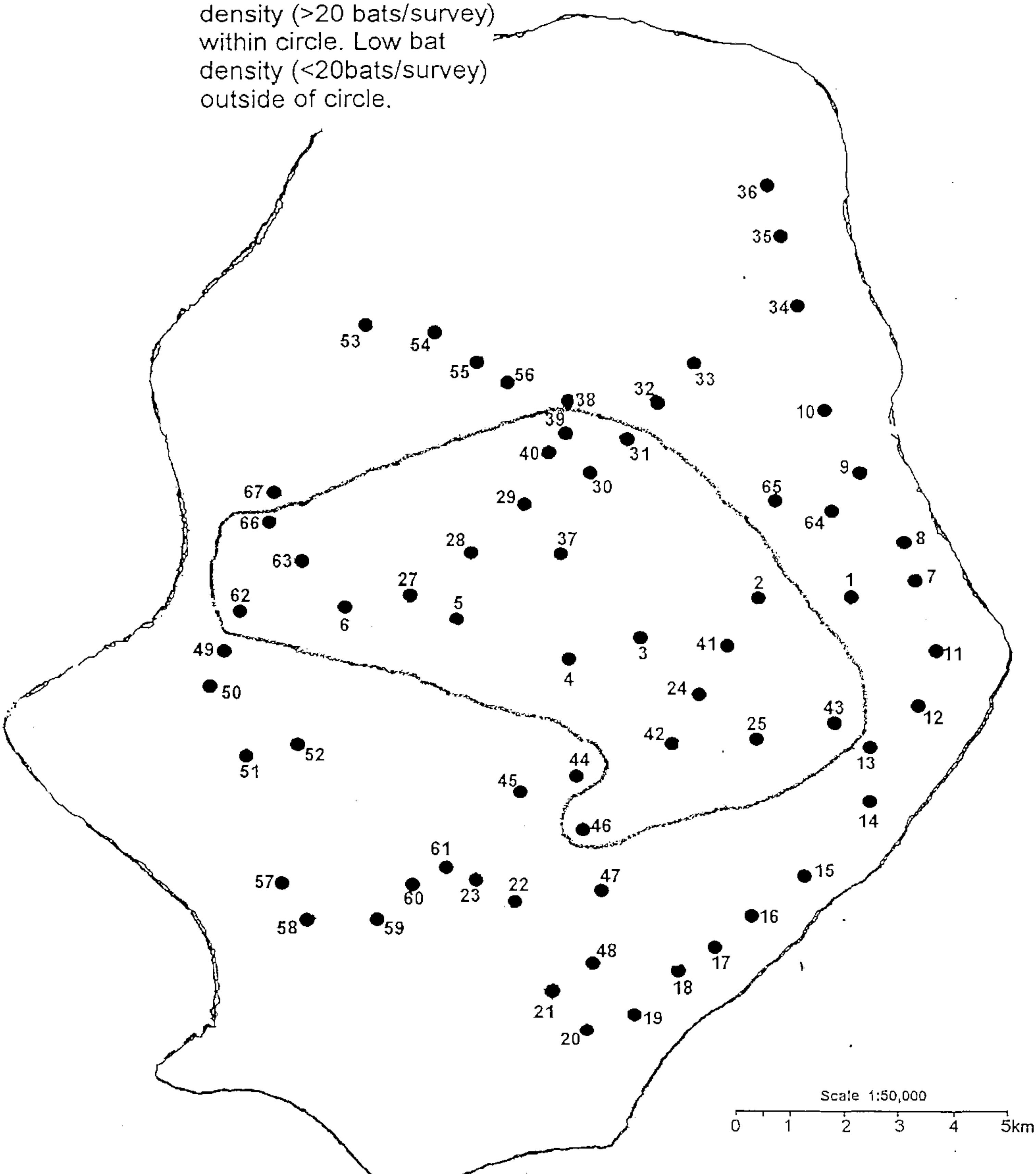


Fig 5 Areas of high bat density (>20 bats/survey) within circle. Low bat density (<20bats/survey) outside of circle.



In and surrounding the Huvalu Forest Conservation Area we conducted 29 surveys at 27 different sites, counting a total of 161 bats. Within the Huvalu Forest, the greatest number of bats were seen from five stations along Vinivini track. Many of the bats seen probably originated within the Huvalu Forest although we had previously observed bats fly into the Huvalu Forest from the north of the Alofi-Liku road (Fig.2; # 2, #3, #4, & #5). It is possible that some of these individuals were counted a second time when we used Vinivini track for survey sites. Surveys were conducted at 14 stations surrounding the Huvalu Forest: the Liku-Hakupu road, a clearing between Hakupu and Pagopago track, Pagopago track, and the Hakupu-Alofi road. We counted a total of 216 bats from these sites, most of which were seen in the Huvalu Forest to the east of Pagopago track (Appendix 1).

The evening surveys appear to be an accurate reflection of the bats present. We rarely saw bats flying before 1800h. Bats began to exit the roost areas at ca 1800h and the greatest numbers of bats were seen dispersing between 1825h and 1845h. No bats were observed seen after dark on three nights that we used a night vision scope, indicating surveys covered the window of time most bats dispersed.

The number of bats sighted on different nights can vary greatly even though the survey is done at the same place and same time. Bats don't always follow the same flight path consequently the number of bats observed at the same station can be quite different. The number of bats counted at stations where surveys were done on two nights differed by as much as 70% (Appendix 1, stations # 3, #24, #25, #63). This large between night variability illustrates why it is important to survey as many stations possible at the same time.

Population estimate and colony size

Based on the number and direction of bats seen in all surveys, we identified the location of four colonies. The two largest roosts that each had ca 600 and 800 bats, were located just north of the Alofi-Lakepa road, west of the Huvalu Forest. A smaller roost of ca 200 bats was south of the Alofi-Liku road. A landowner told us of a fifth colony of ca 100 bats east of Tuapa.

Only one large colony roosted within the Huvalu Forest. From observations of bats flying from east to west over the northern part of Vinivini track, we estimated that ca 200 bats roost in or near the Liku tapu area. Although the Hakupu tapu area is frequently referred to as a major roost, we found no evidence that it was used by a large number of bats at this time. We observed small numbers of bats in other surveys in and surrounding the Huvalu Forest. These animals may have originated from one of the known colonies, from a small colony in the Forest, or have roosted solitary. Wodzicki and Felten (1975) speculated that bats might have roosted in small groups of less than 20 individuals. Although we did not see very small roosts or hear of small roosts from residents, we have no evidence to indicate that they do not exist. Detecting single animals in tall forest is extremely difficult. The occasional solitary *P. tonganus* that have been found in Tonga and American Samoa have all been adult males.

Using the information collected during this study, the population was estimated to be 1,900-3,800 individuals. The lower population number was arrived at by combining the estimates of the 5 colonial roosts. To allow for undercounting and for forested areas where surveys were not possible, the minimal number of bats (1,900) was doubled. I believe that the higher number, 3,800, is probably a realistic assessment of the population at this time.

Hunting

Guns and ammunition

Guns and ammunition are used for both bats and *lupe* (Pacific pigeon, *Ducula pacifica*). In spite of the large number of people who have immigrated to New Zealand, there are more guns on island now than at any time in the past. In September 1998 the Police had registered 355-360 shotguns, double the number of guns registered in 1985. The length of the hunting season for both *peka* and *lupe* (Pacific pigeon, *Ducula pacifica*) and the amount of ammunition sold by the Police are determined by the cabinet. For the upcoming hunting season, December 1998-January 1999, there will be available 3,000 boxes of ammunition or 75,000 shots. Each box of 25 shells sells for NZ$20, a price that has remained the same for the past 8 years. Each registered gun is allotted 4 boxes of shells per month of the hunting season, for a total of eight boxes or 200 shells per gun. Only four boxes of shells or one months supply is sold to a hunter each month.

Hunter surveys

We received 12 written responses from the 21 hunter questionnaires distributed by the Conservation Officers. In the December 1997-January 1998 season, one hunter only shot *lupe*, (Pacific pigeon), two people shot between 0-10 bats, 7 shot 10-50, and 2 shot more than 50 bats. The 15 hunters interviewed shot 272 bats (mean = 18.1, S.D. = 16.1, range 3-50). By combining the mean values from the questionnaires with the results from the 15 verbal interview, 574 bats or an average of 21.3 bats were shot per hunter. I believe this is a high estimate of the number of hunter take killed because the written questionnaires were preferentially given to hunters known to be good shots. Based on this data and informal interviews with an additional ca 30 people, I estimate that 1,000 – 1,500 bats were killed during the 1997-1988 hunt.

I spoke at length with the Huvalu Forest Conservation officers and with the Director of Community Affairs on the importance of finding out the number of bats shot during the 1998-1999 hunting season. Two methods to determine the hunter take that we discussed were: 1) survey a random sample of hunters at the close of hunt, 2) require hunters to report the number of bats shot during the first month of the hunting season when they purchase shells for the second month. This information can then be used to determine harvest trends after data has been collected over several years.

Anecdotal reports of hunting

Several hunters spoke of shooting bats they found roosting and one hunter reported that he shot the bats so that people from a neighboring village wouldn't find the roost first. Hunting is practiced throughout the year by a number of people but the extent of illegal hunting is unknown. It is common knowledge that people hunt bats year-round although the greatest amount of hunting is undoubtedly done during the legal hunting season in December-January. Out of season hunting is an accepted practice and there is no enforcement of the hunting season regulations. We heard shots at dusk on several nights during surveys although we were unable to determine if the shots were aimed at bats or pigs.

Reproduction
There is some evidence that bats in Niue bear young throughout the year or over a long period that lasts from August through February. Wodzicki & Felten (1975) collected two baby bats when their mothers were shot in August and a pregnant female was taken in June. During the surveys in September we observed four different females carrying large young. Hunters report that baby bats of varying sizes were taken when females were shot in December–January. These observations are in agreement with data from other islands of year-round reproduction by *P. tonganus*. Whether there is a seasonal peak in births as suggested by Wodzicki & Felten (1975) is unknown.

The age of first reproduction for *P. tonganus* and the frequency females can bear young is unknown for any population. It is believed that all flying foxes bear a single young a year (rarely twins) and initially give birth when two years old (Pierson and Rainey 1992). Gestation for other flying fox species lasts for 5-6 months or 140-150 days (Pierson and Rainey 1992; Wing 1993). Recent field work has shown that female *P. melanotis* may become pregnant when 6 months old (Tidemann 1992) and female *P. alecto* can reach sexual maturity when 12 months old (C. Tidemann pers. comm.). It is possible that *P. tonganus* can give birth to two pups within an 18-month period but not conceive again for a time as has been predicted for *P. mariannus* in the Yap islands (Falanruw 1988). Alternatively, young females may delay the development of the embryo and not bear young until they are older (Heideman and Powell 1998).

Sustainable yield estimate
Two methods were used to estimate the maximum number of bats that can be harvested without lowering the population, or the maximum sustainable yield. The maximum percent of the population harvestable was calculated directly from estimates of the population growth rate taken from rapidly expanding *P. alecto* and *P. giganteus* populations (Table 1, #1). The maximum number of bats that can sustainibly be harvested from a population of 3,800 is 748 animals.

The second model calculates the maximum possible production of bats in a stable, non-hunted population that has reached the greatest size the habitat can support (Table 1, #2). Under this model, the maximum number that could be harvested is 449 animals. This model gives a conservative estimate of sustainable take because it assumes that the population is stable and not growing rapidly. However, the Niuean population is not at its greatest density and we do not know how large the population would be in a natural state.

The estimated number of bats shot in 1997-1998 is greater than the number that can be sustained by the population by both calculations. If hunting continues at the current level, the population will decline toward extinction. To continue hunting at the current rate with 1,000 – 1,500 bats taken annually, the population should be ca 7,000-8,000 animals and preferably more.

If all hunting in Niue can be stopped temporarily, the population could increase rapidly. Table 2 uses a 0.4 growth rate from *P. alecto* and *P. gigianteus* to estimate the length of time needed for a non-hunted population to grow to 7000-8,000 animals. The equation $N=N_oe^{rt}$

was used to estimate how rapidly the population could increase where N_0 is the beginning population size, *e* is the constant 2.71828, *r* is the growth rate, and *t* is time (Wilson and Bossert 1971).

Table 1 Sustainable hunting estimates

Estimated population	Estimated bats/km^2	Peak density of population	Maximum production	Maximum production available/ km^2	**Maximum Yield from growth rate**	**Maximum Yield of non-hunted population**
	K	.6*K*	P_{max}/ km^2	P_{rr}	#1	#2
1,900	10.44	6.26	3.08	1.23	**371**	**224**
3,000	16.48	9.89	4.86	1.95	**590**	**354**
3,800	20.88	12.53	6.16	2.46	**748**	**449**
5,000	27.47	16.48	8.11	3.24	984	590
6,000	32.97	19.78	9.73	3.98	1,180	708
7,000	38.46	23.08	11.35	4.54	1,377	826
8,000	43.96	26.37	12.97	5.19	1,574	944
9,000	49.45	29.67	14.59	5.84	1,770	1,062
10,000	54.95	32.97	16.21	6.48	1,967	1,080
15,000	82.42	49.45	24.32	9.73	2,951	1,770
20,000	109.89	65.93	32.43	12.97	3,934	2,361

Table 2 Possible population growth without hunting.

Desired Population	Population Estimate	[1]Years to reach
7,000	1,900	3.3
8,000	3,900	1.8

[1](ln desired population) – (ln current estimate) / *r* = years to reach desired number (from Dolbeer et al. 1988)

Habitat: area and status

Bats have two habitat requirements: roost habitat and foraging habitat. Flying foxes utilize a wide variety of habitats for roosts but places where colonies remain for a long time are secure from disturbance. Colonies will move if they are disturbed and hunting pressure drives bats to seek roost locations that are difficult for people to find. Areas identified as having roosts were in mature forest with large trees, were away from roads, where the ground was extremely rocky and walking was difficult. Roosts have been reported in tall canopy emergent trees: *ovava* (*Ficus obliqua*), *pualiki* (*F. prolixa*), and *kanumea* (*Planchonella torricellensis*). The tapu areas of the Huvalu Forest and elsewhere are particularly valuable as roost habitat because hunting is forbidden.

The foraging habitat of flying foxes encompasses anywhere there are fruiting or flowering plants that are used as food: forests, villages, and along roads through cleared land. Cleared agricultural land, fernland, coastal strand, and the airport are not typical foraging areas. A list of 39 plant species that bats are known to eat was compiled from the literature and from observations of the Huvalu Forest Conservation Officers (Appendix 2).

The nine tree species that are the preferred foods of *P. tonganus* make up more than 50% of the relative dominance of trees in the Huvalu Forest botanic study plots (Table 3, Appendix 2). Mature forest has the greatest amount of food resources but food producing trees are found throughout Huvalu Forest in all forest types. By extension, all mature forest on Niue is extremely valuable foraging habitat.

Table 3 Average relative dominance of nine preferred food trees in the Huvalu Forest.

	Mature	Secondary	Coastal	Littoral
Average relative dominance	82.9%	51.6%	58.3%	58.5%
number of plots	7	8	4	2

Species included:	Nieuan name	Parts eaten
Planchonella grayana	*kalaka*	Fruit, pollen
Planchonella samoensis	*kanumea*	Fruit, flowers
Syzygium dealatum	*tuali*	Fruit, flowers
Syzygium inophylloides	*kafika*	Fruit, flowers
Barringtonia asiatica	*futu*	Fruit, flowers
Diospyros samoensis	*kieto*	Fruit
Ficus prolixa	*ovava*	Fruit
Ficus scabra	*mati*	Fruit
Ficus tinctoria	*ata*	Fruit

Data from botanic study plots where proportion of stem area is given by species per plot (Whistler and Atherton 1997). Four species eaten preferentially by *P. tonganus* and *P. samoensis* in American Samoa are given in boldface (Banack 1999).

The 1981 foresty survey (Forestry Survey 1990) used different criteria to classify forest types than was used in Whistler and Atherton's 1997 survey. Merchantable forest includes the prime roosting and feeding habitat of mature forest, covered 32 km^2, or 12% of the total land area. The most extensive land cover, light and scattered forest includes secondary forest (120 km^2, 46% of total land area) and is the least favorable bat habitat for foraging and roosts.

During evening surveys, on nine excursions through the forest, and along bush tracks we searched the ground for fruit that had been partially eaten and discarded by bats. In September we observed numerous fruiting trees including *mati* (*Ficus scabra*), *pualiki* (*F. obliqua*), *kolivao* (*Syzygium samarangense*), and *telie* (*Terminalia catappa*). There was little evidence of partially eaten fruit and we found uneaten *mati*, *kafika*, and *tuali* fruit on the ground. We observed that some mango trees had partially eaten fruit below the trees but bats had not visited all trees with fruit. In the course of nocturnal work, we saw only a few bats visiting fruiting mango trees. Together, these observations suggest there is an abundance of fruit for the number of flying frugivores, both bats and birds, on Niue.

Discussion

Status of flying fox population on Niue

The current level of hunting (1,000-1,500 annually) is greater than the bat population (1,900-3,800) can sustain. Unless action is taken to slow the number of bats shot, the number of bats will decline, leaving a small population that is at risk of extinction from continued hunting, disease, and devastation from cyclones.

How many bats do people on Niue want to harvest annually? The number of bats that hunters would like to be able to take should be decided on. From this, the population size needed to support the level of hunting can be determined. In order to manage the bat population for sustainable harvest, trends in the population size must be monitored and the amount of hunting will need to be regulated. The flying foxes should be managed as a dynamic, island-wide population.

Bat hunting is popular with many people but it is not an economic necessity. It is socially acceptable to hunt bats throughout the year although the legal hunting season is only December and January. Enforcement of hunting regulations relies on the cooperation of the village councils, village police, and their extended families. Enforcement of any law that doesn't have wide popular support will be difficult because of the very small community where everyone knows each other and many people are related. The close ties of the Niuean community can work to maintain a healthy flying fox population if people wish to hunt bats in the future.

The hunt 'traditionally' is held in December-January but when this custom was begun is unclear. In the Cook Islands, Samoa, and Tonga the traditional time to hunt bats is when kapoc trees (*Ceiba pendantra*) flower in July. Setting the hunting season for December-January may be most convenient for people with family and visitors who come from New Zealand for the Christmas holiday. If the hunt were scheduled at a different time of the year, hunting pressure may not be as great.

Because the Huvalu Forest has a large area of mature forest it is extremely important as foraging and roost habitat. Although we did not find large numbers of bats roosting within the Forest during this survey, bats may move into the Huvalu Forest seasonally to feed on fruiting or flowering trees and to avoid hunters during December and January. The tapu areas are important conservation areas for wildlife but many people believe that an enormous number of bats live there and come out of the forest only in December--January. This is an old fashioned idea that has no scientific justification. The bat population is not unlimited, over-hunting can reduce the bats such small numbers that only a few remain. Ultimately, overhunting can kill all the animals.

Only a small amount of mature forest remains on Niue, 32 km^2 or 12% of the total land area (Forestry Section 1990). The wildlife that is most valued, coconut crabs, Pacific pigeons, and flying foxes, rely on fruits and flowers from the forest. These animals will be adversely effected by loss of any of the remaining mature forest because it decreases the food resources available. Protecting the mature trees and not cutting them to plant taro will help to maintain the animals that are most important to people.

Based on the population estimate from this survey, the forest is able to support a much larger flying fox population that is present. The estimated density of *P. tonganus* on Niue, 10.4-20.9 bats/ km^2, is lower than other Pacific Island countries where this species has been studied: Tutuila = 42-140 bats/ km^2, Manu'a islands = 27.7 bats/ km^2 (Brooke 1998), Rarotonga = 23-44 bats/ km^2 (Kelly and Bottomley 1997). The only island where densities are as low or lower than in Niue are the islands of the southern Mariana Islands where predation by the introduced brown tree snake on Guam and constant hunting has reduced the *P. mariannus* population to only a few hundred bats (Wiles, 1987, Wiles et al. 1989). On many islands where *P. mariannus* is hunted the densities are stable and fairly large. In the Ngerukewid Islands Wildlife Preserve, Palau, there were between 150-192 bats/ km^2 (Wiles and Conry 1990). Densities on Ulithi atoll, Caroline Islands range from 54-682 bats/km^2 (Wiles et al. 1991). In the Maldives, Dolbeer et al (1988) found *P. giganteus* at a density of 60-210 bats/km^2.

In addition to the possibility of being hunted to extinction, other dangers to the survival of a small population come from cyclones and epidemics. A strong cyclone has the potential to devastate a population of this small size. A devastating cyclone hits Niue about every ten years, the last severe storm was in 1991. Since then, there have been only five tropical storms with winds over 40 knots (S. Guest, pers. comm.). Niue will be hit with cyclones in the future and the flying fox population will decline after each. If the population is small, a bad storm has the potential of driving the population to such low numbers that it could be exterminated with only a small amount of hunting.

Flying foxes can be infected with diseases people bring to the island. As air travel between islands becomes more common, the possibility of an infectious disease being introduced to the wildlife also increases. In the past, epidemics have killed large numbers of bats in Samoa, Kosrae, Fiji, New Caledonia, Papua New Guinea, and the Solomon Islands (Rainey 1998). Descriptions of epidemics speak of incapacitated bats dropping from the sky and dead bats accumulating beneath roosts (Pierson and Rainey 1992).

The flying fox population can increase by bats moving in from other islands. Bats regularly migrate up to 610 kilometers in Australia (Eby 1991) and are believed to fly between islands in the southern Marianas over distances of 100 km (Wiles and Glass 1990). It is possible that bats occasionally fly the 480 km from Tonga to Niue. If such dispersal events do occur, they have the potential to change the population estimate and alter the growth rate. Any bats that come from Tonga increase the population in excess of the growth rate. It is beyond the scope of this report to evaluate long-distance movements but this information may be important in managing the flying fox population. The most effective way to determine this is by comparing the Niuean population structure with bats from Tonga using microstaellite DNA analysis. Dr. G. McCracken at the University of Tennessee, USA, has an ongoing project examining the movements of *P. tonganus* between the Samoan islands. If the Government of Niue wishes to determine this information, Dr. McCracken's address and the sample vials needed to collect a small bit of wing tissue from bats shot by hunters were left with Logo Seamanu.

Ecotourism potential

Many of the tourists who visit Niue are interested in the marine life, wildlife, and the unique character of the island. During this field study, we found both tourists and residents were interested in seeing bats and we had several people accompany us on evening surveys. The tourists who accompanied us were disturbed at hearing gun shots at dusk as bats were starting to fly. A place where bats could be easily seen in the wild would undoubtedly attract visitors. Bats are social and gregarious; in roosts they interact with each other throughout the day and are entertaining to watch. Bats that are not hunted can become habituated to people such as in the village of Kolovai, Tonga, where several thousand flying foxes hang from trees in the middle of the village and along the main road. Several tourist busses daily bring people to Kolovai daily to see the bats. A person can walk to within 5 m of the trees without any response from the bats.

In contrast, the bats on Niue are extremely wary of people and will fly from a roost if people are seen or smelled. It would be possible to show tourists exit flights from a roost but if hunters become aware of a roost location, the bats will quickly abandon the site or adjust the flight path to avoid the area with hunters. With continuous hunting pressure, it is not possible that wild bats can be a reliable attraction for tourists. If hunting out-of-season hunting and shooting bats at roosts were to be eliminated, flying foxes could become a viable tourist attraction.

Future population management

This study has provided the basis and structure for monitoring the long-term population trends in Niue. The 22 stations established in this study can be used to track changes in the population but are not suitable to estimate population size. The Sept. 1998 surveys should be used as a base line to follow changes since a single survey is insufficient to determine whether the population is decreasing, stable, or increasing.

Because of the level of disturbance from hunting, bats can move to different roost sites frequently. Constant changes in roost sites will affect the results and interpretation of future surveys. One survey should be done in September each year to avoid some of the variation related to fruit availability. If possible, a second survey should be done six months later, in March. Surveys should not be done during the hunting season because the population will be highly disturbed, changing roost sites frequently, and some of the bats observed will be killed making the index will be artificially high.

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Appendix 1 Bat Survey Data

Map #	Sept	Observor	GPS coordinates		Location	1800-1805	1805-1810	1810-1815	1815-1820	1820-1825	1825-1830	1830-1835	1835-1840	1840-1845	1845-1850	1850-1855	1855-1900	Total
1	4	Logo	78-92-811	6-26-865	Paletoto-Liku-Alofi	0	0	0	0	0	0	0	0	1	0	0	0	1
2	4	Ioane	78-92-946	6-26-231	Fue-Liku-Alofi	2	0	0	9	13	3	0	4	4	0	2	0	37
3	2	Anne	78-92-116	6-21-53	Alofi-Liku	0	0	0	4	5	5	8	7					29
3	4	Sani	78-92-116	6-21-53	Alofi-Liku	0	0	1	4	1	4	3	4	14	6	4	0	41
4	4	Anne	78-93-626	6-20-503	Alofi-Liku	0	0	0	0	2	6	5	9	5	4			31
5	5	Anne	78-93-680	6-18-191	Alofi-Liku	0	0	0	2	2	6	9	12	4	2			37
6	6	Anne	78-98-420	6-17-214	Alofi-Liku	0	0	0	0	0	0	11	25	9	1	2		48
7	7	Ioane	78-93-501	6-27-375	Siale-Fulehau	0	0	0	0	0	0	0	0	0	0	0	0	0
8	7	Sani	78-94-208	6-26-956	Malafasi-Liku-Lakepa	0	0	0	1	0	3	0	1	3	0	0	0	8
9	7	Logo	78-94-976	6-26-597	Kaupa Liku-Lakepa	0	0	0	0	0	0	0	0	0	0	0	0	0
10	7	Anne	78-95-778	6-26-341	Kaupa Liku-Lakepa	0	0	0	0	0	0	0	0	1	0			1
11	8	Ioane	78-91-735	6-27-433	Kavaka-Liku Hakupu	0	0	1	2	1	0	0	3	0	0	0	0	7
12	8	Logo	78-91-59	6-27-236	Motoliku-Liku-Hakupu	0	0	0	0	0	0	0	0	0	0	0	0	0
13	8	Anne	78-90-746	6-26-994	Sculpture Park	0	0	0	0	0	0	0	0	0	0			0
14	8	Sani	78-89-478	6-26-396	Vakevake-Liku-Hakupu	0	1	0	0	0	0	2	2	0	0	0	0	5
15	9	Marco	78-86-67	6-22-799	Hakupu-Liku	0	0	0	0	0	0	0	0	0	0			0
16	9	Anne	78-86-489	6-23-472	Hakupu-Liku	0	0	0	0	0	0	0	0	0	0			0
17	9	Ioane	78-85-47	6-22-612	Togo-Hakupu-Liku	0	0	0	0	0	0	0	0	0	0	0	0	0
18	9	Logo	78-86-45	6-22-773	Ana-Hakupu-Liku	0	0	0	0	0	0	0	0	0	0	0	0	0
19	9	Sani	78-85-159	6-21-985	Tumuana-Hakupu-Liku	0	0	0	1	0	2	3	0	0	0	0	0	6
20	11	Ioane	78-84-831	6-21-400	Hakupu-Alofi	0	0	0	0	0	0	0	0	0	0	0	0	0
21	11	Logo	78-87-47	6-19-838	Hakupu-Alofi	0	0	0	0	0	0	0	0	1	0	0	0	1
22	11	Anne	78-87-634	6-19-341	Hakupu-Alofi	0	0	0	0	0	0	0	0	0	0			0
23	11	Marco	78-88-981	6-18-315	Hakupu-Alofi	0	0	0	0	0	0	0	0	0	0			0
24	12	Marco	78-91-10	6-23-372	Vinivini track	4	0	0	3	2	5	4	3	0				21
24	17	Sani	78-91-10	6-23-372	Vinivinii-Tialagi	2	3	5	4	3	12	7	5	5	4	5	6	61
25	12	Anne	78-89-825	6-23-782	Vinivini track	0	1	1	5	7	8	4	2	1	1			30
25	17	Logo	78-89-825	6-23-782	Vinivini-Lotuma	0	0	1	1	3	6	3	11	16	10	6	0	57
27	14	Sani	78-93-14	6-17-243	Mana-Niufela-Alofi-Lkp	1	0	1	1	2	1	4	0	0	0	0	0	10
28	14	Ioane	78-93-700	6-19-212	Niufela-Alofi	8	3	1	6	9	5	3	0	0	0	0	0	35
29	14	Logo	78-94-890	6-20-559	Niufela-Alofi	41	24	14	18	40	27	28	20	13	0	0	0	225
30	14	Marco	78-95-338	6-21-461	Niufela-Alofi	9	8	8	8	7	6	14	3	1				70
31	14	Anne	78-96-669	6-22-293	Niufela-Alofi	1	2	1	4	2	3	7	1	0				22
32	15	Marco	78-97-364	6-23-577	Niufela-Alofi	0	0	0	0	0	0	0	0	0				0

33	15	Anne	78-98-409	6-25-385	Niufela-Alofi	0	0	0	0	0	0	0	0	0				0
34	15	Ioane	78-98-819	6-25-357	Lakepa	0	0	0	0	0	0	0	0	0	0	0	0	0
35	15	Sani	78-99-850	6-25-214	Kepa-Mutalau	0	0	0	0	0	0	1	0	0	0	0	0	1
36	15	Logo	78-96-280	6-20-920	Lakepa-Viatafe	0	0	0	0	0	0	0	0	0	0	0	0	0
37	16	Marco	78-93-575	6-20-515	Clearing	2	45	3	27	18	30	33	18	5				181
38	16	Anne	78-95-865	6-20-333	Niufela	0	1	1	1	0	2	2	1	0				9
39	16	Sani	78-96-993	6-21-61	Niufela	0	0	0	0	19	0	0	0	0	0	0	0	19
40	16	Logo	78-92-910	6-18-100	Niufela	0	0	8	13	7	3	12	16	18	6	1	2	86
41	17	Marco	78-91-27	6-24-21	Vinivini track	0	1	0	0	1	0	2	1	3	0	0		8
42	17	Anne	78-90-137	6-22-976	Vinivini track-gate	0	0	2	2	0	1	13	9	1	2			30
43	17	Ionae	78-90-378	6-25-353	Vinivini-Fuluhina	0	0	0	0	3	1	7	8	12	8	3	0	42
44	18	Logo	78-89-561	6-20-625	Pagopago north	0	0	0	0	0	0	0	0	1	0	0	0	1
45	18	Sani	78-89-218	6-20-246	Pagopago west	0	0	0	0	0	0	0	0	0	0	0	0	0
46	18	Ioane	78-88-76	6-21-148	Pagopago east	0	0	0	0	2	2	6	8	3	7	0	0	28
47	18	Anne	78-87-512	6-21-30	Pagopago south	0	0	0	0	0	4	6	4	2				16
48	19	Anne	78-85-989	6-21-283	clearing-Hakupu	0	0	0	0	0	0	1	4	7	3	1		16
49	21	Marco	78-94-976	6-21-824	Power plant	0	0	0	0	0	0	0	1	5	1			7
50	21	Anne	78-90-924	6-14-320	Power plant	0	0	0	0	0	0	0	0	0	0	0		0
51	21	Ioane	78-90-142	6-15-19	Lalokaffika	0	0	0	0	0	0	0	0	0	7	1	0	8
52	21	Logo	78-90-359	6-15-857	Lalokaffika	0	0	0	0	0	0	0	0	1	0	8	1	10
53	22	Ioane	78-98-220	6-18-473	Logovao	0	0	0	0	0	0	0	0	1	0	0	0	1
54	22	Logo	78-97-538	6-19-517	Logovao	0	0	0	0	0	0	0	0	0	0	1	1	2
55	22	Anne	78-96-476	6-19-832	Logovao	0	0	0	0	0	0	0	0	0	0	0		0
56	22	Marco	78-87-652	6-15-742	Logovao	0	0	0	0	0	0	0	0	0	0	0		0
57	23	Anne	78-86-577	6-16-376	Fuata	0	0	p	0	0	0	0	0	0	0	0		0
58	23	Marco	78-87-652	6-15-742	Fuata	0	0	0	0	0	0	0	0	0	0	0	0	0
59	23	Ioane	78-86-486	6-17-166	Talamaitoga	0	0	0	0	0	0	0	0	0	0	2	1	3
60	23	Sani	78-87-132	6-17-3.9	Talamaitoga	0	0	0	0	0	0	0	0	0	0	0	0	0
61	23	Logo	78-87-615	6-17-812	Talamaitoga	0	0	0	0	0	0	0	0	0	0	0	0	0
62	24	Marco	78-92-606	6-14-690	High school	0	0	0	0	0	14	16	11	1				42
63	24	Anne	78-93-587	6-15-922	Tusekolo	0	1	2	3	5	15	66	55	13				160
63	27	Anne	78-93-587	6-15-922	Tusekolo	0	0	0	1	2	18	30	65	32	3	0	0	151
64	25	Anne	78-94-793	6-24-876	Bush track liku-Lakepa	0	0	0	0	0	1	2	4	2				9
65	25	Marco	78-94-855	6-25-734	Bush track liku-Lakepa	0	0	0	0	0	0	0	1	5	1			7
66	26	Marco	78-95-313	6-15-176	Tusekolo	0	0	1	0	0	6	27	40	10	0			84
67	26	Anne	78-95-313	6-15-176	Tusekolo	0	0	0	0	0	2	6	2	1	0			11

Appendix 2 Long-term monitoring stations

Map #	Date Sept	Observor	GPS coordinates		Location	# Bats counted
4	4	Anne	78-93-626	6-20-503	Alofi-Liku	31
9	7	Logo	78-94-976	6-26-597	Kaupa Liku-Lakepa	0
11	8	Ioane	78-91-735	6-27-433	Kavaka-Liku Hakupu	7
14	8	Sani	78-89-478	6-26-396	Vakevake-Liku-Hakupu	5
16	9	Anne	78-86-489	6-23-472	Hakupu-Liku	0
18	9	Logo	78-86-45	6-22-773	Ana-Hakupu-Liku	0
27	14	Sani	78-93-14	6-17-243	Mana-Niufela-Alofi-Lkp	10
29	14	Logo	78-94-890	6-20-559	Niufela-Alofi	225
32	15	Marco	78-97-364	6-23-577	Niufela-Alofi	0
34	15	Ioane	78-98-819	6-25-357	Lakepa	0
36	15	Logo	78-96-280	6-20-920	Lakepa-Viatafe	0
41	17	Marco	78-91-27	6-24-21	Vinivini track	8
42	17	Anne	78-90-137	6-22-976	Vinivini track-gate	30
43	17	Ionae	78-90-378	6-25-353	Vinivini-Fuluhina	42
44	18	Logo	78-89-561	6-20-625	Pagopago north	1
47	18	Anne	78-87-512	6-21-30	Pagopago south	16
52	21	Logo	78-90-359	6-15-857	Lalokaffika	10
54	22	Logo	78-97-538	6-19-517	Logovao	2
57	23	Anne	78-86-577	6-16-376	Fuata	0
62	24	Marco	78-92-606	6-14-690	High school	42
65	25	Marco	78-94-855	6-25-734	Bush track liku-Lakepa	7
67	26	Anne	78-95-313	6-15-176	Tusekolo	11

Appendix 3 Records of foods of *Pteropus tonganus* from the literature on Niue. Taxonomy follows Whistler and Athrerton 1997, species names in parenthesis were used by Sykes (1970) and Wodzicki and Felten (1975). Expected food plants, reported as foods in Samoa but not observed eaten by bats in Niue, are designated by *.

Niuean name	Family	Genus and species	Parts eaten	Reference
Mango	Anacardiaceae	*Magifera indica*	Fruit	Wodzicki & Felten 1975
Tavahi		* *Rhus taitensis*	Flowers	Mickleburgh et al 1992
Motoi	Annonaceae	*Canaga odorata*	Fruit	Wodzicki & Felten 1980
Pao	Apocynaceae	*Neisosperma oppositifolium*	Fruit	Wodzicki & Felten 1975
Futu	Barringtoniaceae	* *Barringtonia asiatica*	Fruit Flowers	Brooke 1998
Vavae	Bombacaceae	*Ceiba pentandra*	Flowers	Wodzicki & Felten 1975
Loku	Caricaceae	*Carica papaya*	Fruit	Whitmee 1875
Telie	Combretaceae	*Terminalia catappa*	Fruit	Wodzicki & Felten 1980
Malili		* *Terminalia richii*	Fruit	Rainey et al. 1995
Atiu	Curcurbitaceae	*Cucumis melo*	Fruit	Huvalu Forest Conservation Officers
Kieto	Ebenaceae	*Diospyros samoensis*	Fruit	Wodzicki & Felten 1975
Le	Euphorbiaceae	*Macaranga seemannii*	Fruit	Powlesland & Hay 1995
Avoka, Avocado	Lauraceae	*Persea americana*	Fruit	Wodzicki & Felten 1980
Ifi	Leguminosae	*Inocarpus fagifer*	Fruit	Wodzicki & Felten 1975
Pua	Loganiaceae	*Fagraea berteroana*	Fruit	Wodzicki & Felten 1980
Mei	Moraceae	*Artocarpus altilus*	Fruit	Wodzicki & Felten 1975
Jakfruit		*Artocarpus heterophyllus*	Fruit	Wodzicki & Felten 1980
Pualiki		*Ficus obliqua*	Fruit	Huvalu Forest Conservation Officers
Ovava		*Ficus prolixa*	Fruit	Wodzicki & Felten 1975

Niuean name	Family	Genus and species	Parts eaten	Reference
Mati		* *Ficus scabra*	Fruit Leaves	Trail 1994 Brooke 1997
Ata		* *Ficus tinctora*	Fruit Leaves	Trail, 1994 Banack 1999
Fusi	Musaceae	*Musa spp*	Fruit Flowers	Whitmee1875
Lala, kautoga	Myrtaceae	*Psidium guajava*	Fruit	Wodzicki & Felten 1980
Tuali		*Syzygium dealatum (clusiifolium)*	Fruit Flowers	Wodzicki & Felten 1975
Jambolan	Myrtaceae	*Syzygium cumini*	Fruit	Wodzicki & Felten 1980
Kafika		*Syzygium inophylloides*	Fruit Flowers	Wodzicki & Felten 1975
Fekakai		*Syzygium malaccense*	Fruit	Whitmee 1875
Kolivao		*Syzygium samaranagense (richii)*	Fruit Flowers	Wodzicki & Felten 1975
Niu	Palmae	*Cocos nucifera*	Flowers	Wodzicki, 1980
Piu		*Pritcharadia pacifica*	Fruit	Huvalu Forest Conservation Officers
Fa, Favao	Pandanaceae	*Pandanus tectorius*	Fruit Flowers	Wodzicki & Felten 1975
Panopano	Rubiaceae	* *Guettarda speciosa*	Fruit Flowers	Wiles et al. 1991
Moli	Rutaceae	*Citrus sinensis*	Fruit	Wodzicki & Felten 1980
Tava	Sapindaceae	*Pommetia pinnata*	Fruit	Wodzicki & Felten 1975
Oluolu	Sapotaceae	* *Planchonella garberi*	Fruit	Trail 1994
Kalaka		* *Planchonella grayana*	Fruit	Trail 1994
Kanumea, Kanomea		*Planchonella samoensis (torricellensis)*	Fruit Flowers	Wodzicki & Felten 1975
Tomato	Solanaceae	*Lycopersicon esculentum*	Fruit	Wodzicki, 1975
Limulimu	Orchidaceae	*Oberonia equitans*	Leaves	Huvalu Forest Conservation Officers

Appendix 4 Bat survey data sheet

PERSON COLLECTING DATA____________________________________**DATE**________________________

PLACE OF SURVEY____

Direction that bats fly from

Time	South to North	East to West	West to East	North to South	Total
5:45-5:50					
5:50-5:55					
5:55-6:00					
6:00-6:05					
6:05-6:10					
6:10-6:15					
6:15-6:20					
6:20-6:25					
6:25-6:30					
6:30-6:35					
6:35-6:40					
6:40-6:45					
6:45-6:50					
6:50-6:55					
6:55-7:00					
7:00-7:05					
7:05-7:10					
7:10-7:15					
Total					

Appendix 5 Survey instructions

The following information sheet was given to Conservation Officers and others who attended the briefing at the end of peka surveys.

Object of surveys is to create an index that can be used to monitor population changes over time. Since the baseline survey was done in September it would be best to repeat surveys each year at this time to minimize variation due to fruit availability. A second survey could be done 6 months later, in March. Do not conduct surveys during hunting season. Some of the bats counted will be shot and the index will be unrealistically large.

A) Count the number of bats flying overhead just before dark.

At least 3 people are needed to conduct surveys; five or more people per night would be best. It is important *not* to recount the same bats on different nights or the population index will artificially large. To avoid re-counting the same bats, try to do the complete survey within five consecutive days. Bats can move to different roost sites each night so doing the surveys rapidly will lessen the possibility of counting the same animals more than once.

Each observer stands at one of the established survey stations given in Fig 2. Begin counting bats flying from 30 minutes before sunset and continue until it is too dark to see. Record the number of bats seen in five minute intervals on the data sheet given in Appendix 3. For each bat that is seen, you must decide if it has already been counted. Avoid working on very windy or rainy nights.

Surveys data should be collected over several years. This method does not work well if data is collected only once. Surveys are best used as an "index", a number that you can use to look at changes over time. With survey data you can't get the total number of bats, only a rough estimate.

Where bats roost during the day may change during the year and what is a good survey spot at one time may not be good at other times. The idea of the surveys is to always stay at the same places even though the bats move around. Surveys will take several months or years before you have a really good idea of whether the number of bats is going up or down

The bats are on the island all year and they need to eat every night. They will move to different places as trees fruit and flower at different times. People see lots of bats when mangos are ripe or coming from tapu areas in December and January but the bats are here all the time.

Surveys should be done as fast as possible, within a few days. Bats can move to new places during the day and they fly to different places at night to feed. Surveys should be done within a few days so that you don't count the same bats on different nights.

Good days to collect survey data are the same as good days for hunting: not a lot of wind and without rain. Bats have trouble flying in strong winds and many will not come out at all if its raining hard.

We've been collecting data every 5 minutes and the direction that bats are coming from and the direction they are flying in. From this information you can get:

1) Number of bats. If several people do surveys on the same night and they are far enough apart so they are not seeing the same bats, you can add these numbers together. Be careful with data from different nights. Bats can change the way they fly on different days, one night going north and the next night going south. Also be careful not to count the same bat twice during a survey! If they are circling around or some fly out of sight and then might be coming back, don't count these bats two times.

2) Direction. The direction that they have come from CAN indicate where the roost is but bats don't always fly in straight lines. Data from several survey days will indicate what part of the forest the bats are living in.

3) The time. If you see many bats early in the evening it probably means that you are close to a roost. When near a roost, you see bats for a longer time. Bats that you see late in the survey, at dark, probably have traveled longer distance than bats seen early. This is not always true because they could start to fly early or late. If you want to use time to make a judgment, its best if you use data from several people at different survey sites rather than just one person.

Suggested Locations from the survey during September 1998 however these may change. Use your judgment to modify survey locations as needed in the future. 40 survey sites should give you a good estimate for the index. Try to do all surveys this within a week's time. The time of surveys might change a little during the year. Allow enough time at each site so that you are there early and stay until after dark.

B) Count any bats you find hanging in a tree during the day. If you find a roost, count the number of bats on one branch, not the entire tree. Then use this number. Count the number of branches with about the same number of bats. For branches with fewer bats, count these and make an estimate of the number. Add up all the numbers to get an idea of how many there are. Don't try to count every bat in the tree. This method gets a better number than doing surveys but you need to find all the roosts and I don't think that is possible here.

C) Keep track of how many animals you see at other times. If you see lots of bats flying overhead sometime, in the village or at a tree with fruit, count the number you see. There is a big difference between 50 bats and 5. If people say they see " lot of bats" and they are seeing only 5, it isn't very many. Try to get numbers of bats when you can. Write these down so that they can be compared in the future to see if the numbers are going up or going down.