PRELIMINARY REPORT ON DAMAGE TO COCONUTS AND ON THE ECOLOGY OF THE POLYNESIAN RAT (*RATTUS EXULANS*) IN THE TOKELAU ISLANDS

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SUMMARY: Extensive trapping shows that the Polynesian rat (*Rattus e. exulans* (Peale)) is the only rodent present in the Tokelau Islands and that it is responsible for damage to coconuts. Green coconuts 5–25 cm. long are gnawed on the palms and subsequently fall to the ground and disintegrate. Damage was assessed by counting damaged and undamaged nuts in quadrats on various islets of the Nukunonu and Atafu atolls. The numbers of rats on these islets were assessed by using the capture-mark-recapture method. It was found that mature, untended and overgrown islets showed severe damage but had a low rat population. On the other hand, equally mature but relatively well-tended groves carried a much heavier rat population but showed no damage to coconuts.

INTRODUCTION

The Polynesian rat (*Rattus exulans*) has been widespread on Pacific Islands since pre-European times and was probably transported from island to island by the early Polynesian voyagers (Wiens 1962). With the advent of European explorers and traders, rodents such as the brown rat (*R. norvegicus*), the house mouse (*Mus musculus*), but particularly the ship or roof rat (*R. rattus*), frequently became established. When rats become numerous on such islands they often cause considerable damage to coconut plantations. Following repeated reports of such damage in the Tokelau Islands, the writer made two visits there to establish the extent of damage and the species of rodents causing it. The present paper describes the identity, distribution and numbers of rats in relation to damage to coconuts, and will also serve as a background to the more specialised studies mentioned below. Most earlier studies have been concerned with rodents on volcanic islands (see Storer 1962) whereas the present one is concerned with only one species (*R. exulans*) on an atoll.

GENERAL DESCRIPTION OF THE TOKELAU ISLANDS

The Tokelau Islands comprise three atolls bounded by the parallels 8°S.–10°S. and the meridians 171°W.–173°W. The atolls from south to north are: Fakaofo (650 acres), Nukunonu (1,350 acres) and Atafu (500 acres). The nearby American-owned Swain's Island is a private property and is excluded from the present study.

The Tokelaus came under New Zealand administration on 11 February 1926, and were included within the territorial boundaries of New Zealand by the Tokelau Islands Act 1948. The Tokelauans are Polynesians who numbered 1,021 in 1925 and 1,900 in 1966.

Climatically the Tokelau group lies in the belt of easterly winds, has a mean daily temperature of 83°F. and a mean annual precipitation of 114.7 in. spread over all months. As on most atolls with a coral reef embracing the central lagoon, the soil is poor and consists of coral sand with a very low humus content.*

The vegetation is characterised by a relatively small number of species and is assessed on the basis of collections, field observations and published records as comprising 67 vascular plants including 16 adventive weeds and grasses and 13 cultivated plants, with an, as yet, unknown number of non-vascular plants (B. E. V. Parham, *in litt.* 1968).

There are very few endemic species and a preponderance of widely dispersed strand plants, but many species occur in abundance.

The terrestrial fauna is also poor and includes, according to Dr Charles P. Hoyt (*in litt.* 1967), some one hundred species of land invertebrates,

* For further information on the geography of the Tokelau Islands consult Kennedy (1966) and Annual Reports of the Department of Maori and Islands Affairs, Wellington.

amongst them the dynastid beetle *Oryctes rhinoceros*, introduced accidentally to Nukunonu. Few, if any, of land-inhabiting invertebrates are endemic, most of them appear to have come from the Samoan Islands. Among land vertebrates there are seven species of lizards, four of marine turtles, 18 birds (including the Pacific pigeon *Ducula pacifica* and domestic fowl), the Polynesian rat, domestic and feral cats and pigs.

The rat problem has two aspects: an economic one of rats feeding on, and subsequently destroying, immature coconuts and a public health one of damaged nuts providing breeding grounds for mosquitoes that transmit filariasis (Laird 1963).

MATERIAL AND METHODS

The Tokelau Islands were visited from 20 November 1966 to 25 February 1967 and from 21 April to 10 June 1968. The first expedition provided a general survey of rats and other biota and I was assisted by David Gravatt, from Auckland University and Morgan Williams, from the University of Canterbury. The second expedition supplemented the first and was devoted to setting up a rat control scheme and training personnel.

Both expeditions were based on Nukunonu atoll but collections and observations were also made during brief visits to Fakaofo and Atafu. A total of 927 rats was dissected, 496 from Nukunonu, 340 from Fakaofo and 91 from Atafu, and information collected on their taxonomy, biometrics, reproduction, parasites and food habits.

Several quadrats were established in May-June 1968 on Nukunonu and Atafu and, at a later date, on Fakaofo to assess coconut palm productivity and rat damage throughout a year. In some of these there was no rat damage; on some of the islets palms were banded, on others they were not. In all quadrats the palm productivity is, at present, being assessed.

Finally, in six experiments carried out in 1966–67 and 1968 on Nukunonu and Atafu, rats were live-trapped with Chauvancy traps (Petter 1963), marked and released. The results of these capture-mark-recapture experiments were analysed by T. J. Smit, Applied Mathematics Laboratory, D.S.I.R., to assess population densities. Information on movements in various habitats was also obtained. As on many atolls, crabs, hermit crabs and, during daytime, lizards, set off the traps, particularly on the lower islets, it was sometimes difficult to obtain adequate samples.

RESULTS AND DISCUSSION

Identification of rats

Extensive trapping on many Fakaofo and Atafu islets and practically on every islet of Nukunonu yielded only Polynesian rats and all were of the brown colour phase characteristic of *Rattus e. exulans* (Peale). The rarer black phase, *Rattus exulans micronesiensis* Tokuda, has been recorded from Samoa (Marples 1955) and from Ponape in the Eastern Caroline Islands (Marshall in Storer 1962).

Distribution

Extensive snap-trapping on all three atolls and particularly on Nukunonu helped to determine the ecological distribution of Polynesian rats in the major habitats.

The Tokelau Islands, like other atolls, lack the diversity of habitats found on high islands, but it is possible to recognise three ecological divisions between the ocean and the lagoon, based on the nature of the vegetation. According to B. E. V. Parham (*in litt.* 1968) these divisions are: "(a) the fore-shore of sand and rubble between high-tide level, (b) the beach crest of slightly elevated sand, rubble or hard coral limestone and (c) the interior strip of relatively stable sandy soil." In the largest islet, Long Motu in Nukunonu atoll, the total width of the three divisions was 275 m.

No rats were caught in the first zone and only occasionally were rats seen or caught in the beach-crest zone, except in its innermost *Pandanus-Guettarda* facies, which is composed of *Pandanus tectorius* and *Guettarda speciosa* and some other co-dominant trees.

The main rat habitat is in the third community, the *Cocos nucifera/Asplenium nidus* forest on the more sheltered zone of sandy soil which is usually enriched by the decomposing debris of vegetation and often by guano deposited by roosting or nesting birds. According to Parham "the general physiognomy is that of a humid tropical forest, with a closed canopy up to 20 m. or more, provided mainly by the overlapping fronds of the dominant *Cocos* palms."

This community exists in two main types: (i) mature, fairly well-tended groves with totolo (*Triumfetta procumbens*) and some grass on the groves' floor as, for example, at the Church property on Vao, Nukunonu; and (ii) mature, old

untended groves having a dense understorey of young trees, shrubs and a forest floor covered by ferns and ground litter of fallen fronds and other debris.

Rats occurred throughout the *Cocos nucifera*/*Asplenium nidus* forest on all islets. However, contrary to the findings of Strecker and Jackson (Storer 1962), rats were more numerous in the relatively well-tended Church property at Nukunonu than on the other islets with untended old groves.

Finally, Nukunonu village was another important rat habitat. During the 1966–67 survey, rats were occasionally brought to us by the villagers, but no reports were received of rat damage in the village itself. In 1968, however, many people at Nukunonu complained of damage, which was sometimes considerable. A control campaign conducted in May-June 1968 revealed large numbers of rats distributed throughout.

Although rats are widely distributed and abundant on many islets, surprisingly little evidence was found of their presence. The nature of the soil prevents any burrowing and no runways were found. Except on islets carrying large populations droppings were rarely seen, perhaps because of their quick disintegration. On most islets the only evidence of the presence of rats was gnawed coconuts or fruit of various trees.

Like the "*Pirate*" workers (Storer 1962), we encountered some difficulty in finding rat nests; most found were in the crowns of coconut palms and a few in the decaying punk of rotted coconut stumps. The only nest found on the ground was inside a large coconut husk. Presumably, rats avoided nesting on the ground because of the presence of large numbers of crabs and hermit crabs. The nests found were composed mainly of fibres from coconut leaves and occasional pieces of grass or leaves from other plants.

Description and assessment of damage

The primary object of the survey was to obtain information on damage to coconuts. Coconuts form an important part of the islanders' diet and dried coconut meat is sold as copra and is the major product on all three atolls. It was reported that rat damage posed a serious threat to the islanders' diet and was reducing the amount of copra exported. In the South Pacific, such damage seems to be much commoner on atolls than on high islands (Strecker in Storer 1962).

Practically all damage is effected by rats on the green nuts on the trees. Elsewhere this damage has been blamed on ship rats (see Wiens 1962 for a review of literature), which are unknown on the Tokelaus.

The rats gnaw holes 2–4 cm. long, 2 cm. wide and perhaps 1–1.5 cm. deep in the husks. The damaged nuts soon fall to the forest floor and begin to deteriorate.

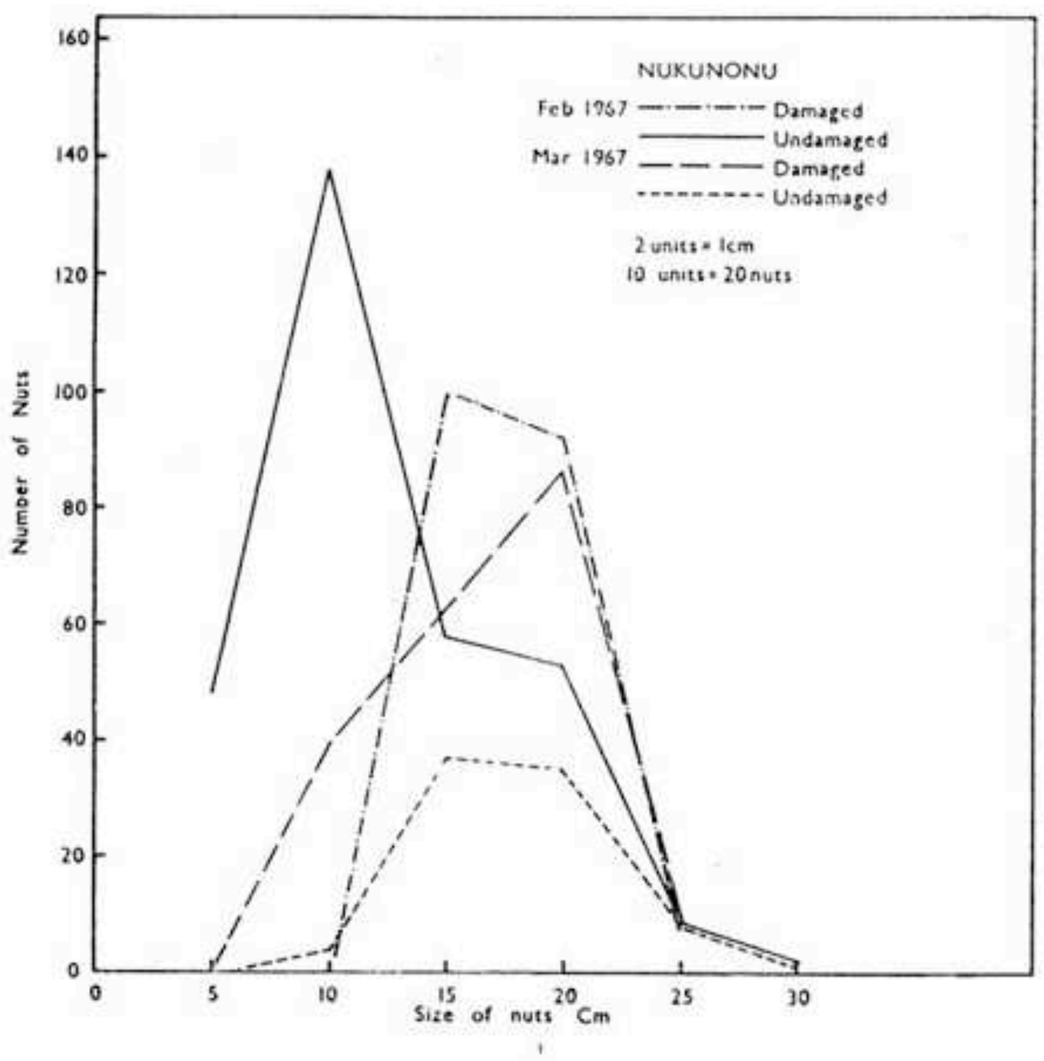

FIGURE 1. *Size of two samples of rat-damaged and undamaged coconuts collected on the forest floor in Long Motu, Nukunonu atoll, Tokelau Islands in 1967.*

The lengths of damaged and undamaged coconuts collected on the ground in the Long Motu, Nukunonu in February and March 1967 are shown in Figure 1. There is a size difference between the two collections in nuts shed and attacked by rats. In February, nuts about 10 cm. long appeared to be most susceptible to shedding. In March, the peak fall was of nuts 15–20 cm. long. It appears that rats become interested in coconuts 5–10 cm. long but nuts 14–22 cm. long are preferred. Few nuts longer than 25 cm. were either shed or gnawed.

The physiological significance of the habit of attacking green coconuts is not clear. Taylor (1930) suggested that rats get water from coconuts

during severe drought but we confirmed Strecker's (Storer 1962) observation of fresh damage to coconuts occurring even when frequent rain had filled damaged shells on the ground. We also found that the Polynesian rat on the Tokelau Islands not only climbs palms with alacrity but often nests in the crowns of the palms and may inflict serious damage to nuts on palms. This is contrary to Strecker's statement (Storer 1962) that "there was no evidence that they climb to the crowns of erect, mature coconut trees".

Table 1 shows numbers of damaged and undamaged coconuts collected on quadrats in the same properties in 1966–67 and 1968; the quadrats themselves were not identical. The most important finding arising from these results is the variation in the number of damaged nuts from property to property and the variation in the ratio of damaged and undamaged nuts and the apparent correlation of both of these with the technique of palm management. Thus the overgrown and untended Avalau and Naniutapu properties of the Long Motu and the adjacent Helakehe islet showed large numbers of rat-damaged nuts both in 1966–67 and 1968. The Motuakea islet, less overgrown than Helakehe, showed little damage in 1966–67 and none in 1968. The Church property on Nukunonu West, though also consisting of mature trees, is relatively well tended. There was no rat damage in this property, except in Quadrat III where it was negligible.

Unfortunately, there is no information about coconut palm productivity nor about the timing of damage during the year. To obtain this information 21 large quadrats each with 3–4 marked trees were established and it is hoped that in 12 months' time the required information obtained will be available.

Population levels

An analysis of rat populations may be approached by studying reproduction and development; and in time much information will be obtained from autopsies of dissected animals. However, as information on population density was urgently required for planning control, an attempt was made to assess it in two ways: (i) by the trap-night index on all three atolls and (ii) by the trap-mark-release procedure.

(i) The first method is not accurate and compares the relative population density in two or more localities; but, if trapping is conducted contemporaneously and under similar conditions, it may detect broad differences. Table 2 shows the results of our work.

TABLE 1. *Numbers of rat-damaged and undamaged coconuts, groves' condition and rat damage assessment.*

Locality	Date	No. and size of quadrats m^2		No. rat-damaged nuts		No. undamaged nuts		Total counted	Condition of grove	Assessment of damage
				Fresh	Old	Fresh	Old			
Church property, Nukunonu West, Vao	1.1.67	1	81	Nil	Nil		15	15	Mature, old but	Nil
Nukunonu West, Vao	20.1.67	2	162	Nil	Nil		40	40	relatively well	Nil
Nukunonu West, Vao I	20.5.68	1	2,048	Nil	4	201	711	916	tended groves	Nil
Nukunonu West, Vao II	8.5.68	1	2,048	Nil	Nil	4	307	311		Nil
Nukunonu West, Vao III	1.5.68	1	2,048	2	19	15	516	552		Negligible
Motuakea	19.12.66	6	486	3	8		76	87	Mature, old, un-	Slight
Motuakea	7.5.68	1	1,024	Nil	Nil	6	130	136	tended and more overgrown than above	Nil
Helakehe	15–16.12.66	3	243	12	229		35	276	Mature, mostly	Severe
Helakehe	22.5.66	1	1,024	83	355	4	13	455	old untended, more overgrown than above	Severe
Avalau, Long Motu	20.1.67	3	300	7	48		11	66	Mature, old, untended	Severe
Avalau, Long Motu	22.5.68	3	3,072	190	904	14	144	1,252	overgrown as above	Severe
Naniutapu, Long Motu	11–13.1.67	2	162	75	80		20	175	As above	Severe
Naniutapu, Long Motu	22.5.68	3	3,072	65	160	39	104	368		Moderate to severe

TABLE 2. *Results of night trapping on three atolls, Nov. 1966 to Feb. 1967.*

Atoll	No. of trap-nights	No. of rats caught	Catch per 100 trap-nights
Nukunonu	922	103	11.0
Fakaofo	520	194	56.5
Atafu	320	67	20.9

Assuming similar trappability in all three atolls, it appears that the population density varied considerably between the three atolls, as it did between islets of one atoll.

(ii) Table 3 shows the results of six trap-mark-release experiments made at Nukunonu in 1966–67 and 1968 and at Atafu atoll in 1966–67. Two of these (Motuakea and Fogalaki-Matagi) covered whole islets but the three remaining covered regions that were part of larger islets, two of them, Avalau and Nukunonu West being of one acre each. There was no control of rats on the sampling areas before the experiments. However, the population estimates in Table 3 cannot be directly compared because of differences in trap density and duration of trapping: but the apparent differences in density were confirmed by field observations such as snap-trapping or numbers of live rats seen during daylight hours. This was done on Nukunonu West in both years and to a certain extent on Motuakea islet. A fuller analysis of these data has been made by T. J. Smit, Applied Mathematics Division, D.S.I.R., and a detailed account will be published elsewhere.

It remains to compare the rat damage with population estimates in some of the sampling areas and Table 4 shows a correlation between the condition of the environment and the amount of damage and population density of rats. Avalau, a property with mature, untended coconut palms and other trees and shrubs, showed considerable damage but had a rat population of only 17.2 per sampling area. On the other hand, the equally mature palms of the Nukunonu West property, which is well tended, showed practically no damage despite a much

TABLE 3. *Population estimates for five areas, 1966/67 and 1968.*

	NUKUNONU ATOLL 1966/67				1968	*ATAFU ATOLL* 1966/67
	Motuakea *	Tepuka North	Avalau Long Motu **	Nukunonu West, Vao **	Nukunonu West, Vao **	Fogalaki-Matagi *
Population estimate *N*	36.0	23.3	17.2	73.9	116.5	31.9
Standard error (*N*)	7.4	4.1	1.0	7.7	7.3	2.4

* whole islet live-trapped ** one acre live-trapped

TABLE 4. *Population density and rat damage.*

	Year	Quadrat size m²	Number of nuts: Damaged	Undamaged	Copra and malformed	Total	Condition	Population estimate
NUKUNONU ATOLL								
Motuakea	1966	324	5	14	—	19	Untended but slightly overgrown, damage slight	*N*.36, S.E.(*N*)7.4
	1968	1024	Nil	44	92	136		
Avalau, Long Motu	1967	200	55	7	—	66	Untended, much overgrown, rat damage severe	*N*.17.2, S.E.(*N*)1.0
	1968	3072	1094	158	1249	2503		
Church Property Nukunonu West	1967	243	Nil	40	—	40	Relatively well tended rat damage negligible	*N*.73.9, S.E.(*N*)7.7
	1968	6144	21	321	569	745		*N*.116.5, S.E.(*N*)7.7
ATAFU ATOLL								
Fogalaki-Matagi	1967	112	106	8	—	114	Untended, overgrown, rat damage severe	*N*.31.9, S.E.(*N*)2.4

larger rat population (73.9 and 116.5 per sampling area respectively). It appears, therefore, that in well managed properties damage to coconuts is negligible, whereas in untended and overgrown areas it is much more severe despite a much smaller population.

The above findings are supported by the results of the interesting work by M. N. Sproat in the American Trust Territory of Mariana Islands (*in litt.* 1967) and by my observations in Western Samoa.

The reason for this discrepancy is not yet clear. More background information on rat biology, including feeding habits and coconut productivity in the Tokelau Islands, is required. Pending the receipt of such information, rat damage in the Tokelau atolls appears to be mainly a question of management. Management is also a vital factor in other agricultural problems in the Tokelau Islands, including the eradication of the rhinoceros beetle.

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