R E P O R T

ON

RESULTS OF RAT CONTROL TRIALS

IN THE TOKELAU ISLANDS

FROM

30 JULY TO 20 SEPTEMBER 1970

AND

RECOMMENDATIONS FOR A COMPREHENSIVE

SCHEME OF RAT CONTROL

by

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I. INTRODUCTION

The visit to the Tokelau Islands described below is the third carried out in a study of ecology, rat control and related problems. The first visit in 1966/67 (Wodzicki 1968 A) was devoted primarily to the study of the ecology of the Polynesian rat (Rattus exulans) and the environment, including the animals and the vegetation, of Nukunonu atoll. The main objects of the second expedition in April-June 1968 (Wodzicki 1968 B) were the initiation of a long-term investigation of rat damage on all three atolls and the training of two men from each island as rat control operatives.

The present visit was planned with the following two main objectives in mind:

1. the study of the relationship of rat damage to various coconut varieties growing in the Tokelau Islands; and
2. the conduct of rat control trials with the view of preparing for the Administrator, Tokelau Islands (Mr Richard B. Taylor) recommendations for a rat control scheme suitable for the Tokelau Islands.

The preliminary analysis of data collected during the fifteen months long investigation of rat damage in 1968/69 on the three atolls suggested that palms belonging to some varieties may be more prone to rat damage than others (Wodzicki 1970). It seemed important that we learn more about the character of palms growing on the three atolls.

With regard to rat control, trials with various kinds of poisons have been carried out since our first visit to the Tokelaus in 1966/67 (Wodzicki 1968 A). However, during our first two visits knowledge of rat ecology was not sufficiently advanced to allow for more sophisticated tests. Since the

author's 1968 visit, the important work on rat control in the Gilbert and Ellice Islands by F.J. Smith (Smith 1969) has become available. This information and our knowledge of rat ecology, gradually acquired since the beginning of the Tokelau Islands rat project, now makes possible a programme that could become the basis of a practical rat control scheme for the three islands.

As most of the previous work had been carried out on Nukunonu atoll only, it was felt that half of the time during the visit should be spent on Fakaofo and the remainder on Atafu.

Following a brief description of these trials is the writer's recommendation of a rat control scheme submitted to the Administrator, Tokelau Islands.

Finally, some other observations on plants, animals and related aspects are briefly reported and collections made for the Botany Division, D.S.I.R. and the Dominion Museum are briefly mentioned.

II ITINERARY AND LOGISTICS

1. Itinerary

The writer's itinerary on his way to the Tokelau Islands included stops at Fiji and at Apia. The former stop, at Koronivia Research Station, Department of Agriculture was to have discussions with J. Morgan Williams, the Vertebrate Ecologist of the Department and to exchange information. During the five-day stop at Apia, while awaiting the arrival of the Air Pacific aircraft, the writer at the invitation of the Manager (Dr Euan C. Young), Rhinoceros Beetle Project, read a paper, "Remarks on Rat Damage to Coconuts", to the Annual Meeting of the Rhinoceros Beetle Operations Board in Apia on July 27th, 1970. The discussion that followed the delivery of the paper and contacts made with researchers working on other coconut pests will be of considerable value for future work.

Upon the writer's departure from Apia on 30 July 1970 two days en route to Fakaofo were spent at Nukunonu atoll to examine briefly some present aspects of the rat problem there.

The writer landed at Fakaofo on 1 August, planning to leave Fakaofo on Monday, 24 August, hoping to work for the

remaining three weeks at Atafu. Most unfortunately and to the writer's regret the Air Pacific aircraft became grounded in August and the author had to remain at Fakaofo until his departure for Apia by the "Aoniu" on 20 September 1970.

For further details see Appendix 1.

2. Logistics

The success of any expedition with an applied ecology objective in mind, much depends on adequate transport and necessary equipment and supplies - all being available at dates and places set out by the programme at its onset. Any experiments with rat control involve considerable planning: 1. detailed scheduling of baiting and laying down of poison; 2. setting aside time for appraising the results; 3. obtaining permission from the owners of the land for the experiments; 4. arranging with village authorities to restrict access by everybody except the rat control personnel to any motu where acute poison is to be laid. Additionally in experimental poisoning it is highly desirable to carry out simple census tests that provide an idea of the rat population present before and after poisoning. And finally, previous rat control work carried out experimentally by Dr Ropati Logologo at Nukunonu has clearly shown that unless a whole motu is poisoned, re-infestation from other parts of the islet takes place in a relatively short time.

The unpredictable grounding of the Air Pacific aircraft was a severe blow: it cut the programme in half by eliminating Atafu from this survey altogether. Furthermore, by delaying the day of the flight to Atafu by a few days at a time, it was impossible to plan an extention of the work at Fakaofo to compensate for the planned work at Atafu.

The lack of motor transportation in Fakaofo was made known to the writer upon his arrival there and proved to be a serious handicap: instead of spending a couple of hours daily in a boat propelled by an engine, five and sometimes up to seven hours had to be spent daily travelling in the village's paopao. With the wellknown irregularity of the breeze on Fakaofo lagoon, it was only owing to the devotion of the rat officers who had to pull or paddle most of the way that it was at sometimes possible to reach the islets.

III. RESULTS

The field work at Fakaofo was concerned with the following two main problems: 1. the nature, distribution and other aspects of rat damage on Fakaofo atoll; and 2. experimentation with rat control methods, suitable for the Tokelau Islands conditions. The logical outcome of the study of these two problems are the recommendations of the Tokelau Islands Administration regarding rat control and related problems. Finally, a very brief account of other observations will sum up the modest contribution during this trip to our knowledge of the natural history of the Tokelau Islands.

A. The Nature, Distribution and Other Aspects of Rat Damage at Fakaofo:

As already mentioned, the preliminary analysis of the data supplied by the long-term study of rat damage on some 67 quadrats, established on all three atolls in 1968/69 called for a closer examination of the coconut palm varieties and of their relationship to rats (Wodzicki 1970). We shall proceed by giving a brief account of what the writer could learn during his stay at Fakaofo and of what was reported to him by Dr Judith W. Huntsman from Atafu about the palm varieties growing on these two atolls. Following a brief description of the developmental stages of coconuts, an account will be given of the way and coconut growth stages at which rat damage occurs. Finally the results of a survey of rat damage in the various islets of the atoll will complete this part of the report.

1. Coconut Palm Varieties at Fakaofo and Atafu

Little is known about the origin and varieties of coconuts growing in the Tokelau Islands. B.E.V. Parham, Botany Division, DSIR Lincoln, (in litt. 10 April 1970) suggested that the palm varieties found at present in the Tokelau Islands were probably "brought from neighbouring islands by canoe or by early Pacific voyagers." This was "followed during the past 100 years by deliberate introductions from Samoa and elsewhere."

Enquiries about palm varieties growing on Atafu atoll were kindly made at the writer's request by Dr Judith W. Huntsman who provided the following information (in litt. 20 April 1970):

"1. There are three crosscutting categorizations of coconuts.

a. On the basis of colour of the nut when at mokomoko or hua stage.

Kafa kukula has reddish cast.

Kafa hihina has whitish cast.

kafa tetea has yellowish cast.

Kafa ui is a strong green.

There is no difference in the taste or quality of the fruits.

b. On the basis of fruit production.

Alakita (probably Parham's 'La'ita' [reported by Parham as grown in Samoa] which has many nuts in each bunch, but does not fruit continually.

Niunoa which has fewer fruits per bunch but fruits continuously.

They taste the same, but the alakita has a thinner husk and shell. Rats are said to prefer alakita because it is easier for them to get inside.

c. On basis of sweetness. The utogau is any sweet coconut. Both the juice and the husk are sweet and these are valued because people like to eat the husk. Rats like the utogau, it is said, because of its sweetness.

Because the categories are crosscutting, one may have an alakita which is also a kafa kukula and an utogau, or a niunoa which is a kafa ui and not an utogau. There is no opposite to utogau, a tree is either an utogau (sweet) or not.

These categories do not run true. People frequently plant an utogau nut and get an unsweet result. Planted kafa kukula come up kafa ui; and alakita planted grow up to niunoa. Genetically the situation is fascinating. One might characterize by the Tokelau phrase: "palu valevale" or mixed every way. However, it is not absolutely hopeless for there is a tendency for the planted nut to produce its like."

At Fakaofo discussions were held, both in the village and in the islets, with Dr Iona Tinielu, Headteacher Hosea and several elders, and produced information which generally agrees with Dr Huntsman's description.

As at Atafu, palm varieties at Fakaofo are also recognised on the basis of sweetness, fruit production and colour of the nut at the mokomoko or hua stage.

The utogau is the only palm variety that is distinguished on the basis of sweetness. In this variety the juice from the husk and the tissues from the front of the nut as well as the juice inside the shell are sweeter than in any other variety. The shell is softer than that of other varieties of nuts. According to Dr Iona the utogau nut can be also distinguished by its shape: the bottom part or back part of the nut is more prominent and has a rounded form.

The utogau can be an alakita, niunoa or kitanoa (Table 1). In most of the utogau palms, the bunches contain nuts which have been arrested in their development; probably they are nuts that at an early (puakoile) stage of development have been disturbed by rat, insect or human activities. Some utogau palms produce fewer nuts and, at times, no nuts at all. The bunches of utogau palms are straight and appear longer with a broader cover of fronds and can be recognised as such. The remarkable softness of the utogau nut remains until the popo stage or even the mature stage of the nut; and because of this softness one can remove the husk of the utogau nut without the use of a crowbar.

TABLE 1

MEASUREMENTS OF UTOGAU, ALAKITA, NIUNOA, KAFA UI, KAFA TETEA AND KAFA KUKULA. ALL MEASUREMENTS IN mm AND AT THE MOKOMOKO STAGE

Palm Variety	Nut's Length	Nut's Width	Kernel's Length	Kernel's Width	Husk at top	Thickness at bottom	Thickness of Shell & Meat	
Utogau 1	185	140						+x
2	180	150	103	95	20	53	4	x
Alakita 1	165	140						+x
2	180	149	114	98	23	45	6	
3	126	85	80	63	11	32	12	x
Niunoa 1	240	180						+y
2	210	160	120	103	35	47	4	y
Kafaui 1	211	175						+y
2	210	176	107	120	44	47	4	y
Kafa tetea 1	167	150						+x
2	157	140	95	89	22	35	3	x
Kafa kukula 1	230	167						xy
2	235	169	129	113	46	57	6	y

+ Botany Div., DSIR, Herbarium specimen; x Alakita; y Niunoa.

On the basis of fruit production the Fakaofoans distinguish three varieties: alakita, niunoa and kitanoa. Beginning with kitanoa, this variety, according to Vaopuka, cannot be distinguished by sight; it is uncommon and its chief characteristic is the lack of sweetness of the juice; it may therefore contrast with utogau.

With regard to the two main varieties - alakita and niunoa some data on the size, husk, shell and meat thickness are set out in Table 1. Half of the dozen of specimens examined have been shipped to the Herbarium, Botany Division, DSIR at Lincoln where they will be studied further while the other half has been cut longitudinally and the measurements are given in the Table. Until a further examination is being carried out by Mr B.E.V. Parham, it would appear that the size of the nut and the thickness of the husk are to be the main characteristics distinguishing an alakita from a niunoa.

The alakita variety is also known as niu-kita or kita. It has the largest and widest spathe and has more than one and up to 12 nuts at the late puakoile stage but the nuts are relatively small. According to Dr Iona the husk is thinner and sweeter than that of niunoa, particularly near the attachment point. The shell keeps its softness until the huamata stage. The meat inside the shell is thicker and sweeter than in the niunoa, and the same applies to the juice and even to the uto. However, the alakita crops at intervals and between two crops there are no nuts on the palm. Most of the alakita palms grow straight, have very thick base and a strong main trunk.

As already mentioned the niunoa bears larger nuts but generally fewer (Table 1). It was quoted to the writer that an alakita may have in the early puakoile stage up to 100 nuts in the bunch, the niunoa never bears more than ten. To Tokelauans the niunoa has two important qualities: it provides a "man's drink" and it bears fruit continuously.

The above descriptions of the alakita and niunoa palm varieties confirm Dr Huntsman's observations that the three remaining varieties (kafa ui, kafa kukula and kafa tetea) are merely colour varieties that can have alakita or niunoa characteristics (Table 1). Apparently these colour characteristics, according to my informants, may be shared by the whole palm: thus the fronds of a palm may have a tinge similar to the colour of the husk. Finally, it is noteworthy that the

fourth colour variety - kafa hihina (mentioned at Atafu) is not known or has not been observed at Fakaofo.

Discussions with several elders at Fakaofo failed to bring any definite evidence of palm introductions within the living peoples memory. One of the elders consulted mentioned palm introductions from outside the Tokelau Islands, made "five generations ago" by a pastor. Other informants reported that about 20 years ago a "niu Samoa" had been introduced but no one could show the writer any such palm. Somebody else reported that the head of the Pereira family of Fakaofo introduced some new palm varieties to Fakaofo but this also awaits confirmation.

2. 2. Distribution and Numbers of Alakita and Niunoa Palms

Visits to a large number of motus in the course of the present work provided a good opportunity for obtaining information about the distribution and numbers of alakita and niunoa palms on the Fakaofo atoll. Table 2 provides this information in absolute and relative numbers of palms belonging to the two varieties.

It would appear that both varieties are well distributed all over the atoll with a definite preponderance of the niunoa variety.

3. Developmental States of Coconuts

Before considering more closely the relationship between coconut varieties and rat damage, we must briefly describe the various developmental stages of the coconut. Table 3 lists the twelve developmental stages and gives the chief characteristics.

4. Rat Damage in Relation to Developmental Stages of Nut

In thirteen localities on both small islets and large motus quadrats (+) were established on which all green coconuts found on the ground were collected divided into 1. alakita and niunoa; 2. nuts rat-damaged and undamaged; and 3. the stage of development of the nuts (see Table 3). The sample shown in Table 4 appears to be fairly representative as it comprises small and large motus on one side and motus with no damage, light and serious rat damage to coconuts. Finally, Table 5 shows rat damage as shown by green nuts rat-damaged and the number of undamaged green nuts, according to palm variety only, collected on a dozen or so quadrats, mostly on different islets than those shown in Table 4.

(+) A quadrat is a square area of ground with its vegetation.

TABLE 2

DISTRIBUTION AND NUMBERS OF ALAKITA AND NIUNOA PALMS IN VARIOUS FAKAOFO MOTUS VISITED

Name of Motu	Date of Visit	Size or type of Quadrat	Number of Alakita	Number of Niumoa	Total Palms	Percent Alakita
Vini	8/9/70	280 ft	50	93	143	35.0
Nukumatau	4/9/70	140 ft.	16	19	35	45.7
Pataliga	"	"	7	24	31	22.6
Fenuafala North	1/9/70	280 ft	59	102	161	36.6
Fenuafala South	"	280 ft.	30	79	109	27.5
Matafaga lasi seaside	31/8/70	1968/69	18	29	47	38.3
Otoka, seaside	"	"	9	29	38	23.7
" central	"	"	19	27	46	41.3
" lagoon	"	"	7	22	29	24.1
Tekololoa central	"	"	12	21	33	36.3
" lagoon	"	"	17	21	38	44.7
Mulifenua central	"	"	13	21	34	38.2
" lagoon	"	"	18	23	41	43.9
Haumatafaga central	28/8/70	"	9	19	28	32.1
Haumatafaga lagoon	"	"	15	23	38	39.5
Tekoko	"	280 ft.	104	88	192	54.2
Tetielau seaside	"	1968/69	16	19	35	45.7
Tetielau central	"	"	18	34	52	34.6
Tetielau lagoon	"	"	8	19	27	29.6
Fenualoa seaside	27/8/70	"	11	25	36	30.6
Fenualoa central	"	"	13	36	49	26.5
Teoni's Lafu	10/8/70	140 ft.	35	27	62	56.4
Matagi Lafu	"	"	17	6	23	73.9
Panai	"	"	21	30	51	41.1
Falatutahi	"	"	11	35	46	23.9
Tofolaelo	"	"	34	23	57	59.6

TABLE 3

DEVELOPMENTAL STAGES OF THE COCONUT

STAGE NO.	TOKELAU NAME	CHIEF CHARACTERISTICS
1	Puakoile	Very small nut (= "button nut" of English research workers), solid, no cavity inside.
2	Pupu	Beginning of inside cavity, little juice, not sweet.
3	Puakoile Matua	Stage at which juice inside cavity begins to be sweet.
4	Mokomoko	Juice much sweeter than in No.3; also much more juice and this can be recognised by tapping.
5	Mokomoko Tafafa	Nut is bigger and contains more juice.
6	Mokomoko Valivalia	At this stage 'meat begins to grow but not enough to scrape it.
7	Huamata Tulua	This stage can again be recognised by tapping - it gives a hard sound in contrast to the soft sound of mokomoko but some people can identify it by sight; this developmental stage preferred for drinking.
8	Huamata	Tapping sound harder again; it has more 'meat'; some people prefer this stage for drinking.
9	Agalele	'Meat' is harder, the juice less sweet and there is less juice; the husk begins to change colour.
10	Niuhami	Husk becomes dry and wrinkled outside; at the opening of husk it gives a noise as if some gas would be released; shell and 'meat' much harder; good for cooking, oil from nut at this stage was used for lighting.
11	Popo	Hard husk, brown, hard shell, hard 'meat' (popo) oily juice coming out from the 'meat'; stage suitable for copra cutting.
12	Uto	The nut has now been for some time on the ground and is sprouting; the 'meat' (= uto) is eaten cooked or raw.

TABLE 4

RAT DAMAGE ACCORDING TO PALM VARIETY AND DEVELOPMENTAL STAGE ON THE NUT

Locality and Quadrat size and Date	Stage of Nut Development	ALAKITA R-D	ALAKITA UND.	NIUNOA R-D	NIUNOA UND	Total
Vini, 280'	Puakoile	2	18	-	5	25
	Puakoile Matua	19	1	4	-	24
	Mokomoko	10	-	8	-	18
	" Tafafa	23	-	4	-	27
	Huamatatulua	-	-	-	3	3
	TOTAL	54	19	16	8	97
Nukumatau 140'	Puakoile	-	4	-	3	7
	Mokomoko	-	3	-	1	4
	TOTAL	-	7	-	4	11
Pataliga 140'	Puakoile	-	4	-	2	6
	" Matua	-	1	-	-	1
	Mokomoko	-	1	-	-	1
	" Tafafa	-	1	-	-	1
	Agalele	-	-	-	1	1
	TOTAL	-	7	-	3	10
Fenuafala 280 paces sq. 1/9/70 North	Puakoile	-	2	-	-	2
	" Matua	2	1	-	1	4
	Mokomoko	7	1	3	1	11
	" Tafafa	-	1	-	1	2
	TOTAL	9	4	3	3	19
Fenuafala 280 paces sq. 1/9/70 South	Puakoile	-	1	-	-	1
	" Matua	2	1	-	1	4
	Mokomoko	5	1	3	2	11
	" Tafafa	3	1	-	-	4
	TOTAL	10	4	3	3	20
Matafagalasi seaside 1968/ 69	Puakoile	5	8	-	-	13
	" Matua	26	-	3	-	29
	Mokomoko	3	2	-	3	8
	" Tafafa	6	-	8	-	14
	TOTAL	40	10	11	3	64
Otoka Seaside 1968/69 31/8/70	Puakoile	5	-	4	6	15
	" " Matua	-	-	-	-	-
	Mokomoko	-	-	2	-	2
	" Tafafa	2	-	3	-	5
	TOTAL	7	-	9	6	22
Otoka Central 1968/69 31/8/70	Puakoile	15	-	4	-	19
	" Matua	6	-	4	-	10
	Mokomoko	-	-	-	-	-
	" Tafafa	4	-	-	-	4
	Huamatutulua	3	-	-	-	3
	TOTAL	28	-	8	-	36
Otoka Lagoon 1968/69 Quadrat 31/8/70	Puakoile	-	-	-	-	-
	" Matua	5	-	6	-	11
	Mokomoko	-	-	10	-	10
	" Tafafa	-	-	4	-	4
	TOTAL	5	-	20	-	25

TABLE 4 CONT.

Tekokoloa Central 1968/69 Quadrat 31/8/70	Puakoile	-	2	-	-	2
	" Matua	3	-	1	1	5
	Mokomoko	3	-	4	-	7
	TOTAL	6	2	5	1	14
Tekokoloa Lagoon 1968/69 Quadrat 31/8/70	Puakoile	11	5	1	3	20
	" Matua	11	-	5	1	17
	Mokomoko	11	8	3	1	23
	" Tafafa	3	2	2	-	7
	TOTAL	26	15	11	5	67
Mulifenua Central 1968/69 Quadrat 31/8/70	Puakoile	-	7	-	-	7
	" Matua	-	1	2	-	3
	Mokomoko	6	1	3	1	11
	" Tafafa	12	-	-	-	12
	TOTAL	18	9	5	1	33
Mulifenua Lagoon 1968/69 Quadrat 31/8/70	Puakoile	1	6	-	3	10
	" Matua	21	-	5	-	26
	Mokomoko	17	-	5	-	22
	" Tafafa	15	-	13	-	28
	TOTAL	54	6	23	3	86

TABLE 5

RAT DAMAGE ACCORDING TO PALM VARIETY ONLY

LOCALITY QUADRAT SIZE AND DATE	PALM VARIETY				TOTAL NUTS
	ALAKITA		NIUNOA		
	R-DAM	UNDAM	R-DAM	UNDAM	
Haumatafaga Central 1968/69 Quadrat 28/8/70	-	3	2	18	23
Haumatafaga Lagoon 1968/69 Quadrat 28/8/70	0	3	0	0	3
Tekoko, 280' square Quadrat 28/8/70	18+24= 42	34	7	22	105
Tetielau Central 1968/69 Quadrat 28/8/70	5	11	-	9	25
Tetielau Seaside 1968/69 Quadrat 28/8/70	0	4	0	11	15
Fenuafala Seaside 1968/69 Quadrat 27/8/70	1	19	5	22	47
Fenuafala Central	13	6	11	30	60
Fenuafala Lagoon	6	-	0	26	32

TABLE 5 CONT.

LOCALITY QUADRAT SIZE AND DATE	PALM VARIETY ALAKITA R-DAM	ALAKITA UNDAM	NIUNOA R-DAM	NIUNOA UNDAM	TOTAL NUTS
Teoni's, Lafu Motu Quadrat 140' sq. 10.8.70	34	12 (all Puakoile	9	3	58
Matagi, Lafu Motu Quadrat 140' sq. 10/8/70	43	5	7	1	56
Falatutasi 140' sq. Quadrat 10/8/70	4	21 (mostly Puakoile	-	2	27
Panai, 140' sq. 10/8/70	5	13 (11 Puakoile)	2	3	23
Tafolaelo 140' sq. 10/8/70	-	10	-	3	13
Otoka, Seaside 1968/69 Quadrat 6/8/70	24	4	4	13	45
Otoka Central	7	8	10	3	28
Otoka Lagoon	59	17(Inu) 15(Pua-koile)	-	1	77
TOTAL	243	17	57	167	637

TABLE 6

KIND OF NUT	ALAKITA NO.	ALAKITA PERCENT	NIUNOA NO.	NIUNOA PERCENT	TOTAL OF ALL NUTS RAT-DAMAGED
Puakoile	39	81.0	9	19.0	48
Puakoile Matua	95	76.0	30	24.0	125
Mokomoko	62	60.2	41	39.8	103
Mokomoko Tafafa	68	66.6	34	33.4	102
Huamatatulua	3	50.0	3	50.0	6
TOTAL	267	69.5	117	30.5	384

The records supplied by Table 4 and 5 are of considerable interest. Firstly they show the developmental stages of coconuts attacked and those that are preferred by rats. The range of nuts attached is, considering the small size of the Polynesian rat, relatively considerable.

1. Puakoile are the smallest nuts attacked;
2. the majority of nuts damaged belong to the mokomoko category with substantial numbers of mokomoko tafafa;
3. huamata tulua are the most mature nut category rat-attacked. These categories of nuts (Table 3) are judging by their characteristics those one would expect to be liked by rats because of their sweet content and the still soft (and at least in alakita) sweet husk. Table 6 sums up the results shown in Table 4.

Secondly both Tables 4 and 5 confirm what was previously known from previous work at Nukunonu (Wodzicki 1968 A & B and 1969) that rat damage to coconuts is (fortunately) not an universal phenomenon but confined to certain islets only. The occurrence of rat damage is not necessarily linked with the size of the islets. If the ratio of rat-damaged nuts to undamaged nuts is to serve as an index we find islets among both categories showing rat damage or without it, e.g. Fenuafala with little rat damage and Fenualoa showing considerable rat damage or for instance the small Vini Motu with considerable occurrence of rat-damaged nuts as against the small islets of Pataliga and Nukumatau where not a single rat-damaged nut could be located. Nukumatau motu is of special interest: on this islet (also known as pig island) rats abound to the effect that within minutes of quiet watching up to a dozen live rats could be observed; yet there was no rat damage whatsoever.

B. Rat Control Trials at Fakaofo

1. Introductory

In 1968 it was already known that zinc phosphide in coconut bait is acceptable to Rattus exulans. Unfortunately, while embarking for Nukunonu atoll in late April, 1968, the zinc phosphide supply together with other poisons was left behind on the wharf in Apia. Fortunately, since then, Dr Ropati Logologo (pers. comm. 1969) and his Nukunonu team used zinc phosphide on the Punelei motu with a spectacular success: rat damage quickly completely disappeared and, some months later, the owners of the land reported an increase in copra cut and a decrease in the mosquito population (Laird 1963).

Since 1968, the writer's attention was directed to the interesting work carried out on rat control by R.W. Smith (1967) in the West Indies. Following some correspondence with R.W. Smith, Dr Charles H. Thomson, Director of Health, Government of Niue and the writer during the latter's visit to Niue Island, South Pacific in July-August, 1969 developed a corn-meal cake containing warfarin, palatable to rats (K. Wodzicki, unpublished). Preliminary tests carried out at Niue Island have proved the cake to be acceptable to rats and a highly effective rodenticide. This cake is at present being made by the Department of Health, Government of Niue for the needs of Niue and the Tokelau Islands.

The work of F.J. Smith (1969) carried out during 1967-1969 in the Gilbert and Ellice Islands Colony (where both Rattus exulans and R. rattus are present) suggested the use of the two poisons in coconut plantations. He recommends that zinc phosphide poisoning should be followed up as soon as practicable by warfarin rat cake, nailed to the palms. Thus, a local or partial failure of zinc phosphide would be rectified and the rats that had missed the zinc phosphide bait would easily be eliminated.

The short time at the writer's disposal (initially three weeks) practically precluded any varied programme of tests with the above mentioned two main poisons.

The preliminary poison trials carried out under the supervision of the three doctors were very important as they all showed a re-infestation and this was because either only one part of an islet was treated or rats had means of access to the poisoned areas from other islets. This fact and the need to give to the rat control team at Fakaofo as much practical experience as possible led to the decision of selecting one island that could be treated in its entirety during the fortnight or so at the writer's disposal. A similar programme was planned for Atafu but as already mentioned, had to be abandoned.

Consequently, Fenualoa islet was selected and it is there that most of the rat control work has been carried out. In addition, a few short-term tests with zinc phosphide, prolin and the Corn meal cake were conducted to elucidate a few other control problems.

2. Brief Description of the Fenualoa Motu

The Fenualoa islet, one of the larger motus of Fakaofo, is situated in the south-eastern corner of the Fakaofo reef, 4½ k.m. (about 4 miles) from Falē. Fig. 1 shows a hand-drawn map of the islet: it comprises according to the Lands and Survey Department in Wellington, an area of 40 acres. As the map was drawn by Rat Officer Vaopuka in the field and as there was no time to check the measurements taken on its borders with the Chief Cartographer, D.S.I.R., there is, as it can be seen from the tables below, a disparity and the boundaries shown are not quite accurate. However, the sketch is sufficiently accurate to illustrate the poisoning procedure described below.

The vegetation of Fenualoa is characteristic of the overgrown and fairly neglected palm groves in the Tokelau Islands (Wodzicki 1968 A & B, 1969). The seaside parts of areas 1, 2 and most of the area 5 contain other trees, such as pukakai (Pisonia grandis), pukavaka (Hernandia peltata) or kanava (Cordia subcordata), that in many places outnumber coconut palms.

Table 7 shows the numbers of tall, fruiting palms and their distribution in all of the five areas with an approximate total of 4,130 palms.

TABLE 7

NUMBER OF PALMS ON FENUALOA

AREA	NUMBER OF PALMS
1	289
2	204
3	533
4 A (seaside poisoning trial)	114
4 B (central poisoning trial)	203
4 C (remaining part of area 4)	1,249
Total area 4	1,566
5 A	885
5 B	653
Total area 5	1,538
GRAND TOTAL	4,130 palms

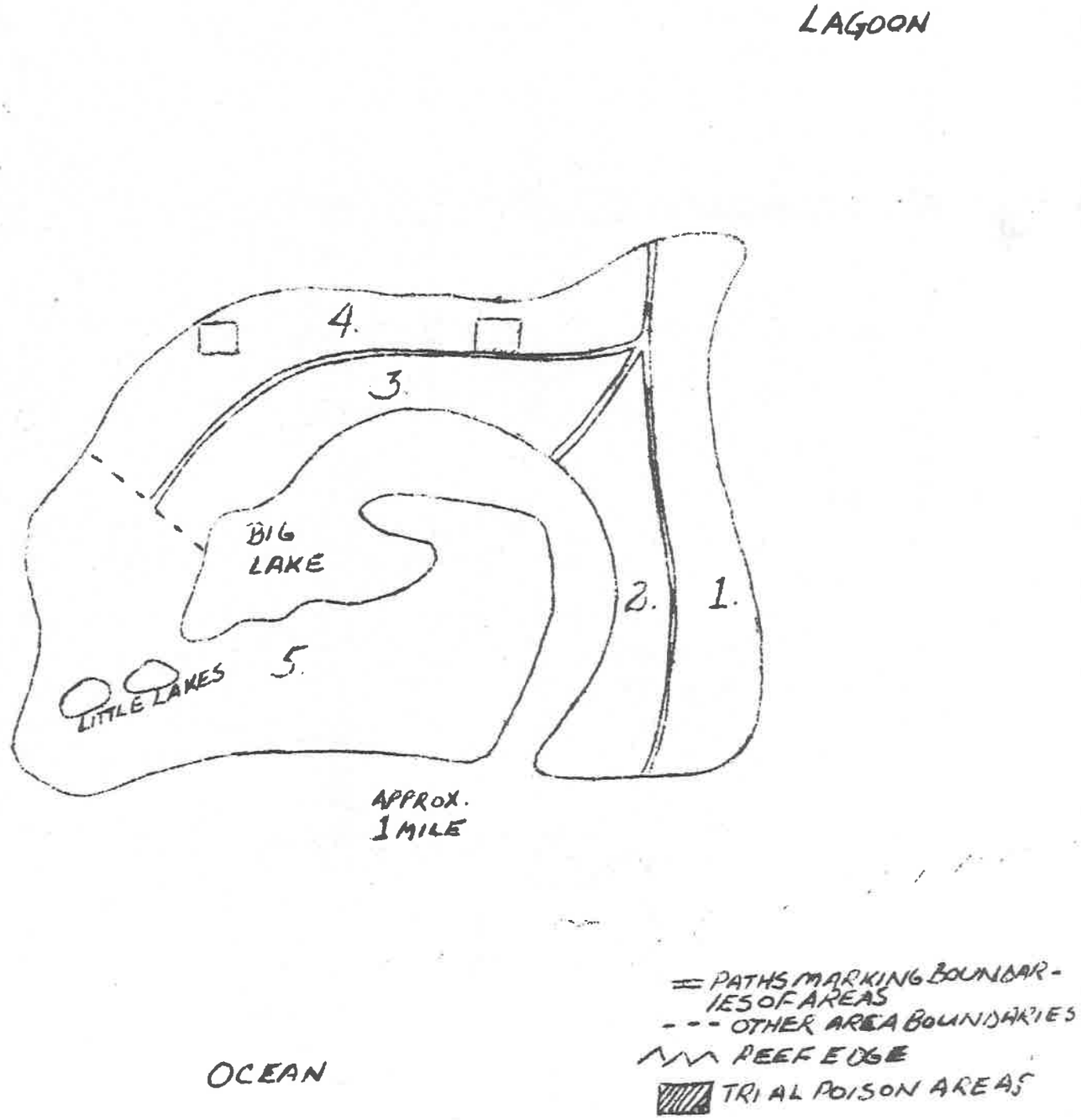

Fig. 1. Map of Fenualoa islet, Fakaofo atoll hand-drawn by Vaopuka showing the five poison areas.

Rats were found very numerous, particularly in areas 3, 4 and 5 (Fig.1): parties of half a dozen rats or more could be seen almost everywhere; they appeared to be very active, presumably hungry as they were foraging early in the afternoon. There were also a few feral cats distributed but no evidence could be obtained as to any effect of these cats on the rat population.

Finally, the numbers of mosquitoes had to be seen to be believed, particularly in the centre of areas 3, 4 and 5. It may be noted that the general situation was not unlike that found on Punelei, and "Long Motu" at Nukunonu where we found the worst rat damage, associated with humid, overgrown conditions and a large permanent mosquito population (Wodzicki 1968 B and 1969).

3. Poisoning Trials at Fenualoa

The selection of the Fenualoa motu for the first experimental poisoning on Fakaofo atoll was prompted by the following reasons:

(a) the damage to coconuts at Fenualoa was some of the worst found at Fakaofo;

(b) Fenualoa is communal property and any improvement in rat damage achieved would be to the benefit of the whole community; and

(c) the size of Fenualoa (40 acres) made this test one of the largest areas tackled at once in the Central Pacific but still manageable with the manpower and time available.

In poisoning any area it is of greatest importance to distribute the poison bait as evenly as possible, making it available to as many animals as possible. Information previously obtained in the Tokelau Islands (Wodzicki unpublished) shows that the territory occupied by a rat living in the Tokelau Islands conditions is not large and probably in the form of a circle; only young animals are moving larger distances but even with this age class, movements of up to 180m are exceptions. In view of this and following F.J. Smith's (1969) practice we chose tall, fruiting palms as suitable points for poison stations. This ensures a fairly even distribution of the poison bait, unless sections of an island are sparsely planted with coconuts, in which case poison stations are placed under other trees.

(i) Preliminary Trials

It would have been ideal if one could repeat at Fenualoa at least one of the catch-mark-liberate experiments that were carried out previously at Nukunonu (Theo Smit and K. Wodzicki, unpublished). These experiments supplied valuable information on the density of rat populations in various habitats of Nukunonu atoll; and at Fenualoa they would have provided a much wanted test of the efficacy of zinc phosphide poisoning. Unfortunately, the lack of rapid transport within the Fakaofo lagoon militated against this idea.

An attempt to use break-back traps as a rough test by setting them before and after poisoning failed and led to loss of valuable time because of crab interference; practically every break-back trap was dragged into the crevasses or under coral boulders an' it was extremely difficult to retrieve the traps.

Only two simple tests could be carried out in order to obtain a better understanding of the intake of zinc phosphide bait in Fakaofo conditions.

(a) Poison Intake in Relation to the Density of Bait Stations

Two areas, one in the seaward side and the second in the inland part of area 4 were marked, measured and all the coconuts were counted.

Table 8 shows the details of the two areas within area 4 used for trials.

TABLE 8

AREA	SIZE SQ.YDS	NO.OF PALMS	NO. OF POISON BAITS	POISON BAIT TAKEN			PER-CENT	TUBES LOST
				ALL TAKEN	½ TAKEN	NIBBLED		
Seaward	5,198	114	71	49	20	2	100	2
Inland	6,864	203	37	27	9	1	100	4

The results of this preliminary experiment were very encouraging. They showed 100% poison bait taken by rats independently whether it was laid in the ratio one bait to every 1.6 or 5.5 palm.

(b) Amount of Bait Required

The large number of tubes in which all the poison was eaten (69% and 73% respectively) suggested the possibility that in view of the attractiveness of zinc phosphide mixed in grated coconut to Polynesian rats, poison bait may be eaten before all the rats would have had access to it. The following

simple experiment was designed: about 100 tubes would receive the usual dose of one spoon (approximately 16g or ½ oz) while on the adjacent land, showing the same rate of rat damage dose of bait would be doubled.

This simple trial was carried out at Otoka between the 5th and 8th September, 1970 and Table 9 shows the results. It would appear from the table that doubling of the amount of poison bait did not increase significantly the poison intake by rats.

TABLE 9

NO. OF TUBES	POISON BAIT TAKEN ALL TAKEN	½ EATEN	NIBBLED	NOT TOUCHED	PERCENT TAKEN
One spoon 93	42	32	14	5	94.6
Two spoons 98	5	39	31	23	76.5

(ii) The Poisoning of Fenualoa Islet

(a) Introductory

The good results achieved by the preliminary trial (Table 8) prompted the decision to poison the whole island.

In view of the presence of a large number of rats it was decided to increase the density of poison stations beyond that recommended by F.J. Smith (1969). Instead of placing bait under every third tree the bait was placed under every second fruiting palm.

Although some workers simply place zinc phosphide bait at the base of a palm, aluminium tubes about 30 - 40 cm long and 8-10 cm wide were used. The use of tubes has the following advantages: (i) the bait is protected from the frequent and heavy showers; (ii) the bait retains its freshness and acceptability to rats much longer; (iii) having bait in tubes is safer for wild life and humans, and rats willingly enter tubes opened on both ends; (iv) tubes make any check of poisons taken easy; and (v) there was an ample supply of aluminium tin in all three islands, originally bought for banding coconut palms.

The next decision important for the outcome of the poisoning on Fenualoa was whether or not to use pre-baiting in zinc phosphide poisoning. F.J. Smith (1969) and E.J. Wilson, the Rat Control Officer, South Pacific Commission (pers. comm. 29 July 1970) favour straight poisoning. Glenn A. Hood, Fish

and Wildlife Service, Hilo, Hawaii (private comm. 1970) finds a significant difference (70% as against 87.5%) in acceptance between "no prebait-treated and prebait-treated" trials. The evidence supplied by our preliminary trial and the short time available disposed us to poison without prebaiting.

To make the bait agalele and huamata coconuts were grated and mixed with 2½% zinc phosphide shortly before laying the bait in tubes. Although zinc phosphide is believed to be attractive to rats per se, the sweet meat of the coconut at the huamata and agalele developmental stages is also an attractant and the writer believes that this has contributed to the high take of the poison bait shown by preliminary trials.

(b) Results

The dates, application of zinc phosphide poisoning and the results achieved at Fenualoa are shown in Table 10.

The outstanding feature of the Fenualoa zinc phosphide poisoning is the excellent acceptance of the poison bait. Only a very small percentage (about 1%) was not touched by rats while 1,787 baits were at least nibbled. The very large number of tubes in which all the bait was eaten (81.3%) suggest a very high acceptability of our poison bait. This was confirmed by inspecting tubes an hour or two after laying them; invariably the great majority of the tubes were already virtuously cleared of bait.

As usual on coral atolls, little direct evidence of the rats killed could be obtained; only three rats and one dead cat have been found, although smell in many places indicated decomposing animal bodies. The rugged surface of any of the islets prevents obtaining any further evidence except that the high toxicity of zinc phosphide makes it unlikely that any rats having consumed even small quantities of the poison are likely to survive.

Another feature that perhaps should be mentioned at this juncture is the relatively large number of tubes that were missing. The probable reason for this was the employment of two extra labourers during the Fenualoa rat control experiment; every day they were new men inexperienced in rat control and retrieval of tubes laid by others.

Finally, an important consideration, particularly from the administrative point of view, is the question of the cost of rat control. This was carefully considered by F.J. Smith (1969) during his work in the Gilbert and Ellice Islands Colony. The

TABLE 10

SUMMARY OF THE FENUAFALA OPERATION

AREA	DATE & NO.OF TUBES LAID		DATE & NO.OF TUBES RECOVERED		NO.OF TUBES LOST	ALL BAIT EATEN	HALF BAIT EATEN	BAIT NIBBLED	NO.OF BAIT TAKEN BY RATS	NO.OF BAIT NOT TOUCHED
1	14.8.70	88	17.8.70	81	7	73	2	4	79	2
2	"	74	"	41	33	39	-	2	41	-
3	"	230	"	197	33	181	10	4	195	2
4	17.8.70	637	20.8.70	505						
	18.8.70	115	20.8.70	128						
	Total	752		633	119	520	61	35	616	17
5	18.8.70	120	24.8.70	857	50	856	-	-	856	1
	21.8.70	758								
	22.8.70	29								
GRAND TOTAL		2,051		1,809	242	1,669	73	45	1,787	22

cost, assuming assistance in the field from landowners, was in 1969 $A0.17 per acre for zinc phosphide poisoning and $A2.19 for warfarin block treatment of an acre of grove. Finally, a "dual strike" i.e. poisoning with zinc phosphide being followed up by the laying of warfarin wax blocks cost approximately $A1.30 per acre.

We have kept a check on the expenses in connection with the zinc phosphide poisoning of Fenualoa. We have excluded the cost of zinc phosphide, which, if bought in bulk and mailed by surface is almost negligible, and tubes, as the material was available free of cost and the tubes will be used again in other places. We also excluded the writer's and Dr Iona's expenses as most of them will not recur. With these considerations in mind the total cost of poisoning the odd 40 acres islet was $WS58.96, i.e. $WS1.47 per acre. In practice that expense will probably be much lower, as in our present case every tube had to be carefully recorded with regard to the poison bait intake; this, of course, in routine poisoning of the islets will not be necessary.

(iii) Follow-up With Warfarin Wax Cake

R.W. Smith (1967) recommended the use of the warfarin wax cornmeal cake as the only treatment against rats (mainly roof or ship rats, Rattus rattus); and this treatment is now widely and apparently highly successfully applied in coconut groves of Jamaica and other West Indies countries. As already mentioned F.J. Smith (1969) recommended for Gilbert and Ellice Islands conditions 2½% zinc phosphide as initial treatment followed up as soon as practicable by an anticoagulant. F.J. Smith contended that despite the fact that the price of anticoagulants has decreased they still may be too expensive for use as the only treatment on a Pacific atoll. He favoured a double strike, the result of which would be the high degree of rat control achieved and the long periods between treatments.

The Tokelau Islands Administration obtains its supply of the cornmeal wax anticoagulant cake from Niue Island, unfortunately still not in adequate supply. The amount available at Fakaofo allowed for some experiments at Fenualoa which are reported below.

(a) Cornmeal Warfarin Cake Trial on Fenualoa

In the first trial 25 tubes were laid in a part of the islet not yet subjected to zinc phosphide poisoning, each containing

4. Other Rat Problems at Fakaofo

Like at Nukunonu, the rat damage to coconuts is by far the most important economic problem. Nevertheless one cannot close one's eyes to the presence and nuisance of rats in the villages of Fakaofo and Fenuafala. There are also some important quarantine problems that are briefly discussed here.

(1) Rat Problem in Fakaofo Villages

On Fenuafala, as it has already been stated, the rat problem in coconut groves is not an economic problem. However, since the beginning of the building of the new village there has been a steady and continuous influx of rats into the school buildings and dwellings. The Education Officer (Mr Derek McKay) reported the presence of rats and some damage in his office and Headteacher Hosea stated that he caught 15 rats in his fale during the first six months of occupation. It should not be difficult for the Rat Officers to assist the residents by occasional snap-trapping and/or placement of warfarin cornmeal cake in the dwellings. On the other hand controlling rats on Fenuafala may not be so simple because of the odd forty pigs roaming all over the island - pigs are relatively more susceptible to anticoagulants than other animals. In fact, semi-feral pigs present a public health problem of their own, and the village authorities may in future decide to keep pigs off Fenuafala. However, in any case it should be possible to control rats at least to the effect that they should be prevented from entering the dwellings. Cornmeal cake laid in tubes set in semi-circles between the fales and bush should serve the purpose; and a couple of strong wire bolts fixed to the tubes should prevent access by pigs to the warfarin cake.

Theoretically, the rat problem at the Fakaofo village is different from that at Nukunonu and Atafu. Firstly, contrary to what we find in the two other villages there is at Fakaofo no "hinterland" of coconut forest where rats could build up their numbers after a successful rat control operation. In theory, Fakaofo village is one of the few places in the world where rats could be exterminated without any chance of re-infestation. Secondly, the high stone wall round the village and the Hospital presents a very suitable, dry habitat in which rats breed and stay during the day and from which they forage into the dwellings at night.

The following observations provide an idea of the numbers of rats living in the wall. Live rats have been seen by us during daytime while sailing round the village. A two nights trapping

with a box trap on the wall produced ten rats on one and 5 rats on another occasion; and the village store, known for numbers of rats seen there, yielded ten rats in a couple of nights. Finally, Table 13 shows the results of anticoagulant rat poisoning in the wall surrounding the Hospital, conducted with the kind permission of Dr Iona. The results of this unfortunately uncompleted experiment seem to indicate that cakes left between stones may fairly easily become the prey of the crabs living in the wall. However, it would appear that placing of the cakes in tubes probably prevents crabs from interfering with them. The increase in the consumption of warfarin cake observed after the 12th of September may be due to new rats having moved into the vicinity of the tubes. Finally, it may be of interest to note that although the village has scores of emaciated cats, the writer failed to see a single cat carrying a rat during his six weeks stay at Fakaofo.

TABLE 13

TAKE OF CORNMEAL WARFARIN CAKE IN THE WALL AT THE HOSPITAL

DATE	CAKE						REMARKS
	ALL EATEN	LITTLE LEFT	HALF EATEN	NIBBLED	NOT TOUCHED	TOTAL	
29.8.70	Nine 4 oz cakes placed between stones						
31.8.70	5	-	4	-	-	9	
2.9.70	All nine cakes disappeared and were replaced by fresh ones.						
4.9.70	All nine cakes disappeared, possible some taken by crabs.						
4.9.70	Nine fresh cakes put in tubes between stones in the wall.						1 live rat seen
10.9.70	5	-	4	-	-	9	Cakes replaced
12.9.70	-	4	3	2	-	9	
18.9.70	6*	-	1	2	-	9	

Most Polynesians have lived with Rattus exulans for so long that they are inured of the rats' presence and somewhat indifferent to the rat nuisance in villages. In fact, Pulenu'u Kolo and several elders were almost opposed to the use of warfarin in the villages even in tubes. It was only during our last conference on Friday 11 September 1970 that Faipule Itieli (taking, as usual

*Crab seen in the vicinity of one tube which may be responsible for eating this particular cake.

with him, a broad view) convinced of the necessity of conducting a rat control campaign in the village, gained their agreement. We all agreed that such "deratization" of the village should be particularly well organised and the cooperation of the Women's Committee and school teachers solicited.

(2) Possible Use of Prolin at Fakaofo

Prolin is a comparatively new warfarin poison (for further details see Wodzicki 1968 A), much used at present in the United States of America, particularly effective in controlling rodents by preventing the formation of vitamin K. An experimental sample was presented by the manufacturers to the writer in 1968, but unfortunately left at that time on the wharf in Apia and never used in the Tokelaus. It was of interest to learn:

i. whether it would be effective against Rattus exulans;
ii. whether it could be mixed successfully with grated coconut which, as we have read above, is such an attractive bait for Polynesian rats; and
iii. whether this poison, after an over two years storage at Nukunonu, would be still effective.

Two "no option" experiments were carried out with this poison (i.e. trials in which no alternative food, except water, was given). In the first experiment six fully grown rats on 24 August were given 4 g prolin mixed with 76 g of grated coconut; the bait was changed daily. Two rats (female, autopsy No.20 and male No.21) died on the 29th. Three further rats (male No.22, female No.23 and male No.24) died on 31 August, the last rat (male No.25) surviving until 2 September 1970.

In the second experiment three male rats, caught on 29 August, were kept on a diet of grated coconut and water ad lib. On the 31st the rats were given 2 g of prolin mixed with 38g of grated coconut, changed daily. The first rat (No.26) died on 2 September and the two remaining rats (No.27 and 28) survived until 3 September 1970.

Although the above tests were with a small number of animals, it may be provisionally concluded that:

(i) prolin mixes with grated coconut well and is accepted by rats;
(ii) as one would expect prolin seems to be as effective against Rattus exulans as it is in the States against R. rattus and R. norvegicus;

(iii) the poison's potency was not affected by over two years storage; and

(iv) the shortest time for a lethal dose to act was two days, the longest period was 9 days and the average period in our sample was $5\frac{1}{2}$ days.

It would appear therefore that prolin is a poison suitable for the control of the Polynesian rat, particularly in conditions where acute poisons cannot be used for safety reasons.

(3) Quarantine Problems

As the western man started to explore and settle all round the world undesirable or noxious animals travelled with him and more often than not settled with him to endanger his health or the health of his animals or to spoil or even ruin his crops. Quarantine or the science to prevent undesirable animals or plants from becoming established in new islands or lands became a household word and it is pertinent that a few words be said on this subject in connection with the Tokelau Islands.

The Tokelau Islands are still one of the few places in the Pacific without mice and the ship or roof rats and Norway rats. The recent appearance of unspecified rodents emerging from a package coming from New Zealand at Fakaofo may be a timely warning that this state of affairs may not continue for long if the lack of quarantine measures continues.

C. Other Observations and Collections

As already mentioned an attempt was made to make additional observations and to collect insects and other invertebrates as much as the work described on the preceding pages would allow. Autopsies of rats will supply additional material for the study of rat parasites, reproduction, age determination and other aspects of the Polynesian rat's ecology. Also observations on birds seen at Fakaofo have been made. A paper on the birds of the Tokelau Islands by Dr Marshall Laird of the Memorial University of Newfoundland, St. John's, and the writer has been accepted for publication and is at present in the hands of the Editor of "Notornis". A comparison of the writer's observations with those by Dr Laird about ten years ago will be of interest to the Tokelau Islands Administration and nature conservationists alike. Has the human population pressure on the Fakaofo atoll during the last decade affected the bird populations and to what an extent?

The collections of marine invertebrates and of insects will be presented to the Dominion Museum and a collection of coconut varieties, as known to residents of Fakaofo, will go to the Botany Division's DSIR Herbarium at Lincoln for further study.

IV DISCUSSION

The information contained in the preceding pages has considerably increased our knowledge of the coconut palm-rat relationship. The information about coconut varieties from Fakaofo and Atafu has greatly assisted us in the evaluation of the rat damage and there is hope that a study of these varieties by the Botany Division, DSIR, will be of further help. This information is compelentary to the work on quadrats in the three atolls in 1968/69 now being processed by Mr Stan Roberts and the writer at the Applied Mathematics Division, DSIR in Wellington. Although we now know that some coconut palm varieties are more prone to rat damage than others, it is doubtful whether a replacement of these varieties by others less likely by rats would be immediately practical.

More support has been obtained for the view that the rat problem in the Tokelaus is a problem of management. As in Nukunonu (Wodzicki 1968 A & B, 1969) and Ellice Islands (Smith 1969) rat damage to coconuts at Fakaofo is serious in islets that are humid and densely undergrown with shrubs and usually bird-nest fern (Asplenium nidus). However, we still do not know what ultimate factor sends the rats to the top of coconut palms and makes them gnaw nuts.

A survey of a large number of the Fakaofo motus has provided us with a good picture of the occurrence and severity of rat damage, separating islets requiring rat control from those which do not need it. However, although we are convinced of the losses sustained by Tokelauans, we would hesitate to express the value of rat damage in dollars and cents until our study (K. Wodzicki and H. Stan Roberts in preparation) and the long-term study of Morgan Williams in Fiji (pers.comm. 23 July 1970) are completed.

Though factors beyond the writer's control prevented him from visiting Atafu atoll to carry out a similar survey of rat damage and experiment on rat control, the writer has had discussions with Dr Iuta Tinielu and Dr Judith W. Huntsman.

It would appear that rat damage at Atafu is at least at the level of that at Fakaofo. It is apparently also confined to a limited number of motus but it is definitely more serious because of the food situation on that atoll. There are in Atafu fewer palms to feed a relatively larger human population. Informal discussions the writer had with some of the Atafu leaders during the "Big Fono" at Fakaofo confirmed the above opinion; some people went as far as to consider a petition to a world-wide organisation soliciting assistance in the destruction of rats at Atafu.

The ecological observations briefly discussed above went hand-in-hand with the few trials that the writer was able to organise and carry out during his stay at Fakaofo. As the result of these trials the writer is inclined to support the "dual strike" of F.J. Smith (1969) than the use of one poison only advocated by R.W. Smith (1967) and E.J. Wilson (pers. comm. 29 July 1970). Admittedly the take of zinc phosphide in grated coconut as shown by the Fenualoa trial and also by the rat poisoning at Otoka is surprisingly high and higher than in the Gilbert and Ellice Islands but other reasons support the "dual strike".

Firstly, both at Nukunonu and Fakaofo (and probably at Atafu) the properties that show considerable rat damage all happen to be large islets that have to be treated from one end to the other. Judging by the time required for the treatment of Fenualoa motu, the poisoning of such islets with zinc phosphide alone will probably take 2-3 weeks. Why not include a follow-up with warfarin cake, which, as shown by F.J. Smith (1969) does not necessarily lead to a substantial increase of the cost of poisoning. On the other hand, a "double strike" would no doubt increase the degree of rat clearance to the effect that two or three years may elapse before a new treatment of such property may become necessary.

The high skill acquired by the Rat Officers and the unique situation of having medical officers as supervisers of the rat control scheme in the Tokelaus allows for the relatively safe use of such a highly toxic poison as zinc phosphide.

Finally, the system of utilisation of the outlying motus and the authority exercised by the faipule, pulenuu and the elders of the community in the Tokelau Islands make it possible to effectively prohibit access to any areas where acute poisoning is taking place.

V. RECOMMENDATIONS

The writer was requested at the time of his departure for the Tokelaus late in July 1970 to answer the following two questions:

i. Is a permanent rat control scheme for the three Tokelau Islands necessary?

ii. In the case of an affirmative answer to the first question, to recommend a practical scheme of rat control, including organisation, financing and materials required.

i. Is a permanent rat control scheme for the Tokelau Islands necessary?

My answer based on three consecutive visits to the Tokelau Islands in 1966/67, 1968 and 1970 is affirmative for the following reasons:

(a) Rat damage to coconuts in the three islands is of sufficient magnitude as to warrant an organised scheme of control.

(b) The nature of the rat ecology on one side and the social and economic organisation on the three atolls on the other make rat control by means of private initiative impossible.

(c) The presence of specially selected, intelligent and already trained rat officers and of three medical officers deeply interested in the welfare of their particular islands make an efficient rat control scheme practical and possible in the Tokelau Islands.

(d) There is no other place in New Zealand territory where the livelihood and welfare of the inhabitants depends so much on a single resource as is the case in the Tokelaus with the coconut palm. The writer feels that it is the paramount duty of the Administration to see that the threat to coconuts by rats be removed.

The following simple equation sums the whole situation well. We can assume that in 1925 when New Zealand took over the administration of the Tokelau Islands the coconut production and the number of rats preying on green coconuts were approximately the same as today but the population was only 900. Today the same area has, despite the migration to New Zealand, to feed 1,745 people (January 1st, 1970 census).

ii. The organisation of the Tokelau Islands Rat Control Scheme.

The study of the ecology of the rats (Rattus exulans) in the Tokelaus Islands has shown that there are two possible methods of rat control in the Tokelau Islands: by changing the environment or by conventional rat control methods. The first method is initially expensive but eventually removes rat damage permanently or at least for a number of years. It consists of removing the undergrowth and generally clearing of the coconut groves. The Vao or Church plantation at Nukunonu where successive missionaries cleared and improved the grove considerably is an example of results achieved by the first method. Regular observations have been carried out for nearly four years; although rat numbers present in this plantation have been considerable, no rat damage whatsoever has been observed during this time. Unfortunately, the objections to any removal of trees from their properties by the Tokelauans and more recently the acute shortage of labour in the islands make this method impractical. Conventional methods of rodent control as described in the second part of the present report remain the alternative.

The organisation of the Rat Control Scheme should remain the same as that used for the collection of information on the quadrats in 1968-69, i.e. two trained rat officers supervised by the local Medical Officer. On Nukunonu and Fakaofo both the rat officers have had substantial training and experience and the Medical Officers are well acquainted with their duties and problems of rat control. The writer has not had an opportunity for an extensive visit in Atafu to get acquainted with the rat problems of that atoll, to supervise two rat officers there (one of whom has had no training whatsoever) and to discuss the problems with Dr Iuta Tinielu. This may make a visit of the writer to Atafu highly desirable, or it may be possible with transfer of Medical Officers or rat officers to solve this problem.

The conditions of employment of the rat officers and the remuneration of the supervising Medical Officers should in principle remain the same, except the following modifications. The rate of pay for the rat officers should be 12 cents an hour for the following reasons:

1. Their job is a highly skilled work for which they had to be trained;
2. Despite all precautions taken, the rat officer's work involves personal risk; and

3. In comparison to the working conditions of say construction workers, rat control officers have to spend most of their time in mosquito-ridden country difficult to penetrate, often for days far from their homes.

At the suggestion of the Administrator, the writer has discussed the question of the number of days the rat officers should be employed with Dr Judith W. Huntsman, social anthropologist well acquainted with the amount of time required by a man in the Tokelaus to obtain food for his family. Dr Huntsman feels that fifteen days a month should be the normal period of employment for the rat officers.

Finally, a word about the cooperation and part to be played in this scheme by the Tokelauans. It has already been made plain that any scheme run privately by the islanders would be a sheer waste of materials and equipment. The fact that the rat control scheme must be run by experts does not mean that there is no room for help and cooperation by the villages and the property owners in particular. In practice, it would mean that the village would have to supply a sea-worthy paopao and shelters on remote motus where rat control would require camping of the rat officers for one or more nights. With regard to property owners, a representative of the family owning the islet should be on hand to supply coconuts for bait and to assist the rat officers in the laying of bait.

Appendix 2 lists the equipment and materials that should be always kept in readiness on each atoll: the lack of perseverance in rodent control and the beginning of the clearing from rats of an islet without completing it are the greatest roadblocks of a successful control.

Before concluding, it remains to discuss briefly the important problem of the cost of the rat control scheme for the Tokelau Islands. The following table provides the details:

<u>Labour and Supervision</u>	
Six rat control operatives' pay 12c per hour, 180 days per year	$1,036.80
Honorarium for three Medical Officers	180.00
<u>Poisons and Other Materials</u>	
Cost of zinc phosphide poison @ 25g per acre for 1,300 acres	65.00
Warfarin wax cake @ 20c per lb for 1,084 lbs.	216.80
Other equipment	118.50

Transport

Rent of paopao @ $60.00 per island	$180.00
TOTAL	$1,797.10

The following additional comments are added:

(i) The area to be treated of 1,300 acres in the three atolls is probably in excess of the land that requires treatment because of the prevailing rat damage to coconuts and probably some saving will be made on expenses on poisons and labour. However, this saving would allow the "deratisation" of the villages not included in the above statement.

(ii) The recent gift of 112 lbs of warfarin by the Rat Control Officer, South Pacific Commission (Mr E.J. Wilson) to the Government of Niue will probably bring down the price of warfarin cake considerably and make another saving possible.

(iii) The experiments on rat control on atolls carried out to date indicate that the "dual strike" control, if conducted properly, may achieve a virtual rat clearance lasting up to 24 months. This may bring down the cost of rat control in the second year.

VI. ACKNOWLEDGEMENTS

My sincere thanks are due to the Administrator (Mr Richard B. Taylor) and the District Officer (Mr Lloyd Webber) for the invitation to visit the Tokelau Islands to carry out the work described in the preceding pages and for making the necessary arrangements. I would also like to thank Mr J. McEwen, Secretary, Department of Maori and Island Affairs and Mr John R. Springford, Director, Island Affairs Division, Department of Maori and Island Affairs for initiating the project, for their continuous interest and for help in many ways.

I am particularly indebted to Dr Iona Tinielu for placing his intimate knowledge of the Tokelau Islands environment, especially of Fakaofo, at my disposal, and for taking such an important part in the present work. This work would not have been done without the eager interest, determination and devotion to duty of the rat officers Vaopuka and Iulio.

The writer thanks also Faipule Itieli, Pulenuu Kolo, the matai and the toeaina of Fakaofo for their keen interest in the work since my landing at Fakaofo, all the help given and

the hospitality provided by the village. I am also very grateful to Peter and Te Aroha Sharples, Dr and Mrs Iona Tinielu and Pastor Kaio at Fakaofo, and Mr and Mrs Alan Barris at Nukunonu for their hospitality and for looking so kindly after the writer's bodily needs.

Last but not least, I wish to thank Dr Judith W. Huntsman for kindly providing valuable information on rat-coconut relationships at Atafu and for assisting me with her knowledge of human problems of the Tokelau Islands.

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APPENDIX 1

LOG OF THE 1970 EXPEDITION

22 July, 1970	Left Auckland by Air New Zealand at 2130.
23 " "	Arrived Nausori, Fiji at 0930, met by Morgan Williams. All day discussions with Morgan Williams of our respective work, particularly of the rat damage problem.
24 " "	Morning with John Parham, Government Botanist at Department of Agriculture's Herbarium, later at British Pacific Commission Archives; afternoon further discussions with Morgan Williams.
25 " "	Travelling from Suva to Apia, arriving Faleolo Airport about 1800.
25 (second day)	Meeting E.J. Wilson, Rat Control Officer, SPC. Preparing paper for Rhinoceros Beetle Research Board Meeting. 0945 depart for whole day excur-
26 July, 1970	sion with Rhinoceros Beetle Research Board, returning 1845; evening further work on tommorrow's paper.
27 " "	Attending the opening and later Rhinoceros Beetle Research Board Annual Meeting; in the afternoon delivered own paper "Remarks on Rat Damage to Coconuts" followed by discussion. Evening attending reception at N.Z. High Commissioner's residence.
28 " "	Whole day at Tokamin office working on paper for WHO rodent control symposium; in the afternoon long discussion on the rat problem at Niue and in the Tokelau Islands with E.J. Wilson. He presents on behalf of the SPC two 56lbs drums of warfarin for making cornmeal rat cake for these islands. Afternoon further discussion with the Administrator regarding certain aspects of rat damage in the Tokelau Islands.
30 " "	Leaving Apia at 0950 and Faleolo Airport at 1120 by Air Pacific Amphibian and arriving Nukunonu at 1232. Staying with Mr & Mrs Alan Barris, Education Officer. In the afternoon and evening discussions with Rat Control Officers (Alofa Isaia & Teoni Basileo) and Faipule Lui Kanava.
31 " "	Whole day in Vao, Punelei and "Long Motu" with Rat Control Officers, the Education Officer kindly providing transport. Late afternoon checking

rat control equipment and stock of poisons. 2000-2200 meeting Faipule, Pulenuu and the Toeaina to discuss rat control at Nukunonu in the light of the previous work and today's visit.

1 August, 1970 — Leaving Nukunonu in Amphibian at 1010, arrival at Fakaofo at 1034. Brief welcome by Faipule Itieli, Pulenuu Kolo, the Matai and Toeaina assembled at Fale Fono. Staying at Pastor's fale. Afternoon meeting and talking with Rat Control Officers (Vaopuka & Iulio), Dr Iona Tinielu, Peter & Tearoha Sharples (Language Laboratory, University of Auckland), Derek McKay (Education Officer) and Geo. Bickerstaff (Work Overseer).

2 " " (Sunday) — Unpacking and preparing programme of work for the next three weeks at Fakaofo.

3 August, 1970 — 0835 leaving in village paopao for Fenuafala. Much rain. Discussing transport and supplies with Geo. Bickerstaff and inspecting and re-measuring the 1968/69 quadrats. Returned Falē at 1730. 2000-2150 meeting Faipule, Pulenuu, Matai and Toeaina and giving an outline of proposed work. Faipule on behalf of the meeting promises wholehearted support.

4 " " — Working on programme. 1000 calling District Officer, Apia requesting authority to employ two additional labourers when required; also that the paopao as the only means of transport would slow up work. 1030 depart for Haumatafaga, Hakeamahaga and Fenualoa islets to inspect former quadrats, and ascertain degree of rat damage. Return Fale at 1758.

5 " " — Left 1050 for Palea (bird islet), 1110 no rat damage, 1330 at Heketai and Olokalaga rats seen but nut damage, Motuakea at 1445 one rat seen but no rat damage, pulaka plantations inspected Teoki islet at 1545 and at 1605 arrived at Tetialau to re-measure three 1968/69 quadrats, again little rat damage. Returned Falē at 1900.

9 " " — 0925 for Mulifenua, Matafagalahi and Otoka re-measuring quadrats and inspecting rat damage. 1750 return to Fakaofo.

7 " " — Left for Fenualoa at 1055 arriving 1400 after three hours hard pulling. Assessing rat damage in seaside and central quadrats. Set 12 break-back traps each in two areas as a precensus

measure, also eight box and Japanese traps each. 2200-2400 Vaopuka and Iulio building roof on shelter.

8 August, 1970 — Most morning trying to recover break-back traps carried by crabs. Afternoon mixing of zinc phosphide bait and laying out poison bait in two trial areas. Return Fakaofo 1835.

10 " " — Left 0848 for Tafolaelo, Falatutahi, Pani islets and Matagi and Teoni's, Lafu Motu inspecting and assessing rat damage. Return Falē 1645.

11 " " — Left for Fenualoa 0833, arriving 1108. Setting first rat cake experiment and 8 Japanese live-traps. 1200 arrival of Dr Iona with two men and inspection and collection of tubes in the two experimental areas; success as 98% take of poison noted. Examination of coconut palm varieties and discussion. Return Fakaofo 1800. 2000-2100 discussion with Pulenuu and Dr Iona.

12 " " — 0700-1000 notes and specimens. 1030 call Mr Lloyd Webber, Apia and Dr Iuta, Atafu regarding Atafu work. Men making poison tubes.

13 " " — Left village 0930, Vaopuka and Iulio hauling and pulling paopao almost whole way, arriving Fenualoa 1245. V. counting palms in area 1 and 2, and K.W. and I. measuring above areas, K.W. later collecting insects.

14 " " — At Fenualoa, 0700, collecting Japanese traps (3 rats). 0720 arrival of Dr Iona with two men. Dr Iona and V. count palms and measure area 3, K.W. mixing zinc phosphide bait and later laying it with Iulio and second man on area 1 and 2. Afternoon new portion of poison mixed and all men laying it in area 3. Return shelter 1830 Fakaofo 2015.

15 " " — Morning K.W. for dressing at Hospital, later writing notes and attending specimens.

16 " " (Sunday) — Evening discussion with Pulenuu Kolo and Dr Iona of present and future work.

17 August, 1970 — Depart from Fakaofo 0900 (no wind), arrival Fenualoa 1300. Inspection of first cake experiment. Lifting tubes and noting bait take in Area 1 and 2 and replacement by cornmeal cake (second cake experiment). Later checking and lifting of tubes in Area 3. Returned camp 1830.

18 August, 1970 — At Fenualoa Dr Iona mixing poison, V. counting palms on Areas 5 and 5; then Dr Iona and I. laying poison in Areas 4 and 5, and K.W., and V. measuring remaining areas of island.

19 " " — Still at Fenualoa. Early morning K.W. mixing poison, later with V. and I. laying 130 tubes under 260 palms, still later dissecting rats. Depart Fenualoa 1045, arrival village 1145. Later K.W. having dressings at Hospital and writing notes. Attending special hiva in the evening.

20 " " — Morning K.W. at Hospital for dressing. 1200 depart for Fenualoa with Dr Iona V., I. and two men. V. completed counting the 1538 palms in area 5, K.W. and one man measuring the remaining part of area 5, Dr I., I. and second man collecting and examining tubes in area 4. 1750 depart of Dr Iona, further searching for tubes until 1900. K.W. mixing poison morning and afternoon. 1,301 tubes with poison laid today in area 5. In the evening arrival of Dr Iona to dress K.W.'s leg and depart.

22 " " — Still at Fenualoa. Early morning laid remaining 29 tubes in area 5 thus completing the poisoning of the 40 acres of Fenualoa. Measuring of 170 Alakita and Niunoa green nuts, K.W. collecting insects. Depart 1308, return village 1460. First cable announcing delay in aircraft's arrival of plane for Atafu. Beginning of K.W.'s gastric trouble.

23 " " (Sunday) — Long discussion with Dr Iona regarding coconut varieties growing in Fakaofo and their characteristics. 200-2100 talk with Pulenuu Kolo and Dr Iona.

24 August, 1970 — Morning attending to specimens and later calling Mr Lloyd Webber in an attempt to learn about date of departure for Atafu. 1645 departing for Fenualoa. Completed 2nd experiment with corn-meal cake on areas 1 and 2.

24 " " — At Fenualoa, 0800-1100 K.W., V., and I. later Dr Iona collecting the remaining 857 tubes with zinc phosphide and noting poison take by rats. Return to Fakaofo at 1100. Afternoon writing notes and preparing for tomorrow's report to Fono.

26 August, 1970 — Morning preparation of material for presentation to Fono on Operation Fenualoa. 1045 call to Tokamin, Apia trying to learn about date of departure for Atafu. 1100-1245 presentation of results of work so far to Faipule, Matai and Toeaina assembled, including map of Fenualoa and tables showing results, followed by prolonged discussion. 1400-1530 ceremonial "kaiga" with Elders. 1600 presentation of gifts by delegation of Elders led by Faipule.

27 " " — Ministrations by Dr Iona bring some improvement K.W. health. Morning, V. and I. collecting tubes at Fenualoa. K.W. on notes and correspondence. Afternoon visit to Fenualoa for further data on rat damage to coconuts in the 1968/69 quadrats. K.W. had long discussion on coconut varieties and rats with Headteacher Hosea.

28 " " — Morning discussion with Dr Iona. 1215 depart for Tetialau, Tekokoloa and Haumatahaga motus trying to work an index for an assessment of rat damage. Return 1750.

29 " " — Morning dissection of rats poisoned in an experiment with Prolin. No work in the afternoon.

31 " " — Morning work on specimens. 1140 with Dr Iona in his boat for Mulifenua, Tekokoloa, Otoka and Matafagalahi lands where assessed rat damage rate in quadrats. On return inspected fishing traps on main reef. Returned 1835.

1 September 1970 — Morning on notes etc. 1010 depart for Fenuafala to set a 280 ft quadrat in the morning and another in southern part of island in the afternoon in order to assess rate of rat damage to both main palm varieties. Return to Falē at 1500 to discuss origin and palm varieties with Dr Iona and elders Nemia, Pela and Teloma. Later photographed dances at Peter Sharple's request.

2 " " — Morning trying to obtain information on the past week already delayed departure to Atafu without avail and attending to notes. 1320 depart for Fenuafala for discussion with Derek McKay, Education Officer on various problems. Also collected several "mutias" from school "malae". Evening ceremonial "hiva" at Uili's. Cable from Tokamin setting depart for Atafu for Saturday,

5th September.

3 September, 1970 Morning and afternoon packing collections and correspondence.

4 " " Tokamin advises of a further delay in aircraft's arrival. Inspection of cornmeal warfarin cake experiment at Hospital. 1.50 depart for Pataliga and Nukumatau islets. returning 1415. Work on report in the afternoon.

5 " " 0920 depart for Otoka; heavy seas, V. and I. paddling both ways. Setting of "one" and "two spoons" experiment. Return 1720.

7 " " Intermittent, heavy rain. Calling Tokamin regarding departure for Atafu; rat officers dismissed by noon; K.W. analysing data for report.

8 " " 0855 depart for rat survey at Otoka and other islets, most of the way paddling - 3 hours 25 minutes to Otoka. Collected tubes and set up quadrat at Vini. Return village at 1745. Telegramme postponing departure for Atafu to Saturday 12th September.

9 " " Death of aged resident. Stopwork to show respect for the deceased. K.W. on report.

10 " " 1000 depart for Nukunonu islet to collect nuts for Botany Division, D.S.I.R. Herbarium. Telegramme from Tokamin delaying departure to Monday 14 September. Food supplies very low. K.W.has to rely on villagers hospitality.

11 " " Mostly packing. K.W.'s gastric trouble recurs, loss of weight. Most of the day compiling tables for report. 2000-2130 long discussion with Faipule Itieli, Pulenuu Kolo and Dr Iona on the rat control scheme for Fakaofo. Faipule agrees to the rat control scheme in the village, pending the Administrator's approval.

12 " " V. and I. complete packing, K.W. on report.

13 " " (Sunday) Evening arrival of Lloyd Webber, G. Garnett and Dr Kirk on Aoniu but no provisions.

14 " " On way to beat news of the final grounding of the Air Pacific Amphibian and cancellation of the Hon. Minister's visit to "big fono". K.W. continuing on report. 2030-0130 an unusually well presented programme of dances and songs by the three atolls.

15 September, 1970		Still at Fakaofo. While waiting for return of Aoniu K.W. analysing data and on correspondence.
19	"	1410 sailing for Apia.
20	"	2212 arrival at Apia.

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APPENDIX 2

LIST OF NECESSARY SUPPLIES AND MATERIALS FOR RAT CONTROL IN THE TOKELAU ISLANDS

The preceeding report has already emphasised the necessity of long-term planning in rat control, particularly in the Tokelau Islands where whole islets have to be treated at a time. The remoteness of the Tokelau Islands and the poor communications makes it mandatory to have sufficient supplies of poisons and other materials on hand. It is recommended that the following supplies should be made available on each of the three islands.

1. Poisons and traps. Each atoll should have 3kg of zinc phosphide (6 flasks), 400 blocks (four blocks to 1lb) of cornmeal warfarin wax cake and 100 operational break-back traps (preferably of the Australian variety).

2. Scales (in grammes) to weigh accurately from 5g to 5,000g.

3. Three large, plastic buckets for mixing zinc phosphide poisons.

4. One, preferably two coconut scrapers.

5. A standing supply of about 1,000 aluminium tubes for laying poisons.

6. Two bush knives for marking palms and for other purposes.

7. A dozen pairs of surgical gloves, 2 bars of soap, a nail-brush and a small basin for hand washing.

8. Lubricating oil for break-back traps maintenance and two gallons of kerosene every three months.

9. A hurricane lamp.

10. A dozen strong, plastic bags and two notebooks.

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one block (4 oz = 110 g) of cornmeal cake. The tubes were laid in area 4 (Fig.1) in a quadrangle of five rows of 5 tubes, each tube about 10 yards (9 m) distant from neighbouring ones. Table 12 shows the take of the cake.

TABLE 11

TAKE OF CORNMEAL WARFARIN CAKE BETWEEN 11 AND 20 AUGUST 1970

DATE	NUMBER OF TUBES WITH CAKE				TOTAL
	ALL EATEN	MUCH EATEN	NIBBLED	NOT TOUCHED	LOST	
13.8.70	-	5	15	5	-	25
17.8.70	1	5	7	9	3	25
20.8.70	10	2	10	1	2	25

It is unfortunate that for reasons already stated this experiment had to be terminated before its natural conclusion, i.e. before all the animals would have been killed and feeding on the cake would cease. Nevertheless it shows the increasing acceptance of the cake, despite the fact that it had been damaged by insects while on its way from Niue Island.

(b) Cornmeal Warfarin Wax Cake as a Follow-up to Zinc Phosphide Poisoning

The inadequate supply of the cake on hand prevented any large scale follow-up except in a comparatively small area (area 1) (Fig.1). Table 12 shows the results.

TABLE 12

FOLLOW-UP WITH WARFARIN WAX CAKE AT FENUALOA LAID ON 17 AUGUST 1970

DATE	NUMBER OF TUBES WITH CAKE				TOTAL
	ALL EATEN	MUCH EATEN	NIBBLED	NOT TOUCHED	TUBES LOST	
24.8.70	55	17	-	-	9	81

The impending departure of the writer for Atafu atoll has not permitted the continuation of this experiment. In view of the high intake of zinc phosphide in this area (Table 10) it seems doubtful that the area 1 still contained a sufficient number of rats to consume as much warfarin cake as shown in Table 12. Although there was no evidence on interference with the bait by large crabs, small hermit crabs and ants were observed in the tubes and it is possible that they may have disturbed the cakes. The nailing of blocks to the palms at about 1 m height and the addition of penthione (R.W. Smith's suggestion) making the blocks even more palatable to rats but preventing any insect attack on the bait, may be the answer.