

Rat Damage to Coconuts in Fiji

Part 1 Assessment of Damage

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Summary. The amount of rat damage to immature coconuts was assessed by two methods. The first involved fortnightly recordings of all coconuts produced, including those rat damaged, at representative sites for up to three years. The second method attempted to utilise decay characteristics of rat damaged coconuts as a basis for projecting spot counts of damaged coconuts to long term estimates of damage.

Damage was concentrated on coconuts aged three to six months with most of the damage being inflicted by *Rattus rattus*. Damage varied considerably from month to month with seasonal trends in damage being apparent at only one site.

Rats clearly favoured particular palms in all plantations, resulting in over 75% of the damage being confined to 30% of the palms. Those selectively attacked were randomly distributed within the survey plots and did not produce significantly fewer harvestable coconuts than those palms seldom attacked.

Tall palms, i.e. over 15 m incurred less damage than those under 10 m.

Decay characteristics of rat damaged coconuts proved to be of limited value as a basis for projecting spot counts to long term losses, but counts of green damaged coconuts accurately reflected the previous 33–35 days damage.

Overall production losses (derived after adjustments for known palm compensation for damage) were relatively low; being 2.7, 2.0 and 1.3 nuts per palm per year during 1970, 1971 and 1972. PANS 20: 379–391 1974.

Introduction

Rat damage to coconuts has been reported in most Pacific territories, Jamaica and the Laccadive Islands of the Indian Ocean and available accounts have been reviewed by Williams (1971). More recent estimates of damage in the Pacific have come from Tonga where Pierce (1971) reported losses of 5.0% (2 nuts/palm/year) on Tongatapu and Whelan and Whelan (1971) 13.0% (6.6 nuts/palm/year) on Vavau.

Rats have been considered an agricultural problem in Fiji for many years, particularly in relation to coconuts. Turbet (1925) estimated that 10.0% of the coconut crop was being lost to rats while Taylor (1930), who made the earliest detailed assessment of rat damage to coconuts, calculated losses as 6.8% (3.6 nuts/palm/year) of the total crop. This estimate prompted a further study by Paine (1934). Regular counts of damaged nuts on the ground at one site (Ura, Taveuni), were supported by a widespread survey and loss was estimated at 28% (about 23 nuts/palm/year) of the total crop.

From 1934 until the start of the present study no detailed estimates of rat damage to coconuts have been carried out in Fiji, although a few spot checks of damage were made (Yelf, 1964; Marshall, 1965).

The paucity of recent damage data, combined with the growers' general concern at the level of rat damage and the cost of the recommended method of control (banding the palm with an aluminium strip), led to the establishment of a four year research project, aimed primarily at investigating rat damage, ecology and control in coconut plantations and groves. The project concentrated on the indigenous Fiji Tall palm as there were only limited areas of other varieties, such as Malayan Dwarfs.

This paper deals with the results of coconut damage surveys.

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Survey methods

A. Assessment approach

Generally crop loss due to pests can best be measured by comparing the yield of pest controlled and untreated plots. Such an approach is impractical with a highly mobile pest such as the rat, as it would require plots so large that adequate surveys of different sites over a number of years would be too costly. This problem was overcome by recording variations in damage symptoms, e.g. coconuts holed by rats, while determining the relationship of this symptom to yield loss.

Where the pest attacks and destroys the mature fruit the relationship may be simple; that is the percentage of fruit attacked equals the percentage of crop lost. Sometimes this appears so obvious, e.g. when the fruit is attacked just prior to harvest, as with rat attack of cocoa (Williams, 1973), that the relationship is assumed without experimental verification. When the fruit is attacked some months before harvest, as in rat attack of coconuts, a one to one relationship between the measure of damage and reduction in yield may not exist, as postulated by Williams (1971).

B. Definition of terms

In the field of crop damage assessment there is often some confusion over terms such as *damage*, *loss* etc. In this paper *damage* will refer only to the attacked immature coconuts, while *loss* will refer to the actual reduction in yield caused by rats after allowance has been made for the responses of the palm.

C. Survey types, data recorded

Two methods of damage survey were established:—

(i) The first consisted of long term (six months to three years) monitoring, on Vanua Levu and Taveuni, of the fall of rat damaged and harvestable nuts at 16 sites that represented a range of palm ages and levels of grove management. As regular visits to the sites were essential these were chosen in accessible places, adjacent to a road or farm track. The locations were all in Cakaudrove (S.E. Vanua Levu and Taveuni) as this area produces 63% of Fiji's total copra production and Paine's (1930) survey indicated that damage in the region could be severe.

At survey sites all trees were numbered and the property owners requested to leave nut collection to the survey team. Nuts were gathered on the ground only. A power slasher was used to control undergrowth at only one site (Tuvamaca) and as slashing was done immediately after nut collection this caused little scattering of nuts.

Coconuts from most plots were collected at fortnightly intervals, graded into 5 cm size classes and recorded in the following categories:—

- (a) With fresh rat damage; Green coconuts with decay at an early stage.
- (b) With old rat damage; Brown or dry coconuts with the decay at an advanced stage.
- (c) With no rat damage; Fresh green coconuts, a category which in effect includes all other forms of premature nutfall.
- (d) Harvestable; Coconuts normally cut for copra (copra being the dried flesh of a coconut).
- (e) Others; This consists mostly of mature barren nuts.

Damage was recorded on an individual palm basis for all plots, while harvestable nuts were recorded for the plot as a whole, except at Salt Lake where each palm was recorded separately. At each recording all nuts were removed from the plot. In 1972, two counts were made of the standing crop (i.e. all nuts on the palm over three months old) on all palms in survey plots. The mean of such counts approximates to a year's production.

(ii) The second type of survey consisted of single or spot counts of rat damaged coconuts at a series of sites. Counts were usually made for each palm with a minimum of 25 palms being recorded at any one site. Damaged coconuts were recorded as with fresh rat damage or with old rat damage. These counts were then correlated with knowledge of the decay rates of rat damaged coconuts and used as a measure of damage over a longer period.

Survey results

A. Long term assessment

(i) Characteristics of damage

Typically rat damage to coconuts consists of a single hole of approximately 65 mm by 40 mm usually found near the nut's point of attachment. As rats appear unable (despite evidence of attempts) to penetrate mature or nearly mature coconuts, damage takes place in the palm crown. Incomplete penetration of the green nut will still cause it to detach after three to five days, the normal time lapse from attack in the palm crown to detachment from the inflorescence.

Damage is concentrated on coconuts aged from three to eight months (Table 1 and Fig. 1).

TABLE 1. SIZE CLASS DISTRIBUTION OF DAMAGED COCONUTS

	Size classes				
	0-4.5	5-9.5	10-14.5	15-19.5	20-24.5 cm
Percentage damaged (N = 1292)	0	2	30	61	7

Endosperm is not present until the sixth month and even by the eighth month it forms only a 6-8 mm thick gelatinous layer. Since over 90% of the damage occurs before the eighth month, rats are gaining access to very little endosperm. It is of note that little damage occurs before the developing nuts are three months old, in spite of claims by earlier authors (Marshall, 1965; Yelf, 1966) that damage to very young or button nuts was important.

Yelf (1966) suggested that the feeding activity of rats and flying foxes (*Pteropus* sp.) on male coconut flowers caused significant premature nut fall. However, extensive inspections of inflorescences during the present survey revealed virtually no damage to the lower spathe or female flowers. Minor damage to the male flowers was observed, but as there is a considerable excess of pollen this is unlikely to have any effect on production. Marshall (1965) observed rats chewing male flowers but also concluded it would not affect production.

(ii) Species responsible for damage

Direct observation of *R. rattus* attacking green coconuts (Marshall, 1965) and the presence of damaged nuts on an island inhabited by only *R. exulans* (Wodzicki, 1969) has established that both these species will inflict damage. However as *R. rattus* forages aboreally far more extensively (data to be published) at greater heights than *R. exulans* it could be expected that they would inflict more damage in Fiji's predominantly mature plantations.

To assess the amount of damage done by the two species teeth marks on damaged nuts were investigated. It was established, by measuring (under a microscope) incisor marks made in a developing coconut with a cleaned skull, that adult *R. rattus* incisors make cuts of 2.5-2.8 mm in width while *R. exulans* make cuts of 1.3-1.6 mm. This technique was then used in different plantations but could only be applied to freshly damaged green coconuts for any shrinkage of the husk altered the cut dimensions. Also, juvenile *R. rattus* made cuts narrower than adults but the percentage of damage inflicted by juveniles was considered to be low.

A survey of damaged nuts at the Salt Lake site, an area containing short palms, revealed that both species were responsible for damage, for of the 46 fresh nuts examined over a period of one year 21 had been attacked by *R. exulans*, 25 by *R. rattus*. At other survey sites on the Vanua Levu coast, where the majority of palms were over 10 m tall, inspection of 75 damaged nuts indicated that only two or three could be attributed to *R. exulans*, the majority being clearly the result of *R. rattus* attack. These results indicate that *R. rattus* is responsible for most of the damage in Fiji and reflect the vertical distribution of the species. No damage has been attributed to the only other rat in Fiji, *R. norvegicus*.

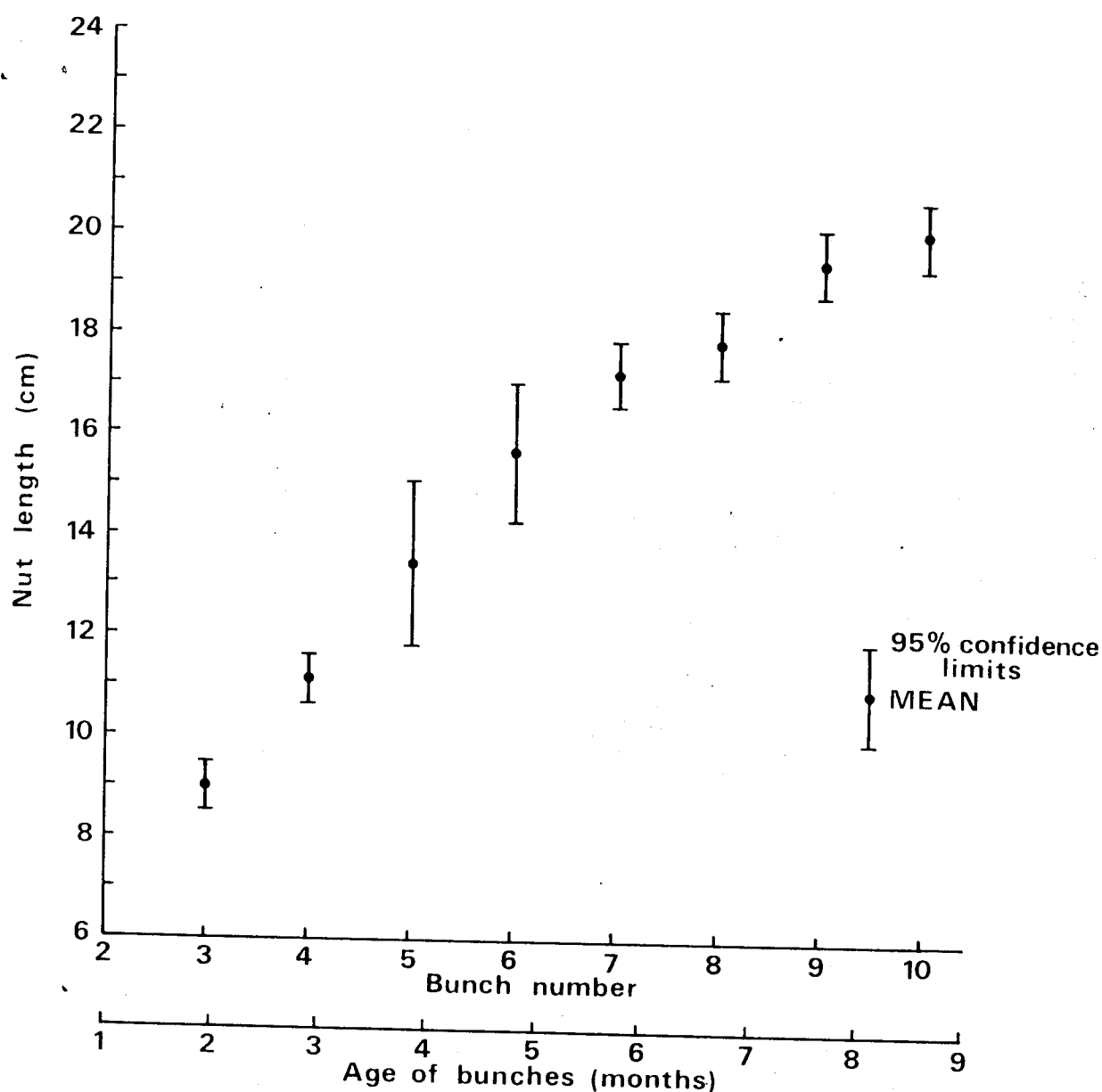


Fig. 1. The relationship between nut length, bunch number of age of developing coconuts.

(iii) Damage levels and distribution through time and space

(a) Seasonal and annual trends

Table 2 summarises damage and production data from 14 sites, incorporating 1070 palms, for one of the three years surveyed. Rat damaged and harvestable nuts are expressed as nuts/palm/year and nuts/hectare/year. Since other workers (Taylor, 1930; Paine, 1934; Smith, 1969) have expressed damage as a percentage of total production this measure is also provided for comparisons, but these can only be valid when harvestable production is similar.

There is clearly a big variation in damage from site to site, ranging from zero to 9.1 nuts/palm/year. Part of this difference is due to palm height (see below) but it is important to note the big differences between plots on a property where ground habitat and palm height are fairly uniform e.g. the Maravu Plots. A difference in rat numbers at the various sites is a possible explanation, except that those sites mentioned are relatively close to each other and there was found to be very little correlation between rat numbers and the level of damage (data to be published).

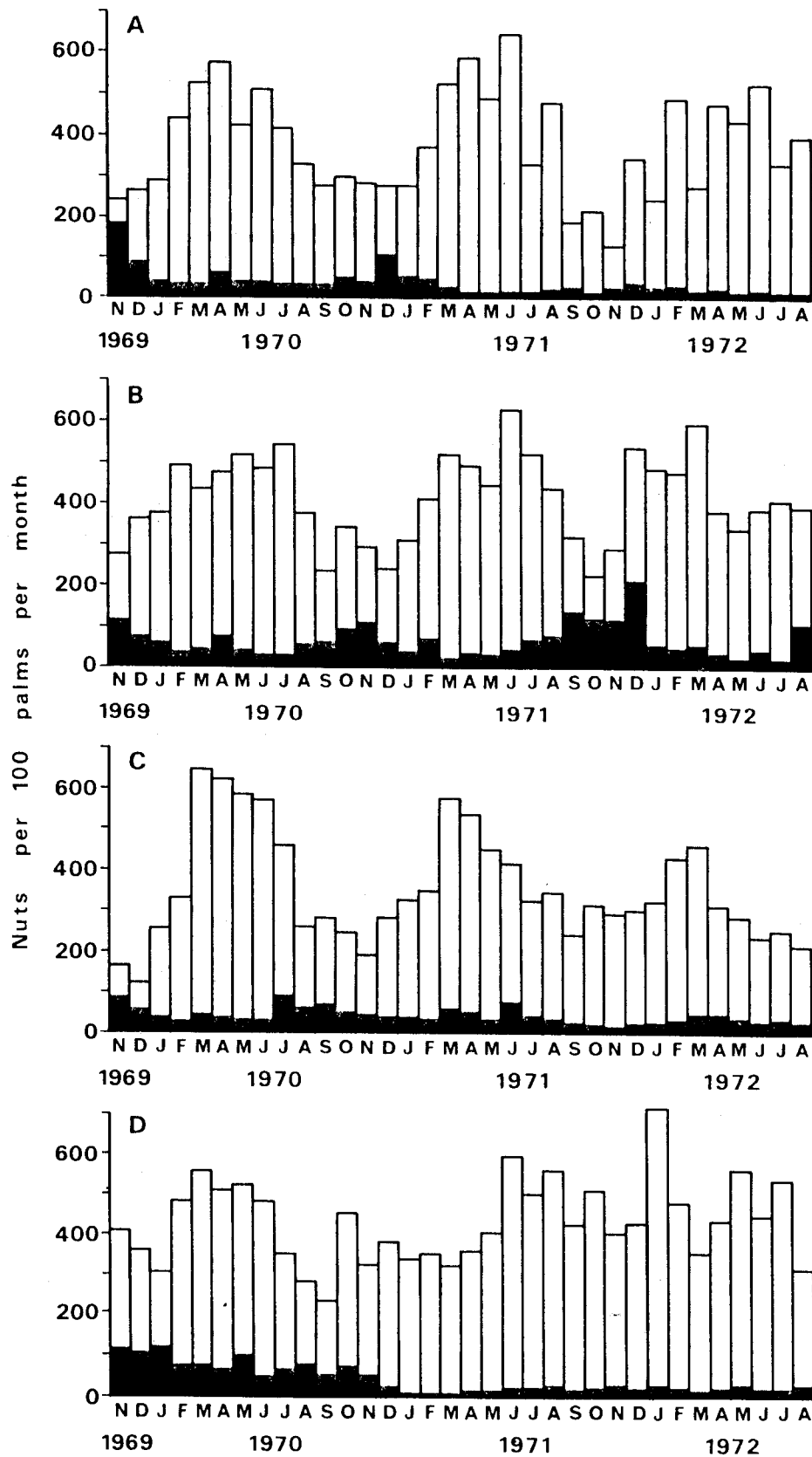


Fig. 2. Monthly distributions of rat damaged and harvestable nuts. Total height of histograms represents harvestable nuts; black represents both fresh and old rat damaged nuts. A, Maravu hill plot one. B, Maravu hill plot two. C, Salt Lake plot. D, Levuka Lailai plot three.

TABLE 2. PRODUCTION AND DAMAGE OF COCONUTS ON VANUA LEVU BETWEEN DECEMBER 1970 AND DECEMBER 1971

Plot site and No. of palms	Rat damaged nuts (X)	Harvested nuts (Y)	Rat damaged		Harvested		Rat damaged nuts as a % of X + Y	Months Recorded
			Nuts/ palm/ year	Nuts/ ha./ year	Nuts/ palm/ year	Nuts/ ha./ year		
Maravu								
Coastal 1 (50)	90	1842	1.8	378	36.8	7729	4.6	12.0
Hill 1 (100)	221	4701	2.2	294	47.0	6271	4.3	12.0
Hill 1 (100)	913	5092	9.1	899	50.9	5031	15.4	12.0
Nabaka (40)	221	2044	6.7	1458	56.5	12285	9.8	11.8
Nagigi (40)	7	1502	0.2	30	41.5	6358	0.5	11.8
Kubunu (40)	16	1942	0.4	91	54.8	12592	0.8	10.6
Salt Lake (60)	277	2723	4.6	660	45.4	6506	9.2	12.0
Levuka Lailai								
Plot 1 (100)	1	2021	Nil		20.2	4042	Nil	12.0
Plot 2 (100)	249	2725	2.5	499	27.2	6721	8.4	12.0
Plot 3 (100)	158	5215	1.6	304	52.1	9914	2.9	12.0
Vunilagi								
Plot 1 (50)	324	1622	6.5	578	32.4	2881	16.6	12.0
Plot 2 (50)	332	1727	6.6	588	34.5	3069	16.1	12.0
Tuvumaca								
Plot 1 (120)	721	4264	6.0	1275	35.5	7544	14.5	11.4
Wainiyaku								
Plot 1 (120)	738	N.R.	6.2	—	—	—	—	11.4

In some areas damage varies considerably on a short or long term basis (Fig.2). Seasonal fluctuations in damage are apparent on a few plots (Fig.2,a and b) and consist of a rise in damage during the periods when there is an increase in the favoured size classes of nuts, that is approximately six months prior to the peaks in harvestable nuts. For example, the harvestable coconut peaks in Figure 2b can be adjusted back six months in time to indicate when peaks of favoured immature nuts occurred. These then positively correlate ($r = 0.52$, $p < .01$) with the level of damage. However this trend is not evident on most plots and may only become apparent at the highest recorded levels of damage (e.g. Maravu Hill Plot 2).

(b) Spatial distribution and selective attack

The spatial distribution of damage and variations in level from palm to palm within a plot are also notable features of rat damage to coconuts (Fig.3, A and B), for they indicate that attack is selective. In most plots damage was confined to a limited number of palms but these were distributed at random throughout the plot; randomness being tested by applying Runs Test (Sokal and Rohlf, 1969) to the accumulated damage for each palm listed according to the number assigned when the plot was established (Salt Lake, $t_s = 1.1$; Vunilagi Plot 1, $t_s = 0.2$; Plot 2, $t_s = 1.7$; Maravu Hill Plot 1, $t_s = 0.6$; Levuka Lailai Plot 2, $t_s = 1.9$; Plot 3, $t_s = 1.0$; where t_s of 1.96 = significant departure from random distribution at the 5% level). Non random distribution of

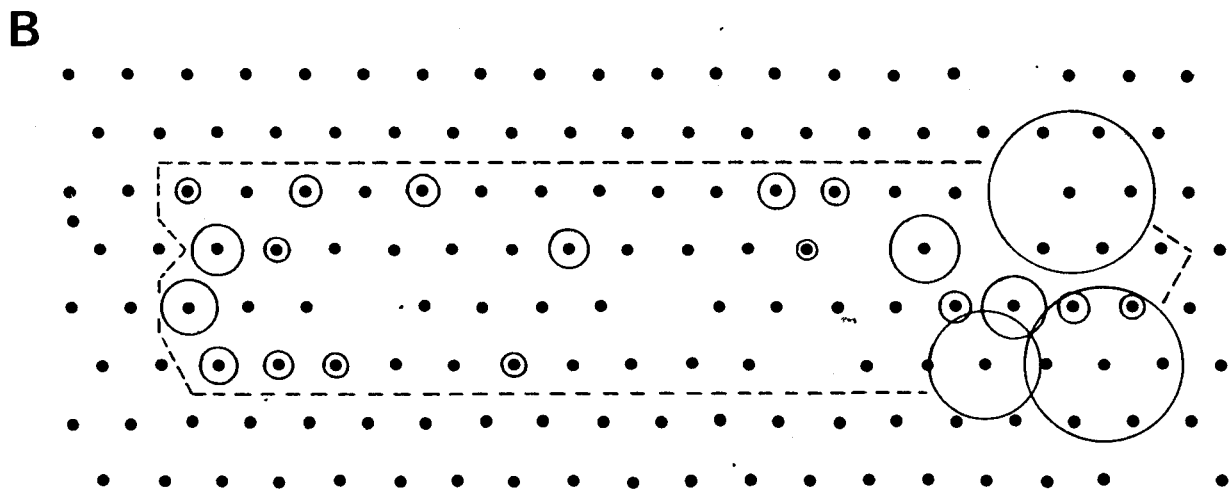
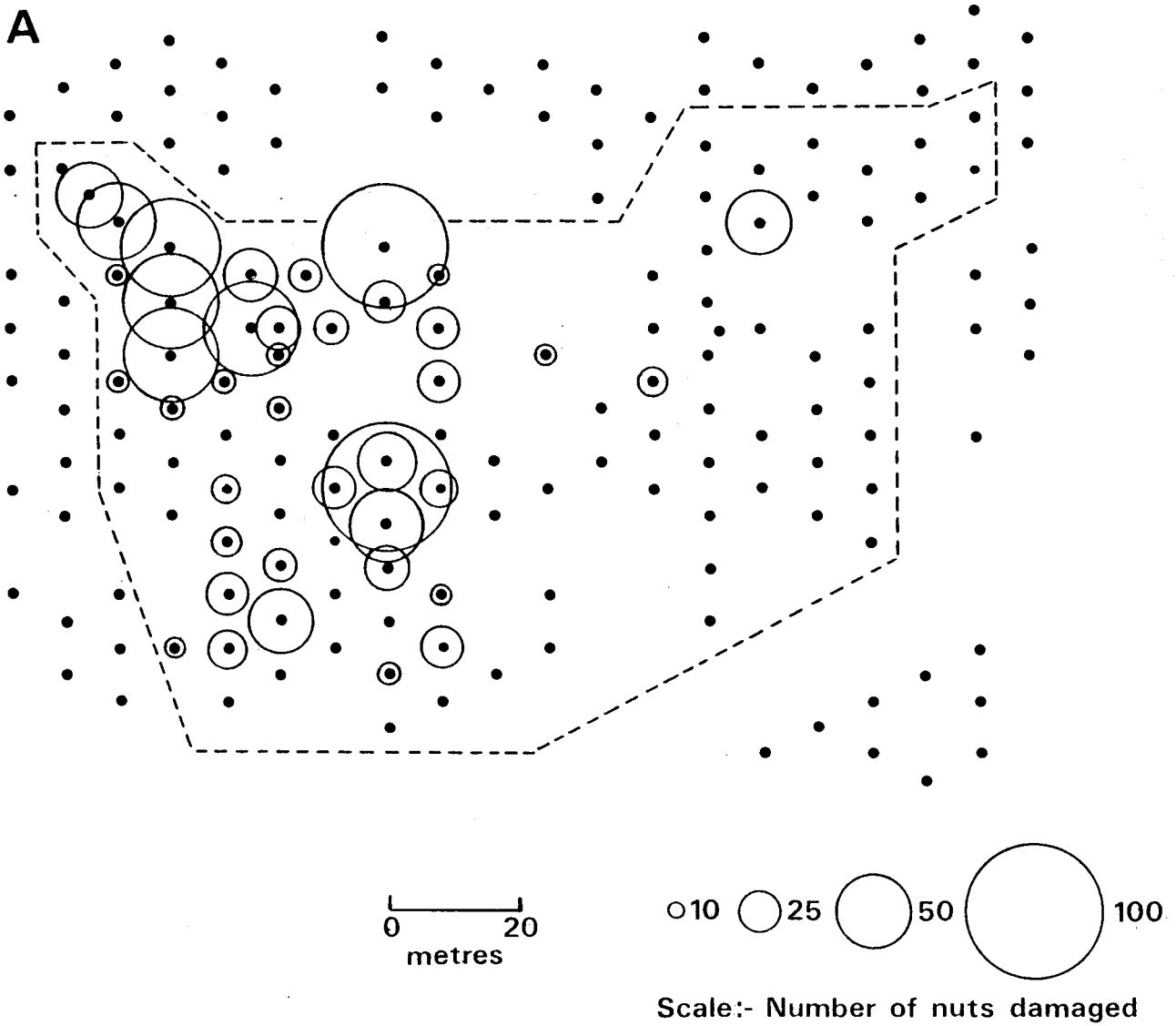


Fig. 3. Spatial distribution of damage on two survey plots. These data for 1970 and 1971 include only palms that lost more than 10 nuts. Circle size indicates the number of nuts damaged and dots the position of each palm. Broken lines indicate the limits of survey plots.

damage was only evident within Maravu Hill Plot 2 (Fig.3, $t_s = 4.2$). Although favoured palms were seldom clumped, total damage for each plot was confined to a limited number of palms, in most plots over 75% of the nuts damaged came from less than 30% of the palms. This distribution of damage is a manifestation of rats apparent ability to select the softest nuts when sugar concentrations are highest (data to be published).

Of particular importance is the effect that selective attack has on the production of the affected palms. A comparison between the number of harvestable nuts produced by palms consistently attacked over three years with production from those seldom attacked showed no significant difference at three survey sites (Tables 3 and 4 A and B; $t = 1.3, 0.8$ and 1.5 respectively). At Salt Lake (Table 3) damage per palm averaged 16.5 nuts/palm/year for the high damage group and less than 1 nut/palm/year for the low damage group. The effect

TABLE 3. DAMAGE LEVELS AND THE EFFECT ON PRODUCTION*

	1970				1971				1972			
	Rat damaged		Harvested		Rat damaged		Harvested		Rat damaged		Harvested	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
Total nuts damaged or harvested	219	0	522	541	194	13	550	535	132	5	517	529
Number damaged or harvested per palm	19.9	0	47.4	41.6	17.6	1.0	50.0	41.1	12.0	0.4	47.0	4.07
Total number damaged or harvested for all palms in the plot	319		2648		277		2725		175		2476	
Percentage of the total damaged and harvested accrued by the palms in each category	68.6	0	19.7	20.4	70.0	4.7	20.2	19.6	75.4	2.9	20.9	21.4

*A comparison based on 11 palms incurring a high level and 13 a low level of damage within the 60 palm Salt Lake survey plot.

this marked concentration of damage has on production of harvestable nuts is illustrated in Fig.4, A and B. For example, in Fig.4A 30% of the palms produced 37% of the plots harvestable nuts, despite damage amounting to 83% of the gross total. This comparison was based on nut number, not coconut flesh yield per nut, for a comparison between flesh yield per nut from high and low damage groups indicated no significant difference (318 g/nut 315 g/nut respectively, $N = 100$).

The apparent lack of effect of quite high levels of damage, i.e. 10–18 nuts/palm/year, on the production of harvestable nuts, is a feature of major significance as it suggests that rats are not causing any reduction in overall production. However, palms incurring high levels of damage may be more vigorous types that in the absence of selective attack produce more coconut flesh than those incurring little damage.

TABLE 4. DAMAGE LEVELS AND EFFECT ON PRODUCTION.
 A. A COMPARISON BASED ON 25 PALMS INCURRING A HIGH LEVEL AND
 25 A LOW LEVEL OF DAMAGE WITHIN THE 100 PALM MARAVU HILL PLOT 2.

	High damage		Low damage	
	Rat damaged (1970–1972)	Estimated number harvestable	Rat damaged (1970–1972)	Estimated number* harvestable
Total nuts damaged or harvested	1413	1014	14	905
Mean number damaged or harvested per palm	56.5	40.6	0.6	36.2
S.E.	4.9	3.8	—	3.5

B. A COMPARISON BASED ON 20 PALMS INCURRING A HIGH LEVEL AND
 20 A LOW LEVEL OF DAMAGE WITHIN THE 100 PALMS IN VUNILAGI PLOTS 1 AND 2

	Low damage		High damage	
	Rat damaged (1970–1972)	Estimated number harvestable	Rat damaged (1970–1972)	Estimated number* harvestable
Total nuts damaged or harvested	638	866	61	741
Mean number damaged or harvested per palm	31.9	43.3	3.1	37.0
S.E.	3.7	3.1	—	2.9

*Harvestable production estimated for 1972 on the basis of two counts of the standing crop on the palm.

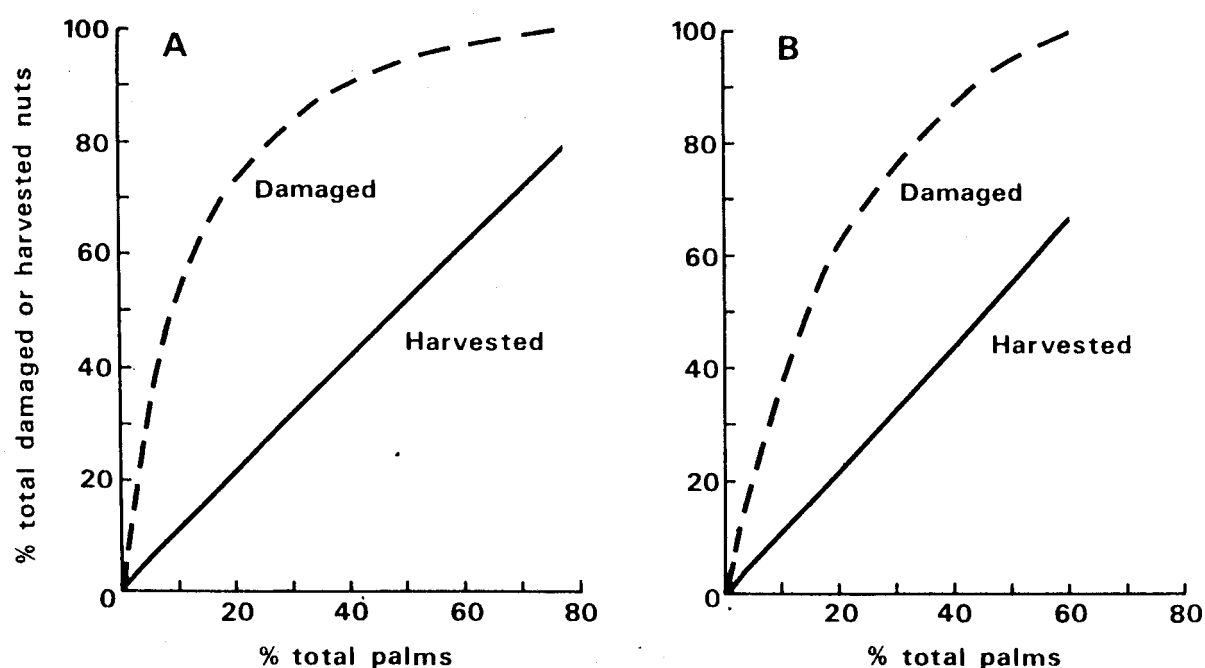


Fig. 4. The relationship between rat damaged and harvested coconuts on two plots. Adjacent vertical points on the two curves relate to the same palm. The percentage damaged curve progresses from the palm with the highest damage to the lowest.

(iv) Palm height and effect on damage

A comparison of damage incurred by short and tall palms during 1971 showed that short palms incur significantly higher damage ($t = 2.35$, $p < 0.05$; Table 5). While nuts on short palms may be generally more attractive to rats, the higher level of damage is almost certainly due to the greater numbers of *R. exulans* foraging in such palm crowns. In effect, coconuts on short palms are at risk to a greater proportion of the total rat population, than those on tall palms. Also, as palms are seldom inhabited during the day, short palms may be scaled more regularly by *R. rattus* since less effort would be required to reach the palm crowns.

TABLE 5. A COMPARISON OF DAMAGE BETWEEN SHORT AND TALL FIJI TALL PALMS FOR 1971

	Short palms (under 10 m)	Tall palms (over 15 m)
Number of plots	9	9
Number of plot sites	5	9
Total number of palms	500	570
Number of nuts rat damaged	2756	1398
Mean number of rat damaged nuts/palm/year	5.5 ± 0.7	2.8 ± 0.9

This effect of height on damage could account for the high estimates (23 nuts/palm/year) obtained by Paine (1934) on Taveuni. Over a period of four months he recorded damage on palms typical of that time, that is only 20–30 years old and probably less than 12 metres high. However, as shown in Fig. 2D, an estimate based on a short recording period at one site (i.e. any four month period in 1970 compared with a similar period in 1971 or 1972) could give a false estimate of long term damage levels.

(v) Ground vegetation and effect on damage

Although clearing of undergrowth in plantations and the maintenance of a weed free environment has been cited as a method of reducing rat damage to coconuts (Wodzicki, 1968; Sproat, 1966), ground cover appeared to have little consistent effect on damage levels in this study.

Three of the survey sites (Nabaka, Kubunu and Nagigi) were overgrown and three others (Salt Lake, Vunilagi Plots 1 and 2) moderately so, i.e. they had tall grass, weeds and guava most of the year. A comparison between the 1971 and 1972 damage levels of these six plots with those on all survey plots which were relatively weed-free throughout the year, suggests that the amount of undergrowth did not affect damage levels. During the two years overgrown plots recorded an average damage level of 3.2 ± 0.7 nuts/palm/year and in the clean plots 4.1 ± 0.8 nuts/palm/year. The effect of plantation habitat on damage levels is undoubtedly complex and while for many reasons plantations should be kept relatively free of undergrowth it will clearly not guarantee low levels of rat damage.

(vi) Summary of long term assessment

The overall level of damage on all plots on Vanua Levu and Taveuni over the three years was:—

	nuts/palm/year	nuts/ha/year	percentage loss	N
1970	5.4 ± 0.45	880	13.3	910
1971	3.9 ± 0.32	544	8.4	1070
1972	2.5 ± 0.23	452	5.6	1070

The data indicate a much lower overall level of damage than Paine's (1934) oft quoted figure for Fiji of 28% (23 nuts/palm/year), although the marked drop in damage between 1970 and 1972 does suggest that levels may fluctuate considerably.

B. Spot assessment of damage

(i) Decay characteristics

A rapid method of assessing the number of nuts damaged by rats must be available if rat control is to be a viable aspect of coconut crop protection. Farmers can clearly not carry out long term surveys to determine damage levels. In an attempt to develop a rapid method, the decay rate of damaged nuts was investigated to enable the accumulation period of damaged nuts, recorded in spot surveys, to be determined. The decay of rat damaged nuts can be considered to take place in two stages, both with definable endpoints. The first stage covers the period of change in colour, from green to brown, that follows attack, while the second corresponds to the whole period of decay from attack to the ultimate collapse of the husk as the nut rots away on the ground.

The time lapse during the first stage of decay was investigated by puncturing a representative sample (i.e. nuts aged three to seven months, $N = 234$) of green coconuts and placing them in the partial shade of 12 year old palms. The time taken for each nut to turn completely brown was recorded and found to be 39 ± 0.4 days.

The total decay period from initial attack to final decay was investigated using 58 Fiji Tall coconuts and 57 Malayan Dwarf coconuts. After two years, all the coconuts kept in a weed-free area under the partial shade of 12 year old palms, could be crushed in one hand, a feature considered an acceptable endpoint for total decay.

The time lapse from attack in the palm crown to detachment from the inflorescence was also investigated as this affects the estimated time lapse for the colour change in damaged nuts collected on the ground. Attack was simulated in the palm crown using a 2 cm diameter steel cork borer and detachment time was found to be 4.5 ± 0.2 days ($N = 130$). Small nuts detached in as little as two days while larger nuts took six to seven days. In repeating the above trials in Tonga, Pierce (1971) found the average time taken to turn from green to brown was 41 ± 0.8 days ($N = 816$) and the time lapse between attack and detachment 4.7 ± 0.3 days.

When the decay rate trials were begun in early 1970, it was hoped that the initial decay period would prove the best basis for extrapolating spot surveys to estimates of damage over longer periods. A trial aimed at investigating the accuracy of damage estimation based on colour change, indicated that estimates extended to only three months (past or future) differed as much as 70% from actual damage, while the average variation between projected and actual damage for six months (48 samples at four sites of 100 palms) was 38%. In retrospect, this discrepancy was to be expected at most sites in view of the marked variations in damage from month to month.

Because of the large number of variables, spot counts of green damaged nuts can clearly not accurately predict past or future damage levels. Nevertheless, such counts will give an accurate estimate over the immediate past 33–35 days (i.e. 39 days less the average detachment time of 4.5 days).

A count of all damaged nuts, that is including coconuts in the second category of decay, does not represent two years accumulation as suggested by the static trial described above. Under average plantation conditions a proportion of the damaged nuts are destroyed by cattle, weeding and burning operations before they have rotted normally.

As the damaged nuts from the long term survey plots were placed in the plantation immediately surrounding the plots, the total accumulation of damaged nuts could be compared with known damage for the area. Two survey plots and surrounding areas were checked and the damaged nuts found to represent only the previous nine months (Maravu Hill Plot 2) to 15 months (Maravu Hill Plot 1) known rat damage, suggesting that the average accumulation represents only approximately a year's rat damage.

(ii) Survey results

Spot surveys carried out at 43 sites on 11 islands in the Fiji group during 1969–1972 are summarised in Table 6. Damage on short and tall palms show the same trend as long term survey plots, shorter palms incurring significantly more damage than tall ($t = 3.2$, $p < 0.05$). The Bua area of Vanua Levu (small stands of old palms), Lau, Lomaiviti and Kadavu islands appear to suffer very little damage assuming the figures in Table 6 represent approximately one year's damage.

Surveys A and B (Table 6) were carried out during 1970–1972 and indicate an average yearly loss of 4.7 ± 0.43 nuts/palm/year. Long term surveys in the same region, but different sites, established an average yearly damage level of 4.5 ± 0.41 nuts/palm/year; a difference of only 4.3% which suggests that a large scale spot survey is a reasonable method of assessing damage, bearing in mind the limitations discussed above.

TABLE 6. A SUMMARY OF SPOT DAMAGE SURVEYS 1969–1972

Islands surveyed	Number of sites	Number of palms	Rat damaged fresh	Rat damaged old	Total damaged	Number damaged per palm	Notes
A Vanua Levu and Taveuni	9	759	691	5001	5692	7.5	Short palms under 10 m
B Vanua Levu and Taveuni	10	635	129	797	926	1.5	Tall palms over 15 m
C Vanua Levu, Bua area	6	203	17	35	52	0.34	Tall palms over 15 m
D Matuku, Moala, Lakeba, Yacata Vanuabalavu Cicia, Koro	10	402	169	569	738	1.8	Lau, Lomaiviti Islands
E Kadavu	8	1132	6	266	272	0.24	

C. Copra loss caused by rats

A comparison of yield (number of harvested nuts) from palms incurring high and low levels of damage indicated that there was no difference between the two groups (Tables 3 and 4). In addition a trial to investigate the effects of known levels of simulated rat damage on palm productivity established that there was an increase in female flower production and no apparent decrease in the number of harvestable coconuts produced, even before the flower increase could influence yields; responses to the loss of developing coconuts that were conservatively estimated to compensate for 50% of the nuts attacked (Williams, 1974a). These two lines of investigation, the first a field observation the second an experimental result, lead to the conclusion that there is certainly not a direct relationship between the damage symptom and actual loss of production. The palm's ability to compensate for nuts lost early in the development cycle means that counts of rat damaged coconuts, as carried out during both surveys, cannot be directly equated to a loss of mature nuts but need to be reduced by about 50% before they indicate actual production loss. To illustrate this point the overall level of damage on all plots over the three years can be recalculated to express actual loss:—

	Nuts/palm/year	Nuts/ha/year
1970 Surveyed damage	5.4	793
Actual loss	2.7	396
1971 Surveyed damage	3.9	544
Actual loss	2.0	272
1972 Surveyed damage	2.5	452
Actual loss	1.3	226

This illustrates that the average loss was relatively low during the survey period and it is of note that even on individual survey sites such as Maravu Hill Plot 2 the loss did not exceed four nuts/palm/year. At these low levels economic control by poisoning or banding the trunk with an aluminium strip is very dependent on the price of copra and overall plantation efficiency.

Control methods and economics are discussed in a separate paper (Williams, 1974b).

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