EVIDENCE FROM THE GREAT BARRIER REEF OF ANCIENT ACANTHASTER AGGREGATIONS

E. Frankel

INTRODUCTION

In some of the more recent literature the suggestion has been made that the presently observed large aggregations of *Acanthaster planci* in the Indo Pacific coral reefs are not an incidental occurrence but are a cyclic or episodic phenomenon (Newman, 1970; Dana, 1970; Walsh *et al.*, 1971; Vine, 1973; Frankel, 1975).

Brown and Willey (1972), Endean (1973, 1975), and Endean and Chesher (1973) have held to the view that previous *A. planci* aggregations have not occurred. Their arguments are based on the premise that aggregations and their effects are not recorded in early literature or in the folklore of native peoples. The conclusion of these authors and others (e.g., Randall, 1972) is that the present large populations are linked by one means or another with man's activity.

Dana *et al.*, (1972), Vine (1973), and Newman and Dana (1974) have continued to question these hypotheses and suggest that the present aggregations occur in response to some natural phenomenon. In addition, Dana (1970) inferred from historical reports that there have been previous aggregations.

Precisely why the aggregations of *A. planci* occur has not been conclusively established; however there appears to be growing evidence for pertubation as a principal factor (cyclones, Dana *et al.*, 1972; salinity change, Pearson, 1975). In addition it should be noted that many modern echinoderms are gregarious, a trait that goes back in the geologic record and that may be related to feeding and/or reproduction (Reese, 1966).

Since arguments about the occurrence of previous aggregations are based on scant and largely circumstantial evidence, one solution to this dilemma would be the discovery of physical evidence of previous aggregations (Frankel, 1975, in press).

An investigation of this possibility in the Great Barrier Reef Province has been carried out with some rather illuminating results.

The study has been conducted in three phases, broadly grouped under:

Department of Geology and Geophysics, University of Sydney
Sydney, New South Wales 2006, Australia

a. Recognition of skeletal remains of A. planci;

b. location of skeletal remains in surface sediments on reefs;

c. examination of subsurface sediment (for skeletal remains).

Recognition

A. planci skeletal remains are recognizable from those of all other echinoderms examined. Briefly the major distinguishing features are (Frankel, in preparation):

a. The large spines and pedicels (Madsen, 1955) of A. planci are distinct from other asteroids;

b. the spines of Acanthaster are morphologically dissimilar from those of ophiuroids and echinoids;

c. an examination of the micro-texture and ultrastructure of ossicles shows that Acanthaster is distinct from other forms;

d. the distinctive mauve color of Acanthaster skeletal debris has proved useful for initial recognition (ossicles of all other stellaroids thus far examined are cream or white).

Location

Having established that A. planci skeletal debris is readily recognizable, detailed sediment sampling on a number of reefs was carried out (Fig. 1).

SAMPLING METHODS

All sampling was carried out using SCUBA. By this means exact location of samples in addition to inspection of sample sites was ensured.

Surface samples of the uppermost 2 to 3 cm of sediment were collected in large, wide-mouth, screw cap plastic jars.

Subsurface sampling (see later) presented some problems. The ill-sorted nature of the substrata, composed of material ranging in grain size from several decimeters to a few microns, made penetration by devices such as piston corers or corers driven by any other physical force impossible. More often than not, a large fragment was encountered within a few centimeters of the surface. Penetration then either ceased, or the fragment was driven deeper into the sediment while blocking the sampling device. Rotated tools suffered from similar limitations; large fragments rotated on the sample retainer in the unconsolidated substratum.

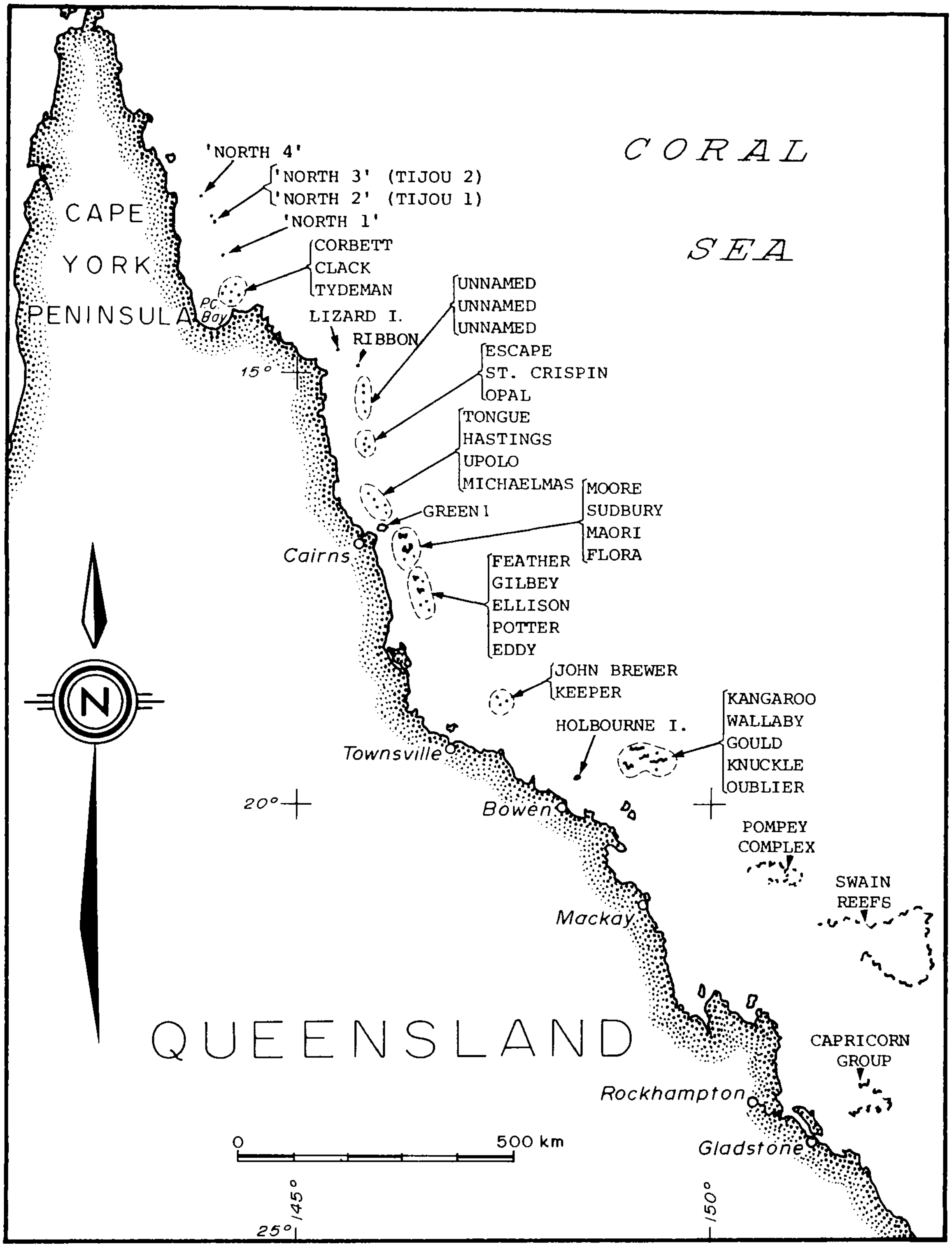

Figure 1. Location map indicating reefs and Islands of the Great Barrier Reef. Refer to Appendix 1 for exact locations.

To overcome these difficulties, an airlift device similar to that described by Shinn (1968) was used to penetrate the unconsolidated sediments. Material was removed from within concentric casings, forced into position as penetration increased (Figs. 2 & 3). Samples were collected at measured depths by placing a fine mesh nylon bag over the airlift tube and allowing the air to flow for a short time (Fig. 2). In this way, spot samples at close intervals, rather than a continuous core through the sediment column, were obtained.

RESULTS

Initially surface sediments were collected from all environments on reefs (Appendix 1; Fig. 1) that:

a. Are known not to have supported recently any Acanthaster aggregation (e.g., Heron Island Reef - 'Type A.' It is implicit that such reefs may, and do, support a resident "normal" population of a few individuals per kilometer of reef);

b. are presently recovering from the presence of a recent aggregation (e.g., Green Island Reef - 'Type B');

c. are presently carrying an aggregation (e.g., portion of Kangaroo Reef - 'Type C');

d. are presently not carrying an aggregation, but where the history of recent aggregation activity is not known (e.g., outer-shelf reefs north of Princess Charlotte Bay - 'Type D').

No Acanthaster skeletal debris was found in any samples from 'Type A' reefs.

Sediments from within about 10 m of the base of lagoonal reefs and on ledges and in sand pockets on fore-reef slopes on reefs of 'Type B and C and some D' were found to contain Acanthaster debris (inset, Fig. 4). Sediments from other areas of these reefs are barren.

When present, generally up to about five individual Acanthaster skeletal components per kilogram of sediment are found (Appendix 1). These are predominantly whole or fragmentary spines and pedicels; ambulacral plates and other ossicles occur more rarely.

With knowledge of the present accumulation of A. planci remains within the reef sediments, subsurface samples were collected from sites where it might be expected to have accumulated in the past (had the organism previously inhabited that area in large numbers). For practical and logistic reasons material was collected in the vicinity of lagoonal-reefs. Figure 4 gives an example of a typical sampling site where two "cores" were taken, and Table 1 summarizes the ^{14}C ages of materials from those "cores."

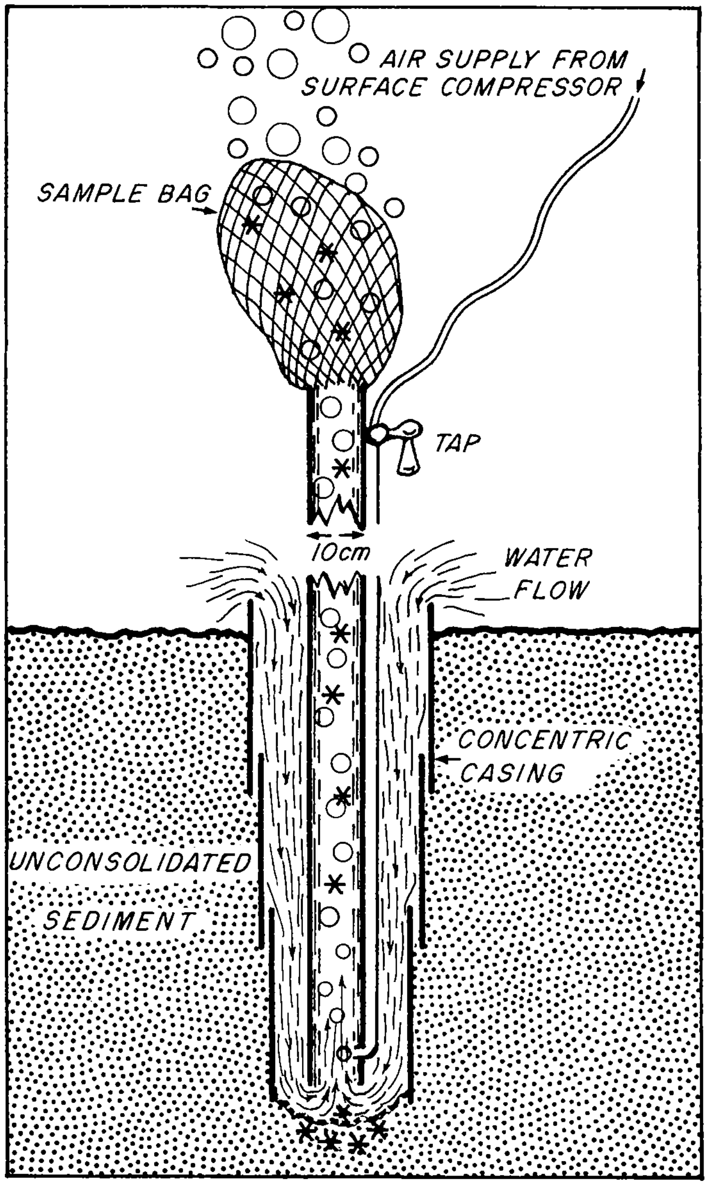

Figure 2. Diagrammatic representation of mode of operation of airlift device used for sampling subsurface sediments. Note sample collecting bag and concentric casings.

Figure 3. Setting casings in substratum during sampling of subsurface sediments using airlift device.

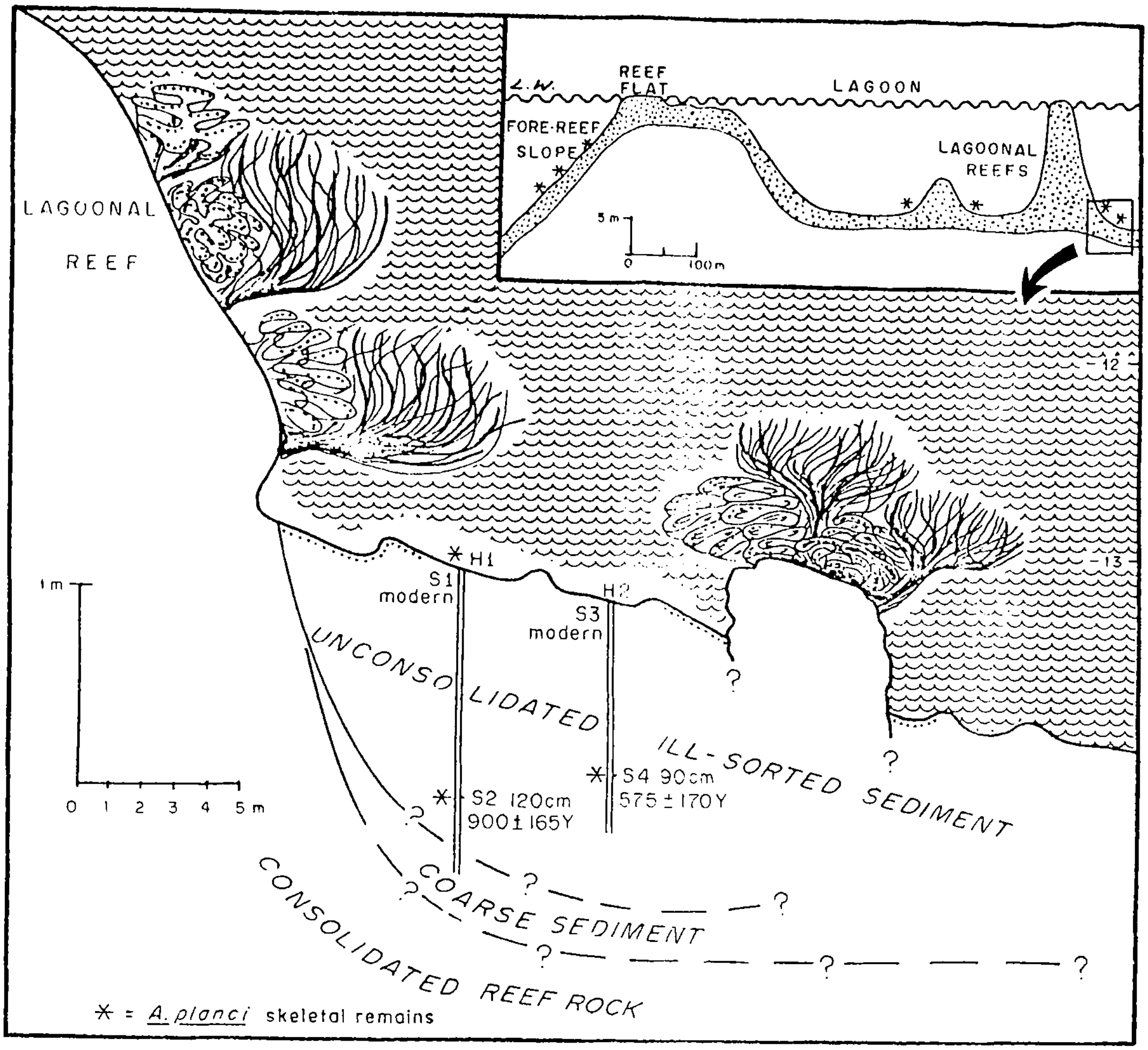

Figure 4. Site in Wallaby Reef Lagoon, showing locations of holes H1 and H2 and samples S1 through S4. See also Table 1. Inset is a cross section of a typical reef, showing the location of A. planci skeletal material in surface sediment.

Table 1. Location and age of samples from site in Wallaby Reef Lagoon. Also see Figure 4.

Sample	Location	Age (years BP)*	Remarks
S1	Surface, Hole H1	-15 ± 20	Contemporaneous *A. planci* present, 3 fragments
S2	120 cm, Hole H1	900 ± 165	*A. planci* present, 2 fragments
S3	Surface, Hole 2	60 ± 120	Contemporaneous
S4	90 cm, Hole 2	575 ± 170	*A. planci* present, 4 fragments

* ^{14}C dating carried out by Krueger Enterprises Inc., Geochron Laboratories Division.

Fifty four subsurface "cores" were collected from 27 different reefs (Appendix 1, Fig. 1; excluding Heron and Wistari Reefs, from 19°30'S (Gould) to 14°39'S (Lizard Island).

In all instances the substrata were unconsolidated and very poorly sorted, the proportion of coarser components (generally Acropora spp. sticks) and the amount of compaction increasing with depth (Fig. 2).

DISCUSSION

Surface Sediments

No evidence of contemporaneous aggregations were observed where samples were collected on 'Type D' reefs. In most cases, particularly in the north of the Province, these reefs were healthy and viable, however 80% of the sites sampled from within those environments where Acanthaster skeletal debris might be expected to accumulate (inset, Fig. 4), had fragments in the sediment.

This leads to two possible conclusions:

a. A 'resident' population of a few individuals per kilometer of reef sheds enough skeletal material to be detected in a random sampling of specific environments.

b. There has been more recent 'aggregation activity' than previously considered, with subsequent regeneration of the reef fauna, particularly hard corals.

The first possibility is unlikely in view of the findings on 'Type A' reefs where 'resident' populations of the starfish are known (e.g., Heron Reef).

Subsurface Sediments

Specific horizons in 41 of the 'cores' from 22 different reefs were found to contain A. planci skeletal debris in quantities similar to those found in surface sediments from 'Type B and C' reefs (Appendix 1).

Although A. planci remains were present on, or just below, the contemporary surface at 17 of the sites, they are not found throughout the entire sediment column. Therefore, the possibility of vertical redistribution of recent Acanthaster material by bioturbation (Clifton and Hunter, 1973) or some other mechanism appears to be negated, or at least confined to the uppermost few centimeters of substrate. Further, the progressively older sediments in sequential horizons in some 'cores' (e.g., 'core 1,' Gilbey Reef) indicate that mixing of recent materials does not extend very deep into the substratum.

There are relatively few *Acanthaster* skeletal fragments in the samples, and these might be interpreted out of context as the remains of individual starfish. However, if all the data are taken into account with reference to reef 'Types A, B and C' where the recent history of aggregations is known, together with a consideration of the considerable dilution of skeletal fragments from a single individual in the mass of reef material, and the random sampling, it seems unlikely that this is the case. Further, Soutar and Isaacs (1969) for example, by counting scales preserved in sediments, were able to demonstrate marked changes in the relative abundance of certain pelagic fish species. This conclusion was based on very few scales per sample.

The subsurface occurrences of *Acanthaster* skeletal debris can therefore be considered conclusive evidence of previous aggregations.

Age of Previous Aggregations

Radiocarbon age dates were obtained for 32 specific horizons containing *A. planci* material in 20 of the 'cores.' These range from 'contemporaneous' (0 - about 25 cm), to 3,355 years before present at 115 cm on Hastings Reef (Appendix 1).

Whether or not the exact age of the previous individual aggregations of *A. planci* is absolutely represented by these dates is open to question. The admixture of younger carbonate material to the '*A. planci* bearing' sediment while still in the zone of bioturbation immediately after deposition, might be considered to 'minimize' the ages. However, there is no doubt that the previous aggregations took place a considerable time ago.

CONCLUSIONS

There appears to be a very rough clustering of the radiocarbon ages of previous aggregations at 250-300 year intervals. If this clustering is real, it indicates population increases ('explosions') periodically at that interval.

If, however, the clustering is an artifact, then there is an almost continuous range of ages indicating that *A. planci* aggregations have been continually present in the region of the Province investigated for a considerable time.

Irrespective of whether their occurrence is periodic, or they are present at all times, large aggregations of *Acanthaster planci* are not abnormal, but are a natural phenomenon inherent in the ecology of coral reef systems.

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Appendix 1. Summary of results of all samples from Great Barrier Reef Province analyzed for *Acanthaster planci* skeletal remains.

Locality	Previous *A. planci** History (Type)	No. Surface Samples	No. Surface Samples W *A.p.*	No. Fragments/kg (Average)	No. Bore Holes	Total Depth (cm)	*A.p.* Present (Depth cm)	No. Fragments/kg	^{14}C Age (Years B.P.)
Lady Musgrave 23°27'S 151°55'E	None known (A)	11	-	-					
One Tree 23°30S 152°04'E	None known (A)	9	-	-					
Wistari 23°28'S 151°52'E	None known (A)	17	-	-					
Heron 23°27'S 151°55'E	None known (A)	38	-	-	1	250	-		
					2	135	-		
					3	80	-		
Unamed 21°25'S 151°47'E	No data (D)	4	-	-					
Rip Cay 20°51'S 151°04'E	No data	5	-	-					

Unnamed 21°33'S 151°48'E	No data (D)	6	-	-					
Oublier 19°32'S 149°23'E	Normal (1973) (D)	10	4	3					
Knuckle 19°32'S 149°17'E	Normal (1973) (D)	23	7	2					
Gould 19°30'S 148°45'E	Infested (1972) (B, C in part)	10	-	-	1	105	-	-	
Holbourne 19°44'S 148°22'E	No data (D)	6	-	-					
Wallaby 19°25'S 148°40'E	No data (D)	9	6	3	1	150	Surface 120	3 2	Contemporaneous 900 ± 165
					2	135	Surface 90	- 4	Contem 575 ± 170
Kangaroo 19°17'S 148°27'E	Infested (1973) (C)	8	4	4	1 2 3	105 120 145	- 60 -	- 5 -	
Keeper 18°44'S 147°16E	Infested (1970) (B)	19	9	4					
John Brewer 18°39'S 147°03'E	Infested (1970) (B)	10	8	3					

Appendix 1. (continued)

Locality	Previous *A. planci** History (Type)	No. Surface Samples	No. Surface Samples W *A.p.*	No. Fragments/kg (Average)	No. Bore Holes	Total Depth (cm)	*A.p.* Present (Depth cm)	No. Fragments/kg	^{14}C Age (Years B.P.)
Eddy	Normal	5	3	2	1	80	50	2	
17°47'S 146°27'E	(1970) (D)				2	40	15	3	
					3	40	-	-	
Potter	Normal	4	1	1	1	105	15	3	Contemporaneous
17°42'S 146°33'E	(1971) (D)								
Ellison	Infested	10	3	5	1	120	30	4	Contemporaneous
17°43'S 146°24E	(1966) (B)						75	6	145 ± 85
					2	130	30	6	Contemporaneous
							130	5	220 ± 100
					3	150	80	6	270 ± 100
							120	9	485 ± 120
Gilbey	Normal	4	2	2	1	120	30	5	110 ± 95
17°35'S 146°35'E	(1969) (B)						70	4	185 ± 100
							120	5	450 ± 100

Feather 17°32'S 146°22'E	Infested (1966) (B)	2	1	1	1	30	30	1	
					2	30	–	–	
					3	45	15	2	
							45	2	
Flora 17°11'S 146°17'E	Infested (1966) (B)	6	3	2	1	95	70	7	350 ± 125
					2	98	75	12	320 ± 120
Maori 17°06'S 146°21'E	Normal (1966) (D?)	7	2	3	1	45	15	2	
							45	1	
					2	45	30	2	
							46	3	
Sudbury 16°57'S 146°10'E	Infested (1966) (B)	7	4	3	1	112	75	4	230 ± 100
					2	108	75	6	215 ± 125
							100	8	
Moore 16°52'S 146°13'E	Infested (1966) (B)	3	1	12	1	65	65	2	
					2	35	–	–	
Green 16°46'S 145°59'E	Infested (1966) (B)	71	42	4	1	185	167	6	610 ± 135
					2	182	60	3	<200
							165	10	315 ± 110
					3	214	45	6	
							105	7	
							200	5	
Upolo 16°40'S 145°56'E	Infested (1967) (B)	3	–	–	1	167	–	–	
Michaelmas 16°35'S 146°00'E	Infested (1966) (B)	6	–	–	1	138	130	4	1250 ± 140
					2	120	90	6	
Hastings 16°31'S 146°00'E	No data (D)	3	–	–	1	124	45	4	
							115	6	3355 ± 150

Appendix 1. (continued)

Locality	Previous *A. planci** History (Type)	No. Surface Samples	No. Surface Samples W *A.p.*	No. Fragments/kg (Average)	No. Bore Holes	Total Depth (cm)	*A.p.* Present (Depth cm)	No. Fragments/kg	^{14}C Age (Years B.P.)
Tongue	Infested	7	4	3	1	68	50	3	
16°19'S 145°45'E	(1966) (B)				2	200	90	4	415 ± 125
							175	5	665 ± 120
Opal	Normal	6	–	–	1	180	120	5	805 ± 135
16°13'S 145°52'E	(1966) (D)						170	3	1145 ± 125
					2	200	75	4	
							150	4	
St. Crispins	Infested	4	–	–	1	65	–	–	
16°07'S 145°52E	(1966) (B?)				2	95	–	–	
Escape	No data	4	2	3	1	90	30	3	
15°49'S 145°49'E	(D)						90	5	425 ± 130
					2	78	45	6	
Unnamed	No data	4	2	3	1	120	120	3	415 ± 125
15°30'S 145°46'E	(None) # (D)								
Unnamed	No data	4	1	2	1	46	–	–	
15°22'S 145°45'E	(D)				2	95	–	–	
					3	75	30	5	<200

Unnamed	No data	4	3	4	1	98	30	3	
15°00'S 145°43'E	(None) # (D)								
Ribbon	No data	4	-	-	1	90	30	3	
14°55'S 145°43'E	(None) # (D)						70	3	
Lizard	Infested	6	-	-	1	167	150	2	590 ± 140
14°39'S 145°28'E	(?)* (B)				2	137	130	6	595 ± 130
Tydeman	No data	3	-	-					
13°59'S 144°30'E	(None)ϕ (D)								
Clack	Normal	4	3	3					
14°05'S 144°15'E	(?)# (B)								
Corbett	No data	2	1	2					
14°00'S 144°05'E	(None)ϕ (D)								
North 1	No data	5	4	4					
13°32'S 144°04'E	(None)ϕ (D)								
Tijou 1	No data	5	3	3					
13°14'S 143°57'E	(None)ϕ (D)								
Tijou 2	No data	5	3	3					
13°07'S 143°57'E	(None)ϕ (D)								
North 2	No data	5	4	3					
12°53'S 143°50'E	(None)ϕ (D)								

* Unless otherwise stated, data from Endean and Stablum (1975).

Pearson and Endean (1969).

ϕ Pearson and Garrett (1975).