Delimiting survey of a yellow crazy ant infestation, and pre-treatment monitoring set-up on Nu'utele Island, Aleipata, Samoa.

DRAFT

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Contents

Executive Summary

Nu'utele Island lies 1.3 kms off the south-east coast of Upolu, Samoa. It is within a Marine Protected Area and in 1991 was identified as an area of high biodiversity value for Samoa. It is the subject of a long-term restoration project that aims to preserve native biodiversity in the Micronesia-Polynesia Hotspot.

A survey in 2003 observed invasive yellow crazy ants, *Anoplolepis gracilipes* (Smith), in high numbers throughout Nu'ulua Island to the south-east, but not on Nu'utele Island. However, in August 2006 yellow crazy ants (YCA) were found by MNRE staff behind the beach on Nu'utele Island, in the vicinity of old leper colony dwellings.

This report describes work undertaken between 19 – 22 September 1006. The team consisted of the terrestrial conservation section of the Ministry of Natural Resources, Environment & Meteorology, ant ecologist Dr Kirsti Abbott, volunteers through the Marine Protected Area committee and Dr Dave Butler.

Yellow crazy ants on Nu'utele Island were confined to an area of approximately eight hectares, and no mote than 10 hectares on the south-southeastern beach flat and up the southern ridge. The invasion front was located on the beach flat itself where the boundary is relatively sharp (< 50 m). Ant activity was relatively high, and large nests were found with winged queens and males inside, indicating that mating will occur most likely within 1 – 4 weeks of the study.

Twelve permanent invertebrate monitoring plots were established on Nu'utele Island, and six more added to Nu'ulua Island. In each plot crab and crab burrow abundance was recorded through visual surveys and five pitfall traps per plot collected ground-dwelling invertebrates over a 24-hour period.

There were more hermit crabs on the low elevation beach sites than in the high elevation forest sites. However, there are more large burrows in the high elevation sites indicating the presence of coconut crabs rather than hermit crabs in these forest plots.

Control of YCA populations on Nu'utele Island using toxic bait is recommended within 12 months of this report. However, prevention of spread of the invasion boundary on the Nu'utele Beach flat is recommended well within this time. Access to this boundary is easy; hand baiting with toxic ant bait, as well as monitoring its advancement every visit to the island is crucial.

Surveys of the permanent monitoring plots are recommended every 8 – 12 months. They provide a greater understanding of the terrestrial invertebrate biodiversity on Nu'utele Island, and aid management decisions based on knowledge of invertebrate populations.

Introduction

The yellow crazy ant, *Anoplolepis gracilipes* (Smith), has been hailed as one of the world's 100 worst invasive species (Lowe et al. 2000). It has the ability to form multi-queened supercolonies, in which foraging ants occur at extremely high densities (1000s of worker ants m^{-2}) over large areas. The ants forage over all available surfaces, and are found on the ground and in the canopies of rainforest trees. Populations of yellow crazy ants can lie dormant for decades on many oceanic islands without any observable impact on the native biota, however, once formed, high density supercolonies can become progressively more widespread on islands. For examples, on Christmas Island the first supercolony was discovered in 1989, but spread to occupy approximately 2500 ha of native forest by 2001 (Green et al. 2004). The infestations ranged in size from a few hectares to hundreds of hectares, and were found almost exclusively in the forest; they have not been found in settled areas, and have only rarely formed in cleared areas.

Two uninhabited offshore islands off the south-eastern coast of Upolu – Nu'ulua and Nu'utele Islands – provide particular opportunities for the conservation of native biodiversity in Samoa. The country's few other offshore islands are either inhabited or within swimming range of rats from the main islands and thus have less current values and potential. Nu'utele and Nu'ulua lie within the Micronesia-Polynesia Biodiversity Hotspot. They provide some of the only undisturbed habitat for nesting seabirds, bats, ground-nesting doves, sea turtles and invertebrates and are now protected within a Marina Protected Area managed by the Samoan government and the Aleipata community. Yellow crazy ants were recorded in high numbers on Nu'ulua Island in 2003, and on Nu'utele Island in 2006. This species poses a serious threat to native biodiversity. Consequently, it is a priority that it is controlled within the Marine Protected Area.

The removal of an invasive species from an area in order to conserve native biodiversity is an enterprise not to be underestimated. Control programs for both vertebrate and invertebrate pests around the world incur large costs, and are often seen to be "one-off" programs. In reality, the movement of invasive species between biogeographical regions is constant, and the need for a control program for the same species is an issue faced by management and funding agencies alike. For an invasive ant control/eradication program to be successful, it should consist of the following components at the very least (in chronological order):

1. *Scoping Phase*
    a. Surveys to determine biodiversity values, extent of infestation and ant activity,
    b. Environmental and economic assessment of toxic bait/IGR application,
    c. Confirmation of commitment of people, time & money dedicated to program;
2. *Operational Phase*
    a. Distribution of toxic bait/IGR by hand or air,
    b. Adherence to environmental and health & safety regulations
3. *Post-Operational Evaluation Phase*
    a. Proper disposal or storage of excess toxic bait/IGR
    b. Surveys to evaluate suppression of ant populations and non-target impacts

[Would you add a fourth – namely contingencies in place to prevent further invasions? Does not fit so well with your order]

This report forms part of the scoping phase, and first describes the extent of the yellow crazy ant infestation on Nu'utele Island. Furthermore, it provides recommendations for management and possible future research activities on the islands. Second, it outlines the establishment of long-term invertebrate monitoring plots and results from the first survey. This report is designed to be read in conjunction with Butler (2006) and Vanderwoude (2006) and as such does not repeat much of the information regarding the biodiversity values and background of Nu'ulua and Nu'utele Islands, and invasive ant ecology found in these reports.

Methods & Materials

All activities described in this report took place between 19 – 22 September 2006.

Extent of the YCA infestation

Visual searches for yellow crazy ants were undertaken at all times whilst walking around the island. Camp was made at Vini Beach and visual surveys by all team members were made across the extent of the Vini Beach area. In addition to visual observation for YCA, team members were on the lookout for scale insects on leaves or twigs in vegetation, and any association of YCAs with insects in vegetation.

On 20 September 2006 the northern boundary of the infestation was located by the six-person team walking in a search and rescue type sweep southward across the Nu'utele Beach flat area until a visual identification of YCA foragers was made. Team members were spread approximately 8 – 10 metres apart starting from the beach edge, and walked in a south-easterly direction in a line. Once the boundary was located, team members rotated the line 90^{o} and lined up perpendicular with the YCA infestation boundary so that three people could see YCAs and three could not. Starting at the beach edge again, a string line was laid along the boundary of the infestation and GPS points taken along the boundary. This continued until the vegetation became almost impenetrable and the team reached the upward sloping base of the southern ridge. The area within this delimited boundary was then searched to ensure YCAs were throughout.

On 22 September 2006 the southern ridge of Nu'utele was inspected for YCAs by a three person team. They walked from the beach edge up the slope and along the north side of the southern ridge. They then traveled south-west along the ridge and down the slope to the beach flat and the western edge of the YCA infestation conducting continual visual searches for YCAs.

Assessment of YCA activity at the boundary and core of the infestation

On Friday 22 September 2006 YCA activity and forager recruitment to tuna baits was assessed at the northern boundary and interior of the infestation on the Nu'utele beach flat. On the boundary, three transects each consisting of five tuna bait cards (laminated white card ?mm square) were set up perpendicular to the invasion front so that three cards were inside the infestation and two were outside. Approximately 5-6 g of tinned tuna was placed on each card. After 60 minutes the number of YCA and other ant species present at the tuna was recorded.

Within the infestation six stations each consisting of three haphazardly placed tuna bait cards were established so that each station was at least 50 m apart and bait cards within the station were approximately 5 m apart. Approximately 5-6 g of tinned tuna was placed on each card and after 60 minutes the number of YCA and other ant species present at the tuna was recorded.

Where YCA were streaming out from underneath logs, vegetation or at the base of trees, these areas were excavated and life stages present were recorded. Life stages recorded included eggs, larvae, worker pupae, workers, winged and unwinged queens, males, and queen and male pupae. No attempt to quantify the proportion of different life stages was made.

Uptake of fish meal granular ant bait matrix by ants on Nu'ulua and Nu'utele Islands

The rate of uptake of granules of free-feed (no active ingredient) fish meal ant bait was assessed to determine the attractancy of the matrix to YCA and other ant species on each island. The outcomes of these observations can be used to help assess the suitability of the bait matrix for use in control programs and to determine the extent and possibility of effects of a toxin on non-target ant and invertebrate species that are attracted to, and remove the bait matrix.

On Nu'ulua, six white laminated cards were placed 2 - 3 m apart in permanent monitoring Plot 1 (Vanderwoude 2006). Approximately 3-4 g of free feed ant bait was placed on each card. The number of granules removed was recorded in conjunction with the identity (YCA or other ant species) of the ant that removed it. Observations were made at 5, 10, 15 and 20 minutes after bait placement, followed by incomplete observations at 90, 95 and 100 minutes. Bait cards were checked again approximately two and a half and four and a half hours later, and again 12 hours after the last check.

On Nu'utele Island, four stations consisting of one laminated bait card and one large leaf were placed approximately 5–8 m apart within the YCA infestation on Nu'utele beach flat. In the centre of the bait card and the leaf 3-4 g of free-feed ant bait was placed and observed for 60 minutes. The number of bait granules removed by both YCA and other ant species (OAS) from each of the bait card and leaf was recorded every 10 minutes.

Establishing invertebrate monitoring plots on Nu'utele Island

On Nu'utele Island, permanent circular plots with a diameter of 25.2 m (area = 0.05 ha) were established in line with protocols developed by Vanderwoude (2006) on Nu'ulua Island. Twelve plots were established on Nu'utele over three days (19 – 21 September 2006), seven in low elevation beach flat areas, and five in high elevation forested sites. Plot locations were chosen haphazardly, taking into account three important factors:

a) Accessibility by survey team,
b) Ease of relocation for repeated surveys, and
c) Being representative of a variety of habitat types across the island.

Plots were set up by assigning a mature canopy tree as the center of the plot, then running a 12.6 m length of string to the edges of a circle. The center tree was marked with pink flagging tape e.g. "PLOT 1 CENTRE" and at least four points on the outside of each plot were flagged and marked with the plot number. This allows quick and easy identification of plots in future surveys. In each plot visual surveys were conducted for crab burrows, empty shells (potential hermit crab dwellings), hermit crabs (*Coenobita perlatus*, *C. rugosus* & *C. brevimanus*), and coconut crabs (*Birgus latro*). Pitfall traps were 60 ml medical specimen vials. Five pitfall traps were placed in a line approximately 2 – 3 m apart with the middle pitfall in the center of the plot. Each pitfall was one third filled with ethanol and left for 24 hours before collection.

In addition to the 12 plots already established, at least eight and perhaps as many as 12 new plots should be established on Nu'utele Island in the future, five in low elevation forest toward the back of Nu'utele Beach flat, four on the western slope up from the beach flat, and three in higher elevation sites at, or near the top of the ridge (Figure 1).

Additional monitoring plots on Nu'ulua Island

Six permanent monitoring plots were established on Nu'ulua Island in July 2006 (Vanderwoude 2006). During this field trip six more plots were added to make the final number of plots on Nu'ulua Island twelve. Plots were established in the same manner as on Nu'utele Island.

Results

Extent of the YCA infestation

The delimiting survey revealed that YCAs are restricted to the southern side of Nu'utele Island covering an area of approximately eight hectares, and no more than 10 hectares (Figure 2). The northern boundary is located approximately half way along the beach flat, and was easily found by walking southeast following the line of the beach. Yellow crazy ants were in relatively low numbers on this boundary, and were patchy. Most often single foragers were spotted, or at the most, a trail of foragers. Large nests were not encountered on this northern boundary. The boundary does not extend very far back from the beach to the south-west. Approximately 200 m south-west of the beach the boundary curves around to the left and continues up onto the south-east ridge.

Yellow crazy ants were detected on the ridge, but the southern side of the ridge was not searched. The southern side of the ridge appears accessible and should be searched for YCAs before finalizing the total extent of the infestation for aerial control using toxic baits. Scale insects were not recorded throughout searches on Nu'utele Island, and YCAs were not observed to associate with any other honeydew producing insects on vegetation.

Assessment of YCA activity at the boundary and core of the infestation

The northern boundary of the YCA infestation on the beach flat was relatively sharp. Some boundaries of YCA infestations on Christmas Island, Indian Ocean, extended for 50 – 80 metres where the abundance of YCA foragers declined very gradually. In contrast, the abundance of YCA foragers on the northern boundary of the Nu'utele Island infestation declined rapidly over a distance of 10 – 20 metres (Figure 3). Foraging ants were conspicuous on the boundary, and were observed foraging on the ground as well as on vegetation.

As the number of YCAs increased at the tuna on each bait card, the number of other ant species (OAS) decreased (Figure 4). This result would benefit from further replication. However, the pattern is consistent with results from Christmas Island, Indian Ocean, and Tokelau, Pacific Ocean. The most striking result was the almost complete absence of the large black trap-jaw ant, *Odontomachus simillimus*, from tuna baits inside the YCA infestation. When YCA were absent from the tuna baits, these large ambush predators dominated the cards, guarding it with up to five individuals that fought off other ants interested in the tuna.

Excavation of three nests was successful within the infestation. Removal of fallen logs, coconut fronds, wood and other debris from the surface of the ground revealed worker eggs, larvae and pupae,

winged and unwinged queens and male yellow crazy ants. The brood (eggs, larvae & pupae) was usually close to the surface and easily identified.

Uptake of fish meal granular ant bait matrix by ants on Nu'ulua and Nu'utele Islands

Other ant species removed more free-feed ant bait than YCA did during trials on both Nu'ulua and Nu'utele Islands (Figures 5 & 6). There was no difference between the numbers of granules removed by YCA or OAS until 15 minutes after bait placement on Nu'ulua and 50 minutes on Nu'utele Island. After approximately 16 hours after bait placement on Nu'ulua Island, bait was completely gone from two of the cards, presumably eaten by hermit crabs, and YCA were not present on the other four cards. Instead, many small ants were in amongst the bait granules.

On Nu'utele Island, there appeared to be no difference in the number of bait granules removed by YCA and OAS on either the leaf or the bait card until between 40 and 50 minutes after bait placement when other ant species appeared to recruit to, and remove bait granules from two of the leaves. After 60 minutes, YCAs had removed a total of 17 granules from bait cards, and 10 from the leaves, and OASs had removed 27 from the bait cards and 68 from the leaves. Overall, OASs removed 3.5 times more granules in 60 minutes than YCA.

Observations from throwing ant bait granules directly onto the ground within the YCA infestation on Nu'utele beach flat suggest that YCA are more likely to remove the bait granules when they are distributed within the habitat matrix rather than on laminated white cards. However, it is difficult to observe ants taking bait granules away from under coral and debris, so no quantification of this was carried out.

Establishing invertebrate monitoring plots on Nu'utele Island

Permanent monitoring plots took no more than 5 – 10 minutes to establish and mark with flagging tape and a GPS waypoint. Crab burrows, hermit crabs and empty shells were found in every plot, but no live coconut crabs were recorded in any of the low elevation (beach flat) and high elevation (ridge) monitoring plots (Figure 7). There was a significant difference in the number of crab burrows, hermit crabs and empty shells between the low and high elevation plots. A total of 84 hermit crabs were counted, 81 in the low elevation plots and three in the high elevation plots. This is not surprising considering that near water is the primary habitat for two abundant species of hermit crab, *Coenobita perlatus* (the red one) and *Coenobita rugosus* (the green/grey one). The larger purple hermit crab, *Coenobita brevimanus*, is found more often in the forest, and was recorded in the high elevation plots, but not in high numbers. Crab burrows were more abundant in the high elevation plots (mean=12.8; n=5) than in low elevation plots (mean=6.1; n=7), most likely because of higher numbers of coconut crabs living in the forest than on the beach flat.

Additional monitoring plots on Nu'ulua Island

In addition to the six existing monitoring plots on Nu'ulua Island (Vanderwoude 2006), six more were established between 19 – 21 September 2006. Similar to Nu'utele Island, no coconut crabs were recorded in any of the plots; hermit crabs were far more abundant in plots on Nu'ulua (Figure 8).

Discussion

Islands provide valuable living laboratories for the study of basic ecological and evolutionary processes; dispersal, immigration, competition, adaptation, extinction and invasion. As such, Nu'ulua and Nu'utele Islands are particularly valuable as rare examples of nearly intact offshore islands in the South Pacific. Island habitats are renowned for their fragility and are among the most highly impacted sites in the world, but by world standards, Nu'ulua and Nu'utele Islands have escaped many of the impacts seen on nearby Upolu. The recent population explosion of YCA on Nu'ulua, and even more recent introduction of YCA onto Nu'utele, poses a significant risk to the invertebrate biodiversity on the islands.

The yellow crazy ant infestation on Nu'utele Island covers an area of no more than 10 hectares, of which the majority is inaccessible for the purposes of hand broadcast baiting. The southern side of the ridge is inaccessible to humans and was therefore not surveyed for YCA during this visit. However, it is possible to survey the less than vertical section of the southern side of the ridge, and this should be done before aerial control of YCA. If YCA are present on this southern side the extent of the infestation could be estimated to cover the whole of the southern ridge. On the northern boundary of the infestation (on the beach flat), nests were sparse and difficult to find, however, within the infestation YCA activity levels were relatively high, and foraging worker ants recruited to tuna baits within minutes of it being placed on the ground. Nests were larger in the core of the infestation. Nests contained worker ants, worker eggs, larvae and pupae, winged and unwinged queens and males. The presence of winged queens and male ants indicates that mating will likely occur within one month and spread of the infestation is **highly likely**. Males only survive for a limited time, often 1-2 weeks so their presence signifies imminent mating and possibly dispersal.

Yellow crazy ants dominated tuna baits within the infestation area, and displaced other ant species from the baits. In addition, the trap-jaw ant, *Odontomachus simillimus* (large black one), was completely absent from tuna baits placed within the YCA infestation, suggesting that they do not coexist with YCA when they are in relatively high numbers. In fact, this pattern has been observed on Christmas Island, Tokelau and on Upolu, and it is typical that other large ants will not coexist with YCA (Abbott 2006, Sarty et al. 2006). Invertebrate faunas of islands typically have low species richness, so it is unlikely that native or resident ants will confer any resistance to the spread of YCA on Nu'utele. Indeed, it appears as if YCA has already displaced some resident ant species from the infested area on Nu'utele.

If control of the infestation is to be successful, it is desirable to act sooner rather than later, before spread occurs. However, a well-developed plan will ensure success.

Permanent terrestrial monitoring plots are an excellent method for increasing our understanding of biodiversity in a given area, fluctuations in population numbers (both seasonally and annually), and creating a link between science and management in terrestrial systems. Information collected from the permanent monitoring plots can not only be used to analyse patterns in species' distributions and associations between the flora and fauna, but carry over to provide informed management decisions on invasive species.

Management thresholds

The concept of an activity/relative abundance threshold at which impacts of YCA become unacceptable is a useful tool in deciding whether to use toxic bait in controlling YCA. Vanderwoude (2006) suggests that, on Nu'ulua, the current levels of ant activity should be viewed as the upper threshold, which could be modified as more information becomes available.

Recommendations

Management of YCA on Nu'utele Island

1. **Postpone full aerial control of YCA populations on Nu'ulua and Nu'utele Islands until dry season 2007.** The timing of a program like this is often crucial to its success. Planning for an aerial bait drop during the dry season would increase the likelihood that bait remained dry for a longer period of time. Furthermore, monitoring ant activity might be easier during the dry season, and allow better data to evaluate success. This will only be feasible if a helicopter is available for use during this time.

2. **Control the northern section of the YCA infestation on Nu'utele beach flat by hand baiting accessible areas before the wet season 2006-07.** I recommend hand-broadcast baiting Indoxacarb within the fish meal ant bait matrix at a rate of between 2 and 5 kg/ha. This will allow a test of Indoxacarb without excessive costs, and contain the infestation until more fully developed aerial control program is possible.

3. **Control YCA on both Nu'ulua and Nu'utele Islands with an aerial drop of toxin followed approximately 3-4 months later by an aerial drop of an insect growth regulator during the dry season of 2007.** The combination of a rapid knockdown technique with a longer-term population control has been used in Queensland on invasive ants and is thought to provide a longer-term control option. If a helicopter is located in the region this option is much more feasible.

4. **Develop long-term management goals for invasive ants/insects on Nu'ulua and Nu'utele Islands that will be overseen and upheld by both MNRE and the Aleipata community.** Managing invasive ants is a long-term undertaking. One-off programs often fail due to the prevalence of reintroduction of invasive species and unforseen population build-ups.

5. **Conduct pre-operational monitoring on all permanent invertebrate monitoring plots within 2 weeks of any large-scale aerial control of invasive ants, then ideally, again 2 months after control and 12 months after control.** Robust evaluation of an invasive ant control program is crucial to the confirmation of your direct project goals, can aid in substantiating conservation goals, and boost the probability of gaining future funding for conservation needs.

Long-term Biodiversity Monitoring

1. **Conduct annual surveys of the permanent monitoring plots.** Annual surveys of permanent invertebrate monitoring plots will increase understanding of terrestrial invertebrate biodiversity, species

distributions, population fluctuations and conservation goals over time. Three days on Nu'ulua and 4 days on Nu'utele Island each year would allow time to complete these surveys.

Using the islands as a scientific research site

Nu'ulua and Nu'utele Islands provide a unique opportunity to investigate hypotheses about island biogeography, invasive species, animal dispersal, restoration among many others. The integration of management and science allows best management practice to be improved continually, and has proven to be successful in numerous restoration projects. Environmental management agencies in Samoa would benefit from collaboration with academic institutions with interests in conservation and restoration research. Here I provide **suggestions for future research projects that are directly relevant to invasive ant species management** (focused on invertebrates & vegetation) on the islands:

<u>Vegetation</u>

1. What is the distribution and phenology of invasive plant species on Nu'ulua and Nu'utele Islands?
2. Are native birds feeding on invasive plant species? If so, are they dispersing seeds of these plants? Are they nesting sites for invasive ant species? What are the implications for conservation management?

<u>Invertebrates</u>

1. The ant fauna of Nu'ulua and Nu'utele Islands – what is the proportion of native vs tramp species?
2. What is the diet of invasive ant species on Nu'ulua and Nu'utele Islands?
3. What is the reproductive phenology of YCA on Nu'ulua and Nu'utele Islands?
4. Are YCA having an impact on native flora and fauna on the islands? If so, what are these impacts?

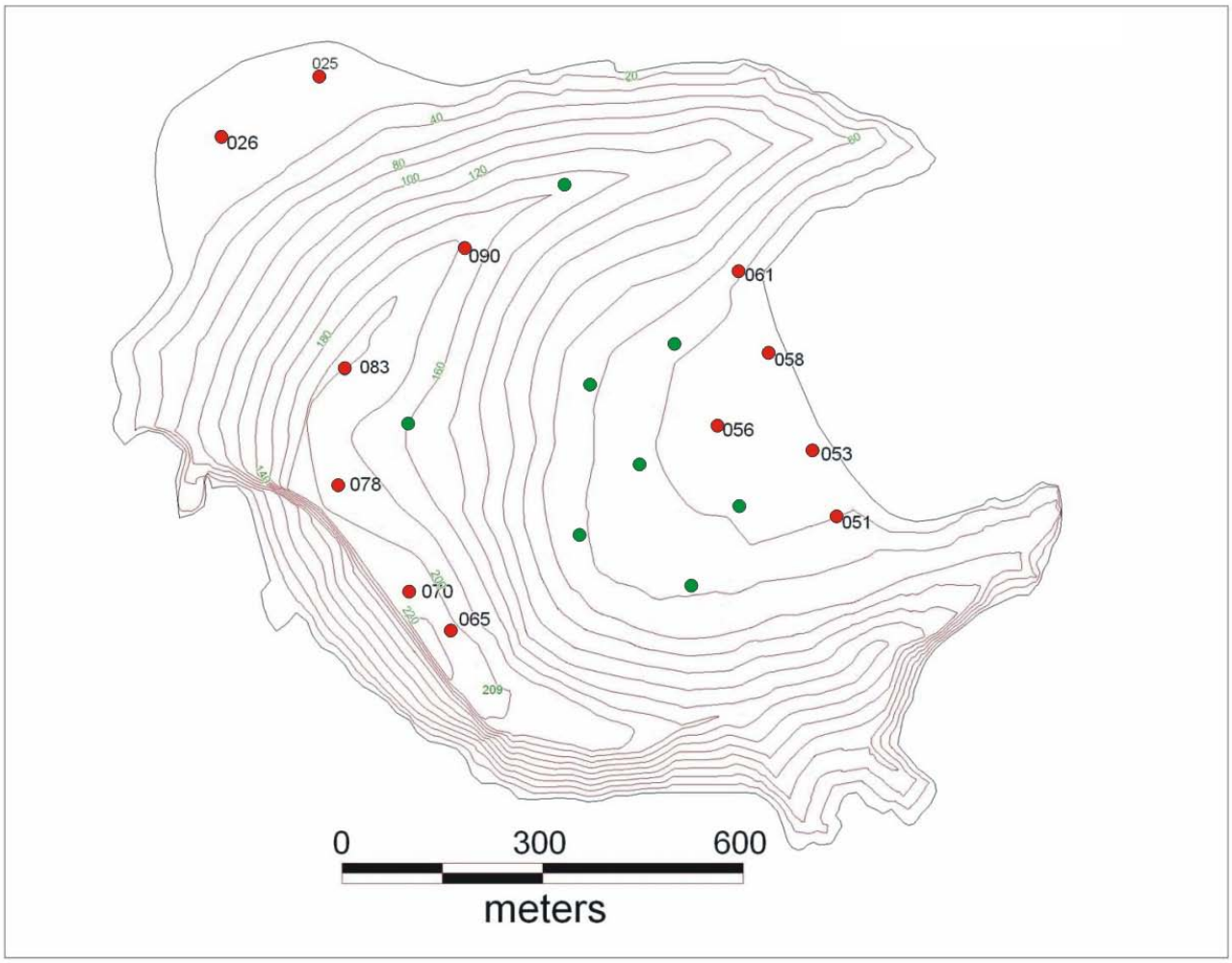

Figure 1 – Approximate locations of established permanent monitoring plots ( ) and recommended additional plots ( ) on Nu'utele Island. Numbers on established plots correspond to the GPS waypoints set for that plot.

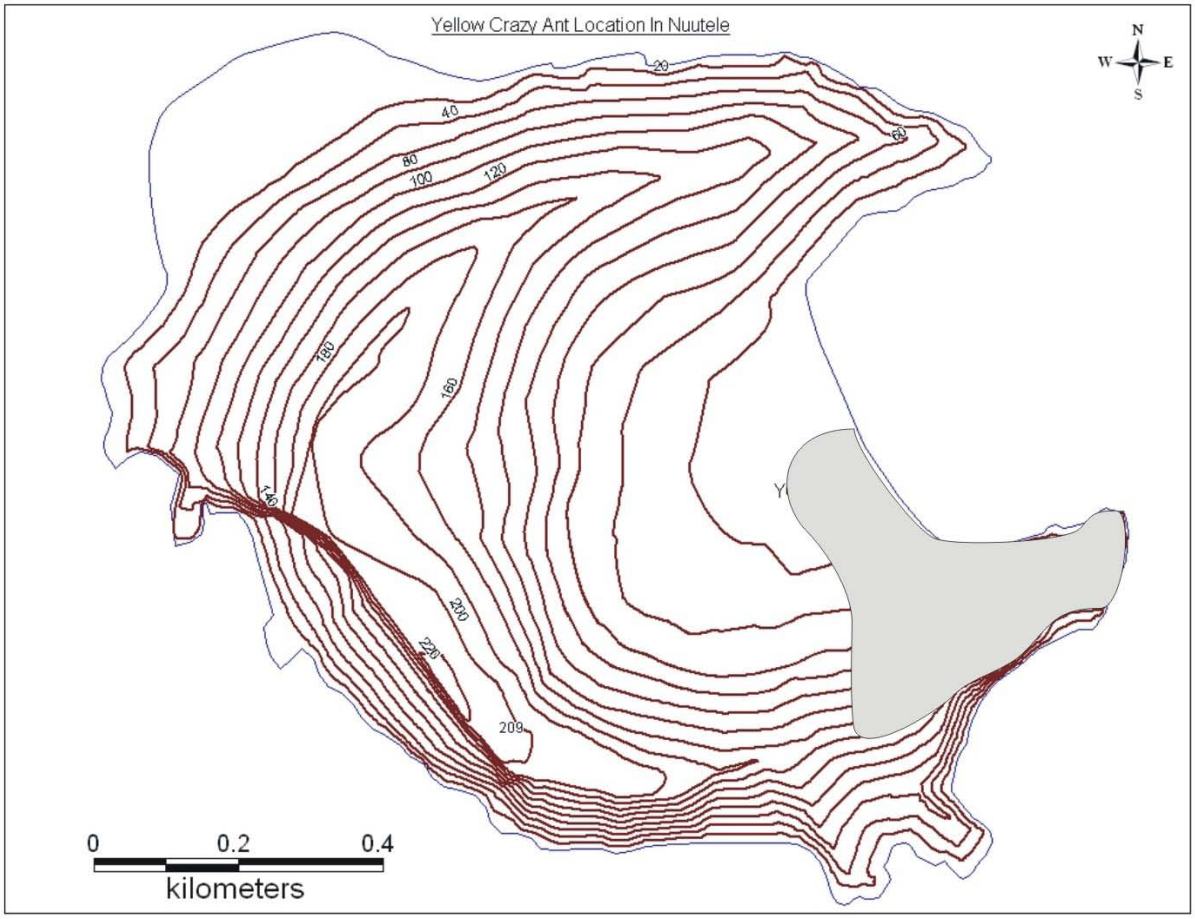

Figure 2 – Map of Nu'utele Island showing the approximate extent of the yellow crazy ant infestation on the south-eastern beach flat and extending up onto the south-eastern ridge. Further investigation of the south side of the ridge is crucial to confirm the presence of YCA there. YCAs are foraging to the water's edge on the beach.

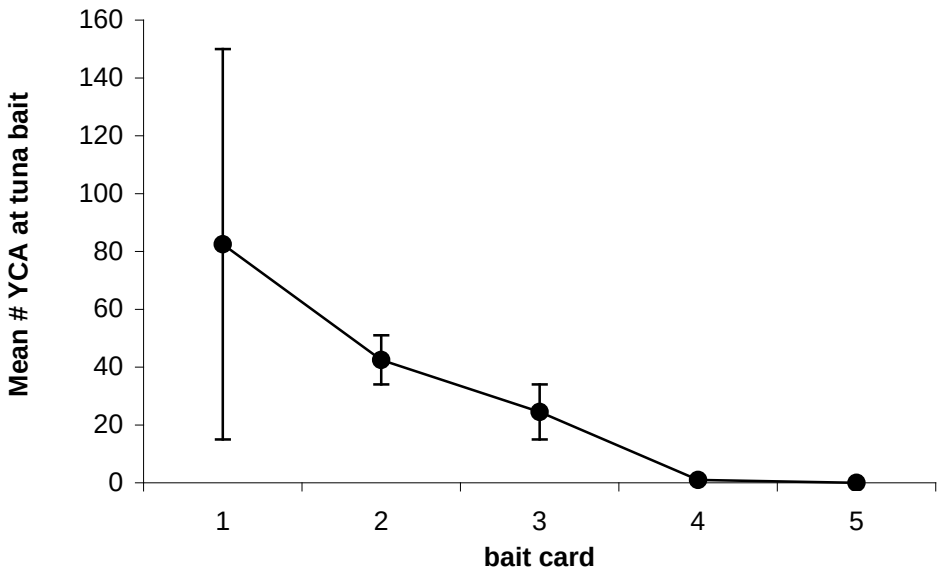

Figure 3 – The decline in the number of YCA at tuna baits across the northern boundary (+/- SE). Bait cards were approx. 5 m apart. N=2 for each bait card. Although there were three transects, only two were across the boundary. No YCA were detected on the third.

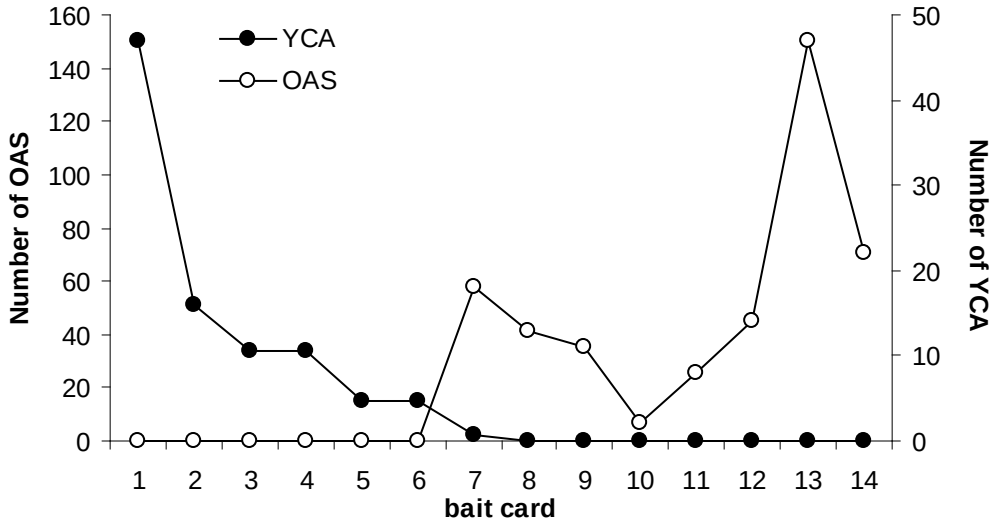

Figure 4 – The number of individual yellow crazy ants (YCA) and other ant species (OAS) at the tuna bait across the northern boundary of the Nu'utele Island infestation.

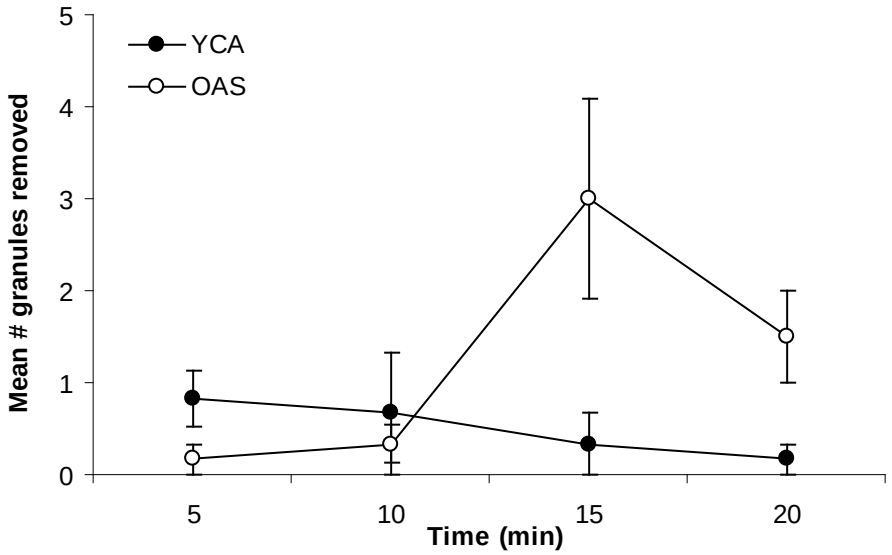

Figure 5 – Mean number of free-feed ant bait granules removed by yellow crazy ants (YCA) and other ant species (OAS) (+/- SE) over a 20-minute period on Nu'ulua Island.

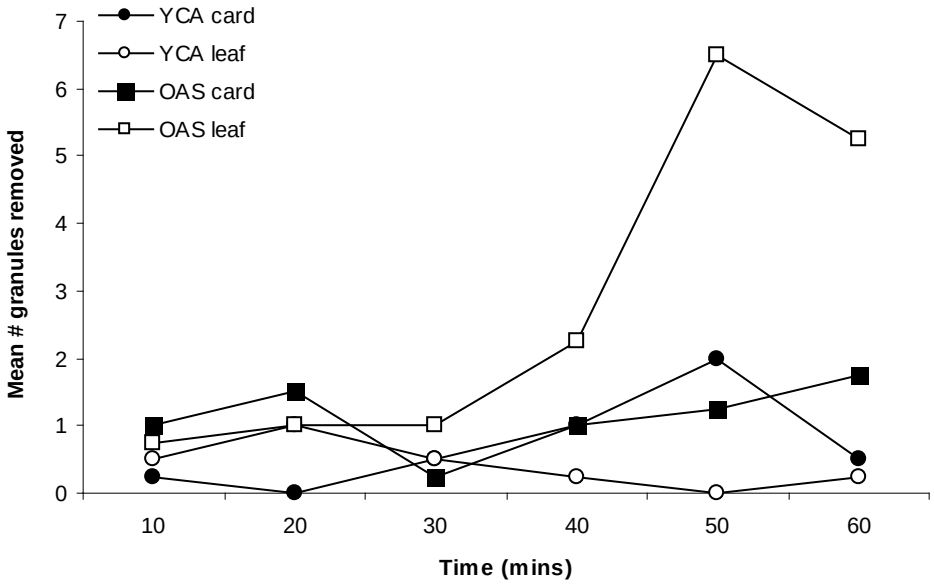

Figure 6 - Mean number of free-feed ant bait granules removed by yellow crazy ants (YCA) and other ant species (OAS) from laminated bait cards and leaves over a 60-minute period on Nu'utele Island. Standard error bars removed for clarity.

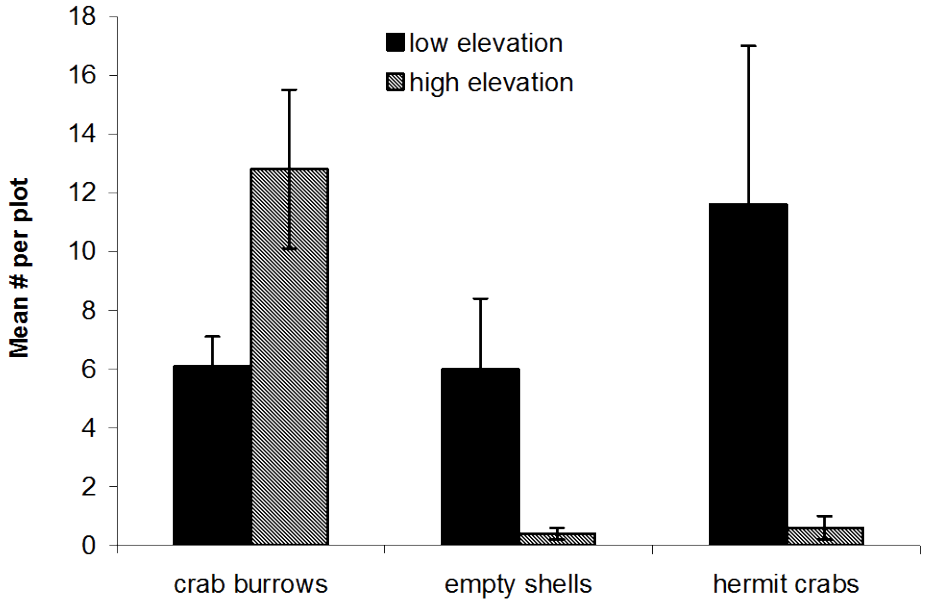

Figure 7 – The mean number of crab burrows, empty shells (potential hermit crab dwellings) and hermit crabs (+/- SE) in low and high elevation plots on Nu'utele Island.

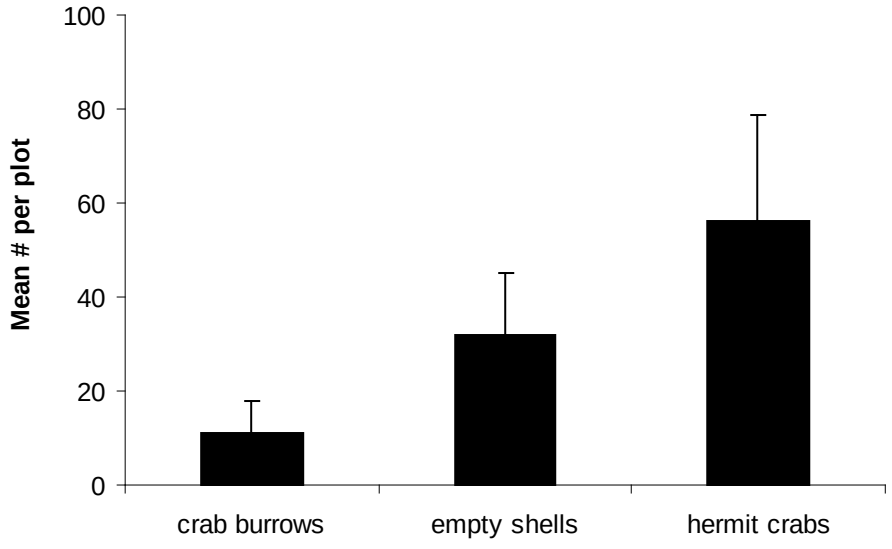

Figure 8 - The mean number of crab burrows, empty shells (potential hermit crab dwellings) and hermit crabs (+/- SE) in additional six monitoring plots on Nu'ulua Island.

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Appendix 1

Yellow crazy ant activity at the boundary and core of the infestation.

YCA infestation on southern end of beach flat and southern slope

Tuna bait cards on boundary
22-Sep-06

		transect 1		transect 2		transect 3	
bait card	**location**	**YCA count**	**OAS count**	**YCA count**	**OAS count**	**YCA count**	**OAS count**
1	in YCA	150	0	15	0	0	8
2		51	0	34	0	0	14
3		34	0	15	0	0	47
4		2	18	0	11	0	203
5	out YCA	0	13	0	2	0	22

Tuna bait cards in infestation on Nu'utele beach flat and up to back boundary
22-Sep-06

	location	**1**	**2**	**3**	**total**	**mean**
Susau	closest to beach	21	155	170	346	115.3
Silau	approx 40m back from beach	40	130	189	359	119.7
Natasha		6	13	14	33	11.0
Ben	at old dwelling	163	92	73	328	109.3
Malarchy	near back boundary in vine thicket	91	89	107	287	95.7
Kirsti	at back boundary	0	0	145	145	48.3
					overall mean	**83.2**

Appendix 2

Uptake of fish meal granular ant bait matrix by ants on Nu'ulua Island

ANT BAIT TRIALS - NUULUA ISLAND
Dave Butler, Susau Siolo, Filipo Sio
19-Sep-06

N/R - card not observed
Trials carried out in Cas's first plot (waypoint 16) - forest flat, high infestation, not far in from beach. Card 3 on a YCA trail.
Figures = no. of ants taking bait off cards.
At 5.40pm, 7.30pm and 7.13am next morning spot checks were made of each card. Bait was disturbed to count tiny ants within it at 5.40.

	Card 1		**Card 2**		**Card 3**		**Card 4**		**Card 5**		**Card 6**	
Time	YCA	OAS	YCA	OAS	YCA	OAS	YCA	OAS	YCA	OAS	YCA	OAS
2.56-3.01	2	1	1	0	0	0	1	0	1	0	0	0
3.01-3.06	0	0	0	0	0	0	4	1	0	1	0	0
3.06-3.16	0	8	0	1	0	2	2	2	0	4	0	1
3.16-3.26	0	3	0	0	0	2	0	2	0	0	1	2
4.34-4.39	0	2	0	2	N/R		N/R		N/R		N/R	
4.39-4.46	N/R		N/R		0	1	0	1	N/R		N/R	
4.47-4.52	N/R		N/R		N/R		N/R		1	0	0	0
5.40pm	2	20+	0	20+	4	8	1	17	0	20	0	24
7.30pm	0	present	0	present	0	present	0	present	0	present	0	present
7.13am	Bait all gone.		Bait all gone.		Lots of bait, no crazy ants on cards, lots of tiny ants, few mid-size dark ones.							

Large number of tiny ants on and around the bait during this check.

An earwig and a cockroach on baits. Hermit crab near cards 1 & 2

Appendix 3

Uptake of fish meal granular ant bait matrix by ants on Nu'utele Island

ANT BAIT TRIALS - NUUTELE ISLAND
Dave Butler, Susau Siolo, Silau & Afa
22-Sep-06

9:49am - 10:49am

		Susau		Dave		Silau		Afa	
Ant species	**Time (min)**	**Card**	**Leaf**	**Card**	**Leaf**	**Card**	**Leaf**	**Card**	**Leaf**
YCA	10	0	0	0	0	0	0	1	2
OAS		0	1	4	2	0	0	0	0
YCA	20	0	4	0	0	0	0	0	0
OAS		0	1	4	3	1	0	1	0
YCA	30	0	2	0	0	2	0	0	0
OAS		0	1	1	3	0	0	0	0
YCA	40	0	0	0	0	3	0	1	1
OAS		3	5	0	3	1	0	0	1
YCA	50	0	0	0	0	6	0	2	0
OAS		2	5	1	20	2	0	0	1
YCA	60	0	1	0	0	2	0	0	0
OAS		6	7	0	13	1	0	0	1
TOTALS	**YCA**	**0**	**7**	**0**	**0**	**13**	**0**	**4**	**3**
	OAS	**11**	**20**	**10**	**44**	**5**	**0**	**1**	**3**

Appendix 4

Permanent invertebrate monitoring plots on Nu’utele Island

Monitoring plots on Nu'utele Island

19 - 22 September 2002

Set date	pitfall coll date	Plot #	Location	Waypoint #	crab burrows	empty shells	hermit crabs	coconut crabs
19-Sep-06	20-Sep-06	1	Vini Beach	25	11	10	42	0
19-Sep-06	20-Sep-06	2	Vini Beach	26	6	17	16	0
20-Sep-06	21-Sep-06	3	Nu'utele Beach flat	51	3	2	6	0
20-Sep-06	21-Sep-06	4	Nu'utele Beach flat	53	5	9	7	0
20-Sep-06	21-Sep-06	5	Nu'utele Beach flat	56	4	0	4	0
20-Sep-06	21-Sep-06	6	Nu'utele Beach flat	58	7	4	4	0
20-Sep-06	21-Sep-06	7	Nu'utele Beach flat	61	7	0	2	0
21-Sep-06	22-Sep-06	8	Top of ridge	65	7	1	0	0
21-Sep-06	22-Sep-06	9	Top of ridge	70	23	0	0	0
21-Sep-06	22-Sep-06	10	Top of ridge	78	11	1	1	0
21-Sep-06	22-Sep-06	11	Top of ridge	83	11	0	0	0
21-Sep-06	22-Sep-06	12	Top of ridge	90	12	0	2	0
				Total	**107.0**	**44.0**	**84.0**	**0.0**
				Mean	**8.9**	**3.7**	**7.0**	**0.0**
				Std dev	**5.4**	**5.5**	**11.9**	**0.0**
				Std err	**1.5**	**1.6**	**3.4**	**0.0**

Appendix 5

Additional permanent invertebrate monitoring plots on Nu'ulua Island

Monitoring plots on Nu'ulua Island
19 - 21 September 2002

Set date	pitfall coll date	Plot #	Location	Waypoint #/GPS	crab burrows	empty shells	hermit crabs	coconut crabs
19-Sep-06	20-Sep-06	A	low elevation/beach flat	14 04 17.7	0	10	0	0
				171 24 36.7				
20-Sep-06	21-Sep-06	T1	low elevation/beach flat	no GPS	33	90	90	0
20-Sep-06	21-Sep-06	T2	low elevation/beach flat	14 04 21.9	33	48	141	0
				171 24 33.2				
20-Sep-06	21-Sep-06	T3	low elevation/beach flat	14 04 22.6	0	13	32	0
				171 24 35.7				
20-Sep-06	21-Sep-06	T4	low elevation/beach flat	no GPS	1	17	0	0
20-Sep-06	21-Sep-06	T5	low elevation/beach flat	no GPS	0	14	73	0
				Total	**67.0**	**192.0**	**336.0**	**0.0**
				Mean	**11.2**	**32.0**	**56.0**	**0.0**
				Std dev	**16.9**	**31.7**	**55.7**	**0.0**
				Std err	**6.9**	**12.9**	**22.7**	**0.0**