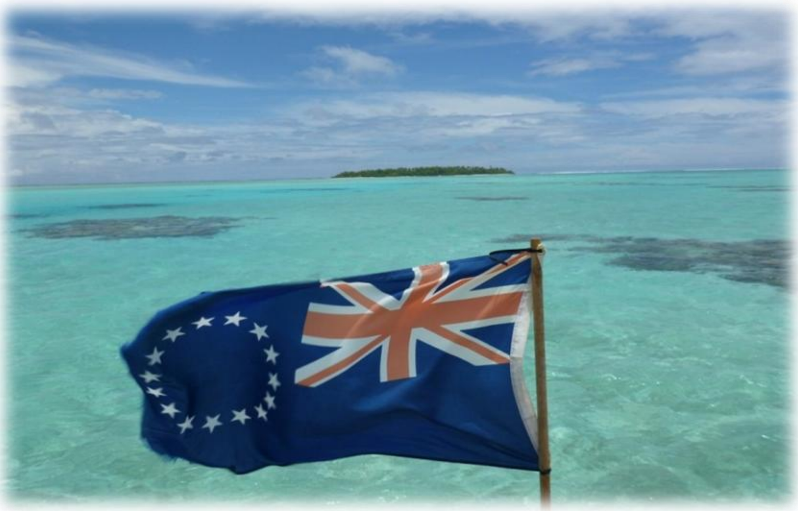
Annual Report 2012 - 2013



Report by Phil Bradshaw

The Cook Islands Turtle Project (CITP) is authorised by the Foundation for National Research and the Office of the Prime Minister

Research Permit # 32/12
Principle Investigator Phil Bradshaw

CITP works in collaboration with the following Government Agencies:

National Environment Service (NES)
Ministry of Marine Resources (MMR)
Ministry of Education (MoE)

CITP would like to thank its supporters including:

Idea Wild, Panasonic (New Zealand), Uniden, CITC, the Secretariat for the Pacific Regional Environment Programme (SPREP), Pacific Divers and the Island Communities of Palmerston, Mauke, Atiu and Aitutaki.

The work of the Cook Islands Turtle Project would not have been possible without the tenacious dedication of Jessica Cramp.

All photographs taken by Phil Bradshaw unless otherwise stated.

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Introduction

The Cook Islands Turtle Project (CITP) is a venture of the Pacific Islands Conservation Initiative (PICI) and was established in 2009. PICI is a registered charitable trust with the goal of preserving species, habitats and communities in the tropical Pacific through science, education and advocacy. In keeping with this mission, the Cook Islands Turtle Project conducts research on marine turtles in the Cook Islands by assessing their current distribution, abundance and population status, and promotes their conservation through education and community outreach initiatives.

The Cook Islands consist of 15 atolls and islands spread over some 2 million square kilometers of the Pacific Ocean (refer to Figures 1 & 2). Due to the lack of contemporary data concerning marine turtle populations in the Cook Islands (Maisson *et. al.* 2010; White 2011; 2012a), their status in this area is listed as data-deficient by the IUCN. While the globally endangered green *Chelonia mydas* and critically endangered hawksbill turtles *Eretmochelys imbricata* (www.iucnredlist.org) are known to be present in Cook Islands territorial waters (White 2011; 2012a), little is known about their abundance and population structure, as well as the way they use the available coral reef and beach habitats. The Cook Islands Turtle Project aims at investigating these research questions as well as promoting conservation on the precautionary principle until their population trends can be established.

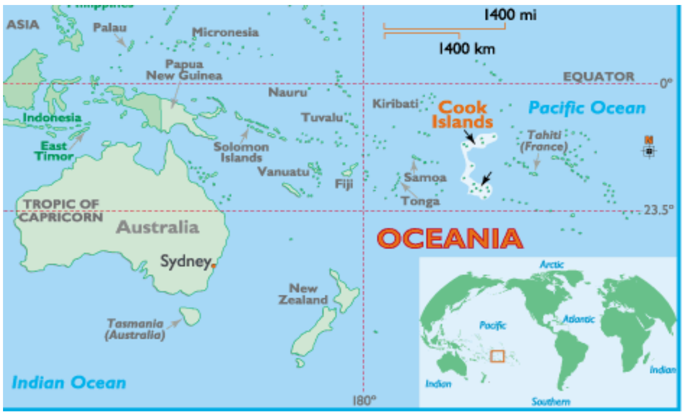

Figure 1 map of Oceania showing the location of the Cook Islands taken from: http://www.worldatlas.com/webimage/countrys/oceania/ck.htm

Figure 2 map of the Cook Islands taken from: https://www.cia.gov/library/publications/the-world-factbook/maps/maptemplate_cw.html

Over the past three years, CITP (under the leadership of Dr Michael White) has conducted surveys on Rarotonga and Penrhyn (Tongareva) and has briefly visited all of the northern group islands (White 2011; 2012a).

In 2012, CITP increased its capacity with a new Science Officer Phil Bradshaw, a Conservation Biologist with twelve years of experience working with marine turtles. Upon Phil's arrival he accompanied Dr White and PICI's Programme Manager Jessica Cramp as part of a seven person research team to the Palmerston Atoll for a four week expedition (White 2012b). Upon completion of this expedition (May 2012) Phil Bradshaw became CITP's Science Officer and Project Manager when Dr White departed CITP to pursue independent research. PICI and CITP would like to thank Dr White for all his hard work and insightfulness in initiating turtle monitoring within the Cook Islands.

Since May 2012, CITP has conducted three expeditions to islands within the southern group of the Cooks; Mauke, Aitutaki and Atiu and has greatly expanded its capacity to conduct expeditions and its outputs through the inclusion of international volunteers and research assistants.

In addition to conducting these expeditions, CITP has conducted marine surveys on Rarotonga, designed a 'Sea Turtle Biology and Conservation Issues' module in collaboration with the Ministry of Education and constructed a Scientific Protocol for Turtle Monitoring in the Cook Islands.

Expedition Objectives

In order to assess the distribution, abundance and population status of marine turtles in the Cooks, CITP leads expeditions to outer-islands to complete the following research objectives. In addition, CITP also conducts various community outreach initiatives, including teaching in schools and involving the community in our survey work and aims to establish local monitoring teams on all outer-islands.

1. **Assess beaches for suitable nesting habitat:**
   - Categorise beaches to target future monitoring
2. **Record nesting activity and measure reproductive success:**
   - Quantify the extent and distribution of nesting
   - Determine the nesting species
   - Monitor incubating nests and record inundation, predation or poaching events
   - Excavate hatched nests to record hatching and emergence success
3. **Conduct night surveys:**
   - Tag nesting females and collect genetic-samples and morphometric data
4. **Conduct marine surveys:**
   - Assess which species of turtle and at which life-stages are present
   - Quantify relative turtle abundance
   - Identify foraging preferences and habitat use
5. **Gather Local Knowledge and anecdotal evidence**
   - Species regularly seen
   - Past nesting abundance
   - Traditional practices involving sea turtles
   - Turtles as a local resource
6. **Identify and quantify threats to sea turtles and their habitats:**
   - Nesting beach impacts - development, artificial lighting and tourist activities
   - Predation (e.g. feral pigs)
   - Marine impacts (e.g. pollution and fisheries bycatch)
   - Quantify mortality
     - the level of traditional take of turtles and their eggs
     - major factors attributing to mortality
7. **Capacity building and training:**
   - Train local and international volunteers in all aspects of sea turtle monitoring and data recording
   - Form local monitoring teams to sustain monitoring

8. Raise awareness concerning marine turtles and related conservation issues:

- Give presentations to the community concerning the project and marine turtles to encourage participation
- Conduct school lectures on sea turtle biology, life history and conservation issues
- Conduct field excursions for school students to observe turtle nest excavations and conduct beach cleaning activities

Aitutaki

November 15th 2012– March 22nd 2013

Project Overview

During the 2012 – 2013 nesting season, the Cook Islands Turtle Project (CITP) conducted two expeditions to Aitutaki. The first expedition ran from November 15th 2012 until January 31st 2013 (eleven weeks) and consisted of a four person research team led by the CITP Science Officer Phil Bradshaw. The second expedition ran from February 28th until March 22nd 2013 (three weeks) and the team consisted of the Science Officer and a research assistant. All of the work was carried out with support from MMR's Aitutaki Marine Research Station, local businesses and individuals.

The research team conducted beach and marine surveys to assess the current distribution, abundance and population status of marine turtles on the island. With no data available in which to compare past abundance; local knowledge was gathered to identify threats, infer population trends and assess the turtle's population viability.

Suitable nesting habitat was found on several of the motu and on the north of the main island. Only six nests were laid during the expedition period, all of which were on the beach running parallel with the airport on the Ootu Peninsular. These six nests and three old nests were excavated to assess their hatching success which averaged 86.5%. In total six hundred hatchlings emerged from the newly laid nests. Evidence of older nests was found from previous years on some motu as well as evidence of nests laid outside of the proposed nesting season (November – February).

The team had one hundred and five turtle encounters with both green and hawksbill turtles in the marine environment. Both species of turtle were confirmed as being present in the lagoon and on the outer-reef, although the green turtle in much higher abundance. It is thought that turtles are more abundant now than fifteen years ago and that they now face fewer threats.

Extensive conservation education was conducted in all four schools with presentations given on marine turtle biology, life history and conservation issues; whale biology and behaviour and coral reefs. All of the schools also took part in a CITP field trip, assisted by the Aitutaki Conservation Trust, to observe turtle nest excavations and to conduct beach cleaning activities.

The initial expedition concluded with a presentation for the community to convey the results of our surveys and to encourage discourse about the future of the project.

The project was very successful in achieving its objectives and will sustain monitoring and conduct community outreach initiatives over future seasons.

Personnel and Funding

The Aitutaki expedition was run by a team of international volunteers led by CITP Science Officer Phil Bradshaw. The research team consisted of individuals from six countries (Australia, New Zealand, United States of America, Switzerland, England and Germany) who come from a variety of backgrounds. Volunteers stayed for between two and eight weeks and paid a small weekly donation which directly funded the expedition's costs. During their stay, volunteers participated in survey work, environmental education and community outreach activities. Thanks to the hard work of the volunteers, CITP was able to conduct the first conclusive assessment of sea turtles on Aitutaki.

The project had tremendous local support from businesses, tour operators and individuals on Aitutaki who assisted the research team to access survey areas and conduct marine surveys. CITP would like to thank all of the individuals and businesses for their support in making this expedition such a success.

Study Area

Aitutaki [S18˚52'; W159˚47', refer to Figures 2 & 3] is situated in the southern group of the Cook Islands and has a population of about 2000 people. It is the second most visited island in the Cooks and derives a large portion of its revenue from the tourist industry. Aitutaki is an 'almost atoll' as there remains a single hill known as *Maunga Pu* with a maximum elevation of 119 metres (Stoddart & Gibbs 1975). Aitutaki has a land area covering 18.05 km^2, of which 16.8km^2 is occupied by the main volcanic island (refer to Figure 4). The Ootu Peninsula protrudes east from the main island in a southerly direction before breaking into a series of smaller motu along the eastern rim of the reef. All of the motu and the Ootu Peninsula are coral formations with the exception of Rapota and Moturakau which are of volcanic origin. The barrier reef is roughly the shape of an equilateral triangle with sides 12 km in length surrounding a beautiful turquoise lagoon which covers approximately 50 km^2 (Stoddart & Gibbs 1975).

A previous attempt was made by Dr Michael White (former Chief Scientist of CITP) to survey Aitutaki in 2010; however the survey work was severely disrupted when Cyclone Pat devastated the island (White 2011). Therefore, CITP conducted this expedition to complete our research objectives and conservation-based community outreach activities.

Figure 3 Aitutaki (photo by Air Rarotonga)

Beach Surveys

The team contributed 240 hours of survey effort[1] conducting nesting beach surveys. The surveys consisted of assessing the beaches in terms of suitable nesting habitat, recording nesting activity, monitoring nests during incubation and conducting nest excavations.

A rental car provided transport to survey locations on the main island. A variety of different methods were used to access the sixteen motu situated around the perimeter of the lagoon (refer to Figure 4):

- Akitua was accessed by a small ferry boat from the Ootu Peninsular
- Angarei, Ee, Mangere, Papau, Tavaeruaiti, Tavaeura and the northern beach of Akaiami were accessed by kayaking from Akitua
- The Vaka Cruise provided transport for researchers and kayaks to Akaiami, Moturakau and Tapuaetai. This allowed the team to then kayak to the other motu in the south-east section of the lagoon (Muritapua, Motukitiu, Rapota and the sand banks to the south and west of Tapuaetai)
- Bishop's Cruises provided transport to Akaiami, Moturakau, Tekopua and Tapuaetai
- Aitutaki Adventures provided transport to Honeymoon and Maina.

All beaches were then patrolled on foot.

[1] The number of surveyors multiplied by survey time

Assessing Beaches for Suitable Nesting Habitat

Methodology

For comprehensive methodology refer to the Cook Islands Scientific Protocol for Turtle Monitoring.

All shorelines were assessed for their suitability as nesting habitat using the following characteristics and categories:

Characteristic	Category
• Substrata type	- sand, kirikiri[2] mud or rock
• Level of beach incline	- shallow, moderate or steep
• The extent of nesting habitat above high-water level	- estimated in metres
• Where the beach is accessed from	- the lagoon or outer-reef
• Obstructions to beach access	- no obstruction, rocks or raised makatea
• Vegetation or beach surround	- mixed forest, coconut, ngangie [3] (mangrove), low bush, makatea or man-made structure

Dependent upon several of these characteristics; the shoreline is grouped into one of three categories of nesting suitability after White (2012a). These were as follows:

Type A – Confirmed nesting; evidence of nesting found
Type B – Characteristics suitable for nesting but no nesting confirmed
Type C – Unsuitable; these may include some areas which at times could support some nesting; however their general characteristics render this unlikely.

Sections were delineated upon a decisive change in habitat type; at these points GPS (Global Positioning System, Garmin GPSmap 78 www.garmin.com) coordinates were recorded. For each section, characteristics were noted (in the above mentioned categories); representative photographs taken and the suitability category assigned (refer to Appendix 1).

This data was then used to construct a nesting suitability map (refer to Figure 4) and target future monitoring efforts.

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[2] Coral fragments
[3] *Pemphis acidula* locally known as ngangie raupunupunu and *Suriana maritima* locally known as ngangie moe

Summary of Results

For full results on the habitat suitability assessment, refer to Appendix 1

The only suitable nesting habitat on the main island ran from Amuri (on the west coast) north past Base One and then along the beach running parallel to the airport on the north-eastern side of the Ootu Peninsular (refer to Figure 4). The stretch of beach from Amuri to Base One constituted a mix of Type B and Type C habitat with the most favourable nesting habitat in front of the resorts where the beaches have been modified through the removal of vegetation and kirikiri.

The beach from Base One to the east-end of the airport runway is classified as Type A nesting habitat and supported all nests laid during this expedition. A majority of this beach has a wall of makatea running along the water's edge preventing beach access to nesting turtles; this confines nesting to short strips of beach where the makatea is absent.

<u>Akitua</u>, the home of the Aitutaki Lagoon Resort and Spa had visually suitable beaches for most of its surround. However, these beaches are heavily modified which can alter sand morphology causing inadequate nest construction or incubation conditions. Nesting is not known to occur on Akitua; however it remains classified as Type B and should be monitored.

The northern three motu (<u>Angarei, Ee, and Mangere</u>) do not offer suitable nesting habitat with the exception of the southern end of Ee's western beach.

<u>Papau, Tavaeruaiti, Tavaerua</u> and <u>Muritapua</u> offered suitable nesting habitat in the form of short sandy spits on their northern and southern shores. There is also a passage just north of Papau providing easy access for turtles from the outer-reef. An old nest (PA01) was found on the eastern beach; a beach which did not conform to the normal characteristics of a suitable nesting beach (refer to Appendix 1).

<u>Akaiami</u> had several suitable beaches including; the northern beach where evidence of previous nesting was found; the eastern beach which continued on from the northern beach after a short stretch of raised makatea; the southern half of the western beach, where the accommodations are situated and a small beach on the southern shore.

<u>Muritapua</u> had suitable nesting habitat on the sandy spits located on its northern and southern shores.

Tekopua had suitable nesting beaches along its eastern shore and a short stretch of beach on the southernmost point of its western shore.

Tapuaetai provided good nesting habitat on its northern and southern beaches as well as two small sandy motu (or sand bars) situated to its south and to its west.

Motukitiu had suitable beaches along its western shore, although nests would be shaded by overhanging trees and two small beaches on its north-eastern and south-eastern shores.

Moturakau had small but suitable nesting beaches on its northern and southern shore.

Rapota had no suitable beaches for nesting.

Honeymoon has a large expanse of wide sandy beach with evidence of nesting found on its southern shore.

Maina had suitable nesting beaches everywhere except for its eastern shore.

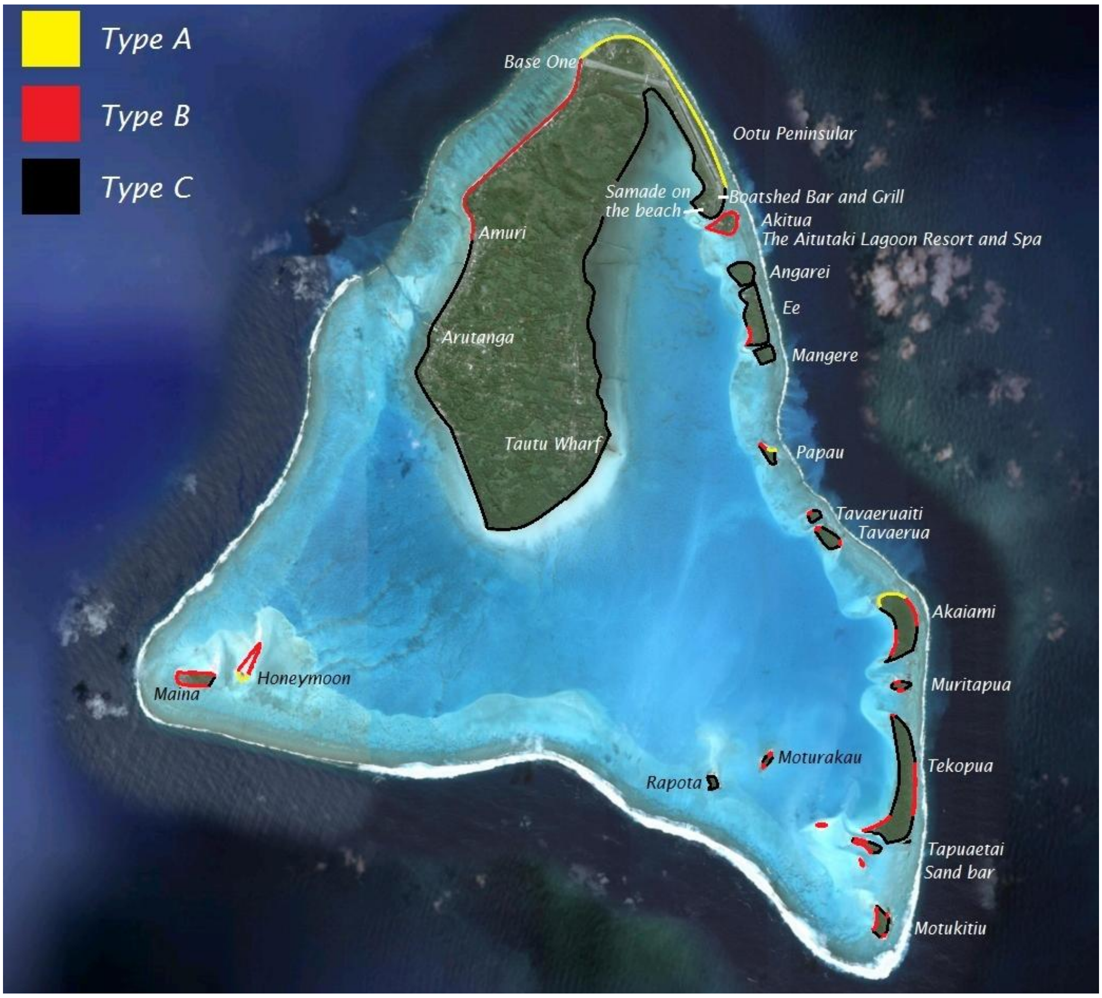

Figure 4 map of Aitutaki showing the distribution of suitable nesting habitat

Nesting Activity

Nesting beach surveys are the most widely implemented monitoring tool applied by the global sea turtle community and are an important component of a comprehensive monitoring programme to assess and monitor the status of sea turtle populations (Schroeder & Murphy 1999).

Methodology

For comprehensive methodology refer to the Cook Islands Scientific Protocol for Turtle Monitoring.

Nesting activity surveys were conducted on all Type A and Type B beaches as often as logistics and weather conditions allowed. The beach (running parallel with the airport on the Ootu Peninsular) which supported current nesting was patrolled every three days.

All tracks were recorded with nesting attempts listed and nests confirmed by locating the top egg. Track age was estimated and track locations were recorded by GPS; waypoints were taken for nests. All nests were mapped by triangulation to markers along the back of the beach and the distance to sea was measured. A stone with the nest-code and date was placed one metre behind the nest to facilitate monitoring during the incubation period and to identify the hatched nest. Any event which may affect embryonic development was recorded.

When old nests and nesting attempts were found (made previous to the study period); a rough estimate of their age was made. If the nest was thought to be less than a year old, then a nest excavation was attempted (refer to Reproductive Success). These older nests were recorded separately to the nests laid during the survey period.

Results

During the initial eleven week survey period, 8 tracks were found with a total of twenty nine attempts and six nests (refer to Table 1, Appendix 2). No tracks were recorded during the second survey period. All tracks were made by green turtles; which was confirmed during nest excavations. Two tracks did not result in successful nests; one was a false emergence with no attempts to nest and the other comprised of eight attempts and extended for approximately one hundred metres along the back of the beach; both tracks were made on the same night. All tracks were within a few hundred metres of each other along the beach running parallel to the airport on the north-eastern shore of the Ootu Peninsular (refer to Figure 4). The number of attempts to nest ratio (3.6:1) conveys the difficulty in nest construction on this beach which has a lot of large kirikiri layering the beach.

Thirteen old nests were found from previous years or from earlier in 2012. One old nest was laid on Papau, eleven nests were on the northern beach of Akaiami (as well as several nesting attempts) and one nest was laid on Honeymoon. Whilst nests laid on Papau and Akaiami were considered to be at least one year old, the nest on Honeymoon would have been laid around August 2012 (estimated from the nest excavation and the visible nest features). This nest supported anecdotal evidence concerning track or nest sightings on Maina (an adjacent motu in close proximity to Honeymoon, refer to Figure 4) in August or September ('Captain Fantastic' Kia Orana Cruises *pers.com.* 2012); green turtles lay multiple nests in a season on the same beach or beaches in close proximity. This would suggest that there may be a low level of annual nesting activity on Aitutaki as opposed to a clearly defined nesting season.

All evidence of nesting was located on the reef-side of motu or the main island with the only exception on the northern beach of Akaiami (AK01); a nest was laid on the northern tip of the motu which could have been accessed from the lagoon or the outer-reef. The lack of nesting on the lagoon side of motu suggests that turtles do not use the lagoon as an inter-nesting habitat and that breeding turtles access the nesting areas by coming over the fringing reef or via the numerous small passages.

All nests were routinely monitored (every three days) during the expeditions and several nests were recorded as washed[4] by large waves on the 11th of December (ON01, ON02 and ON03) and the 26th of January during Cyclone Gary (ON02, ON03 and ON05). There was no evidence that these events had any detrimental impact on the nests (see Reproductive Success) except for large pieces of kirikiri being deposited directly on the egg chamber of nest ON01, these were removed.

The incubation duration was recorded for three of the nests (CITP was conducting surveys on Atiu when three of the nests hatched) with an average of 59 days (range = 55 – 66 days).

Reproductive Success

Methodology

For comprehensive methodology refer to the Cook Islands Scientific Protocol for Turtle Monitoring.

All excavations were conducted using standard excavation techniques and the contents evaluated by the Marine Turtle Specialist Group guidelines (Miller 1999).

Live hatchlings were reburied in twenty to thirty centimetres of damp sand ten metres from the sea and allowed to emerge in their own time. Hatchlings which were too active to be reburied were allowed to go to sea.

[4] Waves wash over nests but the nests do not remain inundated

Results

Nine nests were excavated, three old nests laid before the survey period (PA01 on Papau, AK01 on the northern beach of Akaiami and HM01 on Honeymoon) and six nests laid during the survey period (refer to Tables 2 & 3, Appendix 2).

The mean clutch size for all nests was 98.6 eggs (SD± 14.24, range = 74 – 125, n = 9) with a hatching success of 86.5% (range = 24.2% – 96.6%, n = 9) and an emergence success of 84.1% (range = 24.2% – 96.6%, n = 9). However, the overall hatching and emergence success was considerably reduced by the nest laid on Papau (PA01, refer to Table 3, Appendix 2) which had a hatching and emergence success of 24.2%; with this nest discounted we maintain a 94.2% hatching success (range = 90.5% – 96.6%, n = 8) and an emergence success of 92.0% (range = 80.4% - 96.6%, n = 8).

The mean distance that nests were laid from the sea was 26.2 metres (SD± 11.5, range = 6.2 – 47.1, n = 9). The mean depth of the top egg was 31.6 cm (SD± 8.4, range = 20 – 48, n = 9) and the mean depth to the bottom of the egg chamber was 48.6 cm (SD± 9.1, range = 38 – 70, n = 9).

From the six nests laid during the survey period, a total of 634 eggs were laid of which 609 hatchlings were produced. At the time of excavation, 578 hatchlings had successfully left the nest, seven died whilst 'pipped'[5] and two had died in the egg chamber trapped by roots or stones. Three hatchlings were found alive and 'pipped' and nineteen hatchlings were found alive but trapped within the nest.

Ten of the twenty two hatchlings found alive were from one nest and were released during the excavation as they were too energetic to be reburied; all of the other live hatchlings were reburied. The team checked on reburied hatchlings the following day and found all hatchlings had gone to sea.

Therefore 600 hatchlings emerging from the six nests laid during the survey period

The remaining twenty five undeveloped eggs were opened to examine the reason for embryonic failure. Four eggs were found to have dead embryos inside (one early stage[6] and three late stage[7]) and twenty one eggs were identified as unfertilised as there was no visual sign of embryonic development.

[5] A pipped hatchling is when the hatchling first breaks out of it's shell and sits inside the shell with its head and flippers outside of the shell

[6] An early stage embryo is identified when the embryo is smaller than its yolk sac

[7] A late stage embryo is identified when the embryo is larger than its yolk sac or when the hatchling is full term but un-hatched.

Night Surveys - Tagging and genetic-Sampling

No turtles were tagged or genetically-sampled due to the very low number of nesting females. Two night surveys were conducted to target the re-nesting emergence of females; however, no turtles were encountered.

Marine Surveys

Marine surveys were conducted to asses which species of turtle were present and at which life-stages; to assess their relative abundance and population structure, identify their foraging preferences and their use of the available habitat.

Methodology

For comprehensive methodology refer to the Cook Islands Scientific Protocol for Turtle Monitoring.

Two methods of marine surveys were conducted on Aitutaki due to the poor visibility (< 2 metres) in the northern half of the lagoon (from Akaiami north). In lagoon areas where the visibility was poor, kayak based surveys were used. In areas where visibility was better (> 5 metres) snorkel surveys were conducted; these were generally restricted to the shallow areas in-between the motu (eastern side), between the main island and the fringing reef (west side) or around the southern motu (Moturakau, Rapota, Honeymoon and Maina).

All marine surveys in the lagoon, regardless of type, were conducted for one hour. The location of surveys were recorded by GPS with the weather conditions and visibility assessed (spotting distance for kayak-based surveys, underwater visibility for snorkel surveys). We recorded average depth and habitat type; frequency of bommies was assessed using the DAFOR[8] scale.

Two marine surveys were conducted on the outer-reef where the team free-dived with snorkel equipment. These two surveys were conducted for 40 minutes to conform to the dive schedule of the boat operator (Onu Hewitt - Bubbles Below).

Marine surveys targeted areas identified as being 'good for turtles' and where logistics dictated (where we could kayak or swim from, taking into consideration wind speed and

[8] The DAFOR scale is an ordinal scale using the following categories: Dominant, Abundant, Frequent, Occasional or Rare

direction). Only a limited number of marine surveys were conducted in the southern half of the lagoon as this was logistically challenging to survey and not thought to host a high abundance of turtles (see Gathering Local Knowledge).

Kayak-based Surveys

Methodology

For comprehensive methodology refer to the Cook Islands Scientific Protocol for Turtle Monitoring.

The research team spread out in a line perpendicular to the wind and allowed the kayaks to drift. Turtles were recorded as they came up to breathe or whilst on the water's surface. The researchers recorded the turtle species, behaviour, and estimated the size-class of the animal based on TREDS (Turtle Research and Monitoring Database: http://www.sprep.org/treds/TREDSnews.aspx). Gender could not be determined as tail morphology was not observed. The 'time spent on surface' and 'the number of breaths taken' were recorded to evaluate activity levels which will be used as part of a multiannual dataset to determine habitat use.

Researchers used the time-frame and location of surfacing events to distinguish between turtle sightings; if two turtles sighted were the same or different. Only turtles which surfaced within a short space of time in a similar location were recorded as the same. If there was any doubt, then turtles were recorded as different animals.

Results

The researchers spent fifty three hours (survey effort) conducting twenty one kayak-based surveys; these were mainly targeted on the eastern side of the main island (refer to Figure 5). During these surveys, a total of seventy five turtle encounters occurred; an average of 1.5 turtles (SD± 1.9, n = 21) per unit effort[9].

[9] Number of turtles observed divided by the number of surveyorson each survey

Figure 5 shows the areas covered by kayak-based surveys

Turtles were more commonly encountered in areas where bommies were 'Frequent' (median = 2.5, interquartile range = 1 - 3.1, range = 0 - 4.5, n= 7, refer to Figure 6) or 'Occasional' (median = 1.3, interquartile range = 0.8 - 2.6, range = 0 – 7, n=8; refer to Figure 6) as opposed to 'Rare' (median = 0, interquartile range = 0 - 0.3, range = 0 - 0.5, n=5, refer to Figure 6) although this was not significant (Fishers Exact Test, p= 0.9). Only one survey was conducted where bommies were considered 'Abundant' and no turtles were observed; however, this survey was conducted between Akitua and the main island where the substrate was muddy, the water shallow (less than one metre deep) and the bommies were heavily covered in algae (refer to Figure 5, survey #A26).

All encounters were with green turtles except for three occasions where turtle species could not be accurately identified; one of which was thought to have been a hawksbill.

In addition to turtles sighted during marine surveys, twenty one turtle encounters occurred whilst researchers moved (by boat or kayak) in-between survey areas. A majority of these sightings were in

Area ‘A’ (refer to Figure 18); however this was also the area of the lagoon which was most frequently traversed.

All turtles encountered from marine surveys and casual sightings were used in analysing population structure (size-class) and behaviour.

Turtles were recorded in all size-classes with juveniles (n=38) being most commonly encountered, then sub-adults (n=28) and adults (n=21); researchers could not ascertain the size-class of nine individuals as they were observed from a distance (refer to Figure 7).

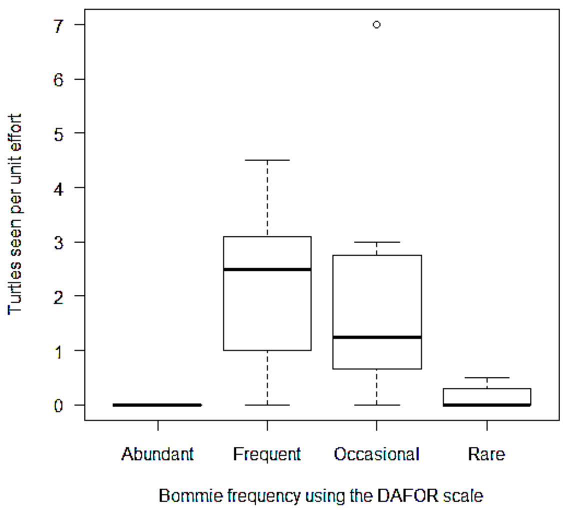

Figure 6 shows the number of turtles observed (per unit effort) during marine surveys in relation to the density of bommies. Abundant (no turtles observed, n=1), Frequent (median = 2.5, interquartile range = 1 – 3, range = 0 - 4.5, n = 7), Occasional (median = 1.3, interquartile range = 0.8 - 2.6, range = 0 – 7, n = 8) and Rare (median = 0, interquartile range = 0 - 0.3, range = 0 - 0.5, n = 5).

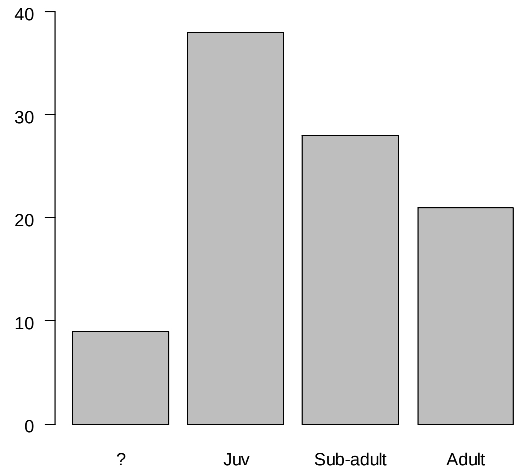

Figure 7 shows the size-class of turtles encountered from kayaks/boats (Juveniles = 38, Sub-adults =28, adults =21; unknown = 9; n = 96).

Turtles were usually observed on the surface as they came up to breathe, whilst basking[10] or swimming on the surface (refer to Figure 8).

[10] Turtles which remained stationary on the surface for more than 30 seconds were recorded as basking

On three occasions turtles were observed on the surface in what could be termed as 'social behaviour'; two turtles within a couple of metres of each other and facing each other - The density of turtles in the lagoon is not high enough to necessitate turtles being in close proximity to each other, especially during the short time in which they are at the surface.

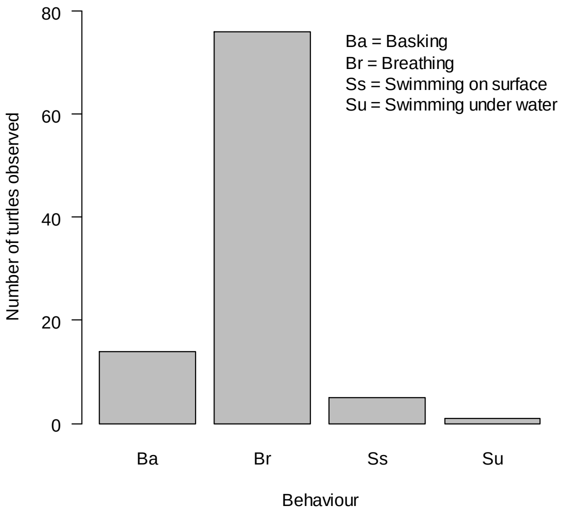

Figure 8 the behaviour of turtles encountered (n = 96)

Snorkel Surveys

Methodology

For comprehensive methodology refer to the Cook Islands Scientific Protocol for Turtle Monitoring.

Survey areas were defined and specific areas were designated before researchers entered the water. Surveys were conducted by researcher's free swimming and looking in, around and under bommies. When turtles were spotted, the researchers recorded the species, gender, size-class, behaviour and habitat. Gender was assigned based on tail morphology of adult turtles (Casale *et. al.* 2005).

Results

The researchers spent sixty seven and a half hours (survey effort) conducting twenty eight snorkel surveys (refer to Figure 9) in which nine turtle encounters occurred, an average of 0.2 (SD± 0.4, n= 28) per unit effort.

Snorkel surveys were generally limited to the peripheral edge of the lagoon (refer to Figure 9), due to poor visibility, in shallow water less than 2 metres deep (refer to Figure 10). The two surveys classified as being more than four metres deep were conducted on the outer-reef (surveys # A3 & A4, refer to Figure 9). All snorkel surveys were conducted with fifteen metres or less of visibility which severely restricted the chances of encountering turtles (0 - 5 metres, n = 10; 5 - 10 metres, n = 12; 10 - 15 metres, n= 6). Visibility in areas considered to host high turtle abundances (Turtle Hole and Area 'A', refer to Figure 18) was less than two metres and were not surveyed by snorkel; therefore, we did not expect a high encounter rate of turtles during snorkel surveys.

Figure 9 shows areas covered by snorkel surveys

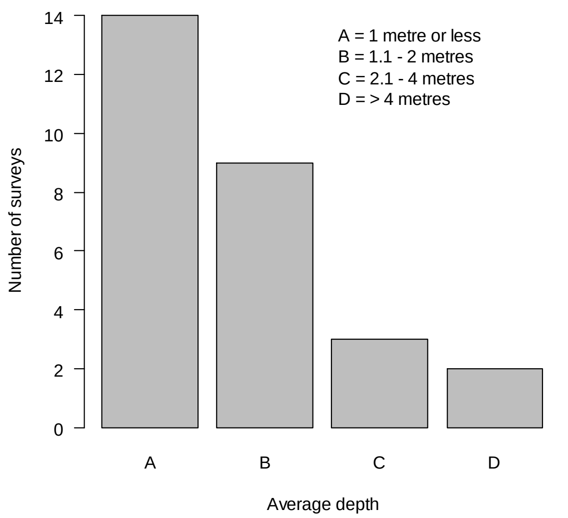

Figure 10 average depth of water during snorkel surveys

All turtles encountered were green turtles with the exception of a single hawksbill encountered to the west of the main island (refer to Figure 9, survey # A28 & Figure 12). It is indicated that turtles were encountered significantly more (Fishers Exact Test; $p = 0.009$) where bommies were 'Frequent' (median = 0.25, interquartile range = 0 - 0.5, range = 0 - 0.5, n= 5; refer to Figure 11) as opposed to any of the other bommie density classes. However, due to the very low sample number (n = 9); no conclusions should be drawn from this.

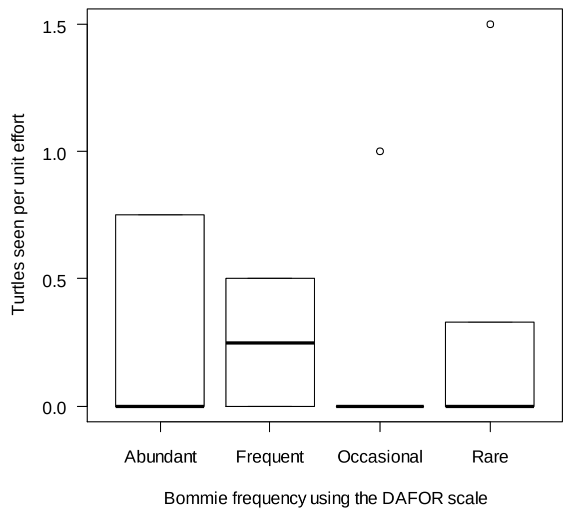

Figure 11 the number of turtles encountered (per unit effort) during snorkel surveys in relation to the density of bommies. Abundant (median = 0, interquartile range = 0-0.56, range = 0-0.75, n=6) Frequent (median = 0.25, interquartile range = 0 – 0.5, range = 0 – 0.5, n = 5) Occasional (median = 0, interquartile range = 0 – 0, range = 0 – 1, n = 12) and Rare (median = 0, interquartile range = 0 – 1, n = 5).

Figure 12 hawksbill turtle identified during snorkel survey #A28 (refer to Figure 9)

With the exception of an adult male and a sub-adult green turtle observed on the outer-reef, all turtles encountered were juveniles (refer to Figure 13); therefore genders could not be determined.

Five turtles were encountered whilst 'Swimming underwater' including the two turtles on the outer-reef; one juvenile was seen 'Foraging' on the southern point of Moturakau; one juvenile green was observed 'Basking' and one was 'Resting' on the sandy bottom north of the clam reserve. The hawksbill was observed 'Resting' under a bommie in one metre of water (refer to Figure 14).

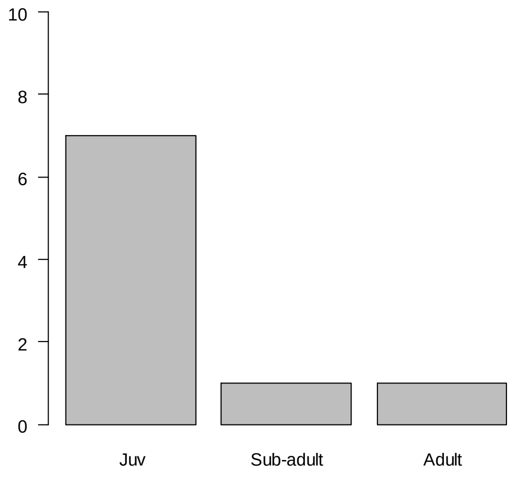

Figure 13 the size-class of turtles encountered during snorkel surveys (n = 9).

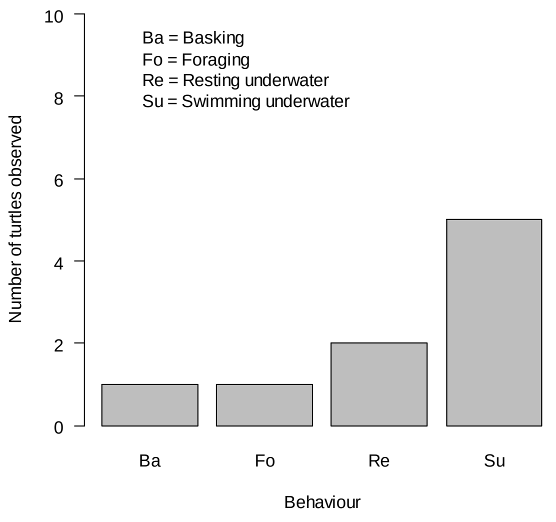

Figure 14 behaviour of turtles encountered during snorkel surveys (n=9)

Identifying Foraging Areas and Habitat Use

Four foraging areas within the lagoon were suggested to the research team; Area ‘A’ (Itu Davey *pers. com.* 2012, Varu John *pers. com.* 2013 & Jubilee *pers. com.* 2013, refer to Figure 18), Turtle Hole (Puna ‘Aitutaki Adventures’ *pers. com.* 2012 & Richard Storey *pers.com.* 2013, refer to Figure 18), the southern point of Moturakau (Itu Davey *pers. com.* 2012, refer to Figure 18) and the sand flats south of Arutanga Passage (Varu John *pers.com.* 2013, refer to Figure 18). Turtles are known to forage on the outer-reef; however, surveying the outer-reef was beyond the scope of this expedition.

Two vegetation surveys were conducted, one on the bommies in Area ‘A’ and another on the sand flats south of Arutanga Passage. The survey in Area ‘A’ brought inconclusive results as algal coverage was high but mainly consisted of fine filamentous algae which would be difficult for turtles to graze. There were variable quantities of spiny-leaf seaweed *Turbinaria ornate* on some of the bommies (refer to Figure 15) and a small amount of sea-grapes seaweed *Caulerpa racemosa* (refer to Figure 16) but no other species were recorded in any form of abundance. The sand flats south of Arutanga Passage were found to have a high abundance of sea-grapes seaweed growing on the sandy bottom as well as on the bommies.

The only time a green turtle was observed feeding was south of Moturakau. This sample of brittle-disc seaweed *Halimeda spp.* (refer to Figure 17) was collected from where the turtle was grazing.

Turtle Hole was not surveyed due to its depth, low visibility and distance from shore. There were few bommies located in this area and the habitats purpose remains unclear.

Figure 15 Spiny-leaf seaweed known locally as Remu taratara

Figure 16 Sea-grapes seaweed known locally as Remu Kai

Figure 17 Brittle-disc seaweed known locally as Remu Kirikiri

Turtles are not known to occur in abundance around the southern lagoon north of Moturakau or near the Clam Reserve (Richard Storey *pers.com.* 2013) and these areas were not surveyed due to logistical reasons; CITP will conduct surveys in these areas next year.

Anecdotal evidence (see Gathering Local Knowledge) suggested that the sand flats south of Arutanga Passage and Area ‘A’ are used as resting habitats at night. Turtles were said to enter the lagoon from the outer-reef at dusk and can be seen resting on the sand flats. Area ‘A’ used to be a favoured area by traditional spear fishermen to hunt turtles during a full moon. Night time marine surveys will be attempted next year to verify this.

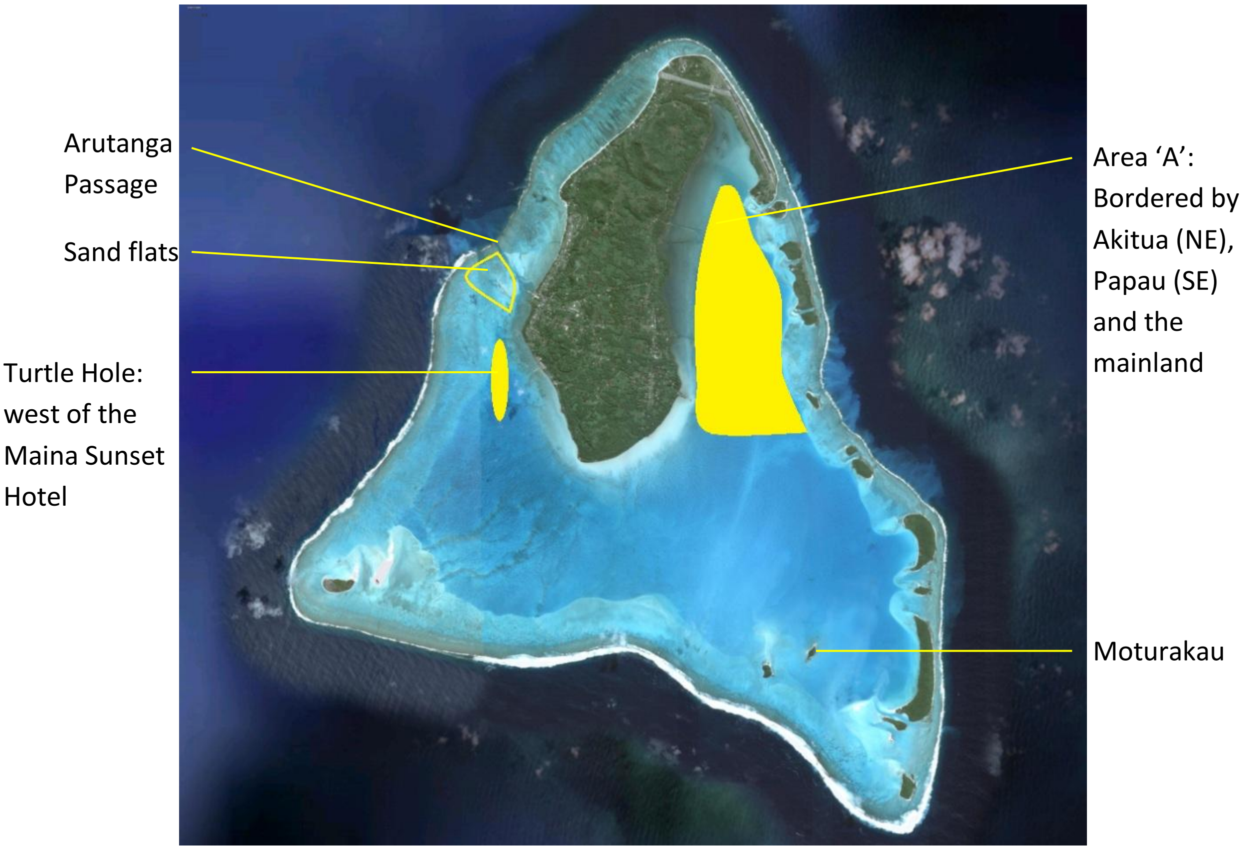

Figure 18 areas of high turtle abundance as identified by anecdotal evidence and marine surveys

Juvenile turtles were encountered in shallow lagoon areas, in water less than one metre deep. It was not determined why these turtles were here as they were only encountered whilst swimming underwater. However, they may be utilising a food source which is unobtainable to larger turtles, seeking refuge or searching for warmer waters. These shallow areas may provide a developmental habitat, but juveniles were found in a higher abundance in Area ‘A’.

The lagoon is not thought to be used as an inter-nesting habitat as no evidence of nesting was found on the lagoon-side of motu.

Gathering Local knowledge and Anecdotal Evidence

Six interviews were conducted and recorded with people on Aitutaki who were considered to have a good knowledge of the lagoon, turtles, interactions with turtles or how the community perceives turtles and conservation. All interviews were tailored to the interviewee; however a majority of the questions were the same or similar in nature. A seventh interview had previously been conducted with Mike Tavioni on Rarotonga. All interviews were recorded and Intellectual Property Rights obtained for the information to be used in this report and any future reports or papers written by the author.

Interviews were conducted with:

1. Onu Hewitt (2012): Dive operator (Bubbles Below)
2. Neil Mitchell (2012): Dive operator (Dive Aitutaki)
3. Itu Davey (2012): Bone fishing guide and former gill-net fisherman
4. Varu John & his wife Mama Vara (2013): Traditional spear fisherman & school teacher (respectively)
5. Richard Storey (2013): Senior Fisheries Officer, Aitutaki Marine Research Station
6. John Baxter (2013): Island Mayor
7. Mike Tavioni (2012): Artist and wood carver, expert on Cook Islands culture and tradition.

The interviews were extremely useful and are summarised here[11]:

[11] In the following text, references are given by the numeric value adjacent to the interviewees name

1. Which turtle species are present?

Two species of turtle are known to Aitutaki, the green turtle (1, 2, 3, 4, 5 & 6) and the hawksbill (1, 3, 4, & 5). All size-classes of green turtle are regularly observed in the lagoon (3, 4 & 5) and on the outer-reef (1, 2 & 5). Different sizes of hawksbill were not mentioned but they are less commonly encountered and usually termed as small (3 & 5).

2. Are there more turtles now than in the past?

It is universally thought that green turtle abundance has risen dramatically over the last ten to fifteen years both in the lagoon (3, 4, & 5) and on the outer-reef (1 & 2). John Baxter thought that their numbers were not be as high as when he ran a tour company twenty five years ago but he no longer spends much time on the lagoon. The abundance of turtles within the lagoon is not thought to alter seasonally (3 & 4) although their abundance is thought to change between years (5). Abundance on the outer-reef is thought to increase around November to December (1 & 2); however both dive operators state that they can 'virtually guarantee seeing turtles' at all times of year.

3. When do you typically see mating turtles?

Mating is observed on the outer-reef in early November with sometimes more than one turtle coupled together (1). Varu John spoke about mating turtles within the lagoon, typically during a full moon, but a time of year was not mentioned.

4. Where are turtles commonly seen?

Green turtles were said to occupy several areas within the lagoon namely; Area 'A' (3, refer to Figure 18), Turtle Hole (5 & Puna 'Aitutaki Adventures' *pers. com.* 2012, refer to Figure 18), the sand flats south of Arutanga Passage at night-time (1 & 4, refer to Figure 18), Moturakau where the green turtles feed (3, refer to Figure 18) and smaller turtles on the sand flats in the south of the lagoon (3). Turtles are not thought to occupy the lagoon around the Clam Reserve (5). Green turtles are encountered everywhere on the outer-reef (2 & 5) and are very common near the entrance to the main passage (1, 2 & 5).

Hawksbill turtles are known in the shallow areas in-between the motu on the east side of the lagoon (3), the area north of the golf course (5) and one was caught near Rapota (5). They are generally seen in shallow areas and are small in size (5).

5. Where do turtles nest?

Turtles are known to nest on the beach to the north-east of the airport on the Ootu Peninsular (3 & 5) and they used to nest near the hatchery at the Aitutaki Marine Research Station about five years ago (5). Turtles are also thought to nest on Honeymoon (5) and Maina (4 & Captain Fantastic 'Kia Orana Cruises' *pers. com.* 2012) and in the past on Moturakau and Rapota (3). During conversation with other Aitutakians, Honeymoon and Maina were mentioned several times as being good for turtle nesting; other motu mentioned included Papau, Tavaerua, Akaiami and Motukitiu. All nesting was considered to be by green turtles; nesting by hawksbills was never mentioned.

6. What are the main threats to marine turtles on Aitutaki?

There was a mixed response about whether turtles were still taken for food. Itu Davey, John Baxter and Varu John said that they had not heard about any turtles being taken for several years. However, if a turtle is taken, then the older community members would still enjoy eating the meat. They thought that most of the 'young ones' have not tried turtle meat and that they preferred burger and chips. Richard Storey, Onu Hewitt and Neil Mitchell thought that some turtles may still be taken, although much less than in the past, but 'you do not hear about it' as it is thought to be illegal or not widely accepted anymore.

Turtles may be targeted if an older community member makes a request but this was rare (3). Turtles may also be targeted by visitors to Aitutaki as they are easily hunted in the lagoon and are considered a delicacy (5).

It is commonly thought that the increase in turtle numbers in the lagoon and on the outer-reef is due to the fact that turtles are no longer being eaten (1, 2, 3, 4, 5 & 6) and all interviewees concurred that there is no need for people to take turtle anymore, stating "it is no longer an important food source (on Aitutaki) and that there are plenty of other sea creatures or food sources available".

Turtle eggs are not eaten on Aitutaki (3 & 4) although Varu John recollected how to find the eggs using a stick. Other interviewees did not mention about people eating turtle eggs.

Gill netting is thought to be the number one threat to turtles in the lagoon (1, 2, 3, 4, 5 & 6). If turtles are taken for food, it is thought to be through incidental capture in gill nets (1, 2 &

4) and most likely by the communities on the eastern side of the island (Vaipeka, Vaipai and Tautu) as they are more reliant on a subsistence life-style (1).

During the second expedition, it was brought to the authors' attention that two turtles had been caught in a net and brought to shore by fishermen. One turtle was alive and released the other was dead and taken for food (*pers. com.* 2013)

It is thought that most turtles which are caught within gill nets are released (3 & 5) with some turtles bought to the Aitutaki Marine Research Station for tagging (5). The level of gill netting within the lagoon is lower now than in the past and this has aided the recovery of turtle populations (3 & 5).

Onu Hewitt mentioned that the planned dredging of Arutanga Passage for the new harbour development may have severe repercussions for turtles and the coral reef outside of the Passage entrance due to the disturbance and an increased sediment load.

7. What techniques were / are used to hunt turtles on Aitutaki

Varu John and Itu Davey recollected how turtles were traditionally hunted on Aitutaki - Turtles were usually hunted during a full moon in the lagoon (Area 'A', refer to Figure 18). The turtle's shine white in the moonlight and are easily seen biting on to the bommies asleep (4) or drifting up to the surface (3). Hunters would then either throw the spear from the boat or get into the water to spear the turtle. If the turtle had a nice shell or it was large, then it would be speared through the head. If you have a very heavy spear (made from a boat engine prop) then you can throw it right through the shell (Jubilee *pers. com.* 2013). If you were using a light three pronged spear, then you would throw it through the shoulder and tie the rope to a bommie or a float. If the turtle was not required immediately, then you could spear it through the shoulder and it would remain in the local area for several weeks.

Nesting females (3, 4 & 6) and mating pairs (3 & 4) were not targeted.

Turtles were locally prepared by slitting the turtle's neck and placing an arm into the split to pull out the guts and innards. A slit was also made at the posterior end of the plastron so that the gut could be cut at the colon end. Two or three red hot stones (about 8 – 10 inches across) were then inserted in to the neck slit and the whole turtle placed into the Umu and cooked all day (4 & Jubilee *pers. com.* 2013).

If the turtle had a beautiful shell then the meat and fat would be removed and the shell preserved (4).

Some community members are said to really relish turtle meat and it was recollected that ‘one old lady would walk from Arutanga to Vaipai with her bowl to collect meat if she heard a turtle had been caught’ (Jubilee *pers.com.* 2013). Turtle meat was sometimes referred to as a ‘kings food’ (4) and it was always shared amongst the whole community; it would have been considered disrespectful to keep a turtle to oneself (3, 4 & Jubilee *pers. com.* 2013). The neck and shoulder region is said to be favoured (4) as is the black oily area where the carapace and the plastron meet (Jubilee *pers.com.* 2013).

8. Are turtles protected on Aitutaki?

Some of the interviewees thought that turtles are protected through the National Environmental Regulations for Endangered Species (5 & 6) or within local bylaws (3). Two of the interviewees (1 & 5) thought that Aitutaki should write turtle protection into local Island Regulations; the Mayor John Baxter agreed if it was thought necessary.

9. Are sea turtles culturally significant to Cook Islanders?

The turtle’s main significance to Cook Islanders is as a source of protein (1, 2, 3, 4, 5, 6 & 7), which to many in the southern group, is no longer pertinent as there is now better access to food resources.

Turtles were not considered to have a lot of cultural significance to the people of Aitutaki (1, 3, 4 & 5) but they are thought to have a higher cultural significance to islanders in the northern group (3 & 7). John Baxter thought that turtles did have some cultural significance locally and recalled a legend, which contained a turtle, about a warrior coming to one of the motu. He also spoke about symbols and dances encompassing turtles.

It was generally thought that there would be little reflection by Aitutakians if turtles were to become locally extinct.

10. Do turtles provide any other form of resource to Aitutaki besides food?

The dive operators (Bubbles Below and Dive Aitutaki) thought turtles were sort after by recreational divers and that they significantly increased a diver’s enjoyment when seen (1 &

2). However, turtles may not have any relevance to the actual number of divers as Aitutaki is off the radar to 'mad keen divers' (1). Neither operators particularly use turtles in advertising (1 & 2); however, Bubbles Below prominently features a turtle in their logo and on their hand-outs (1). Both operators feel they could guarantee seeing turtles every dive and that turtles are found in regular hangouts (1 & 2). Some turtles are regularly seen and are quite tame allowing divers to pat them; however, both dive operators prevent divers grabbing the turtles when they swim away; 'turtle rodeo' (1 & 2). Neil Mitchell didn't think that turtles added any incentive to people diving or that diver numbers would be affected if turtles became extirpated[12]; however, Onu Hewitt and John Baxter disagreed with this viewpoint saying it would affect diver numbers and satisfaction.

Onu Hewitt and John Baxter thought that tour operators would be affected if turtles were lost from the lagoon. During lagoon cruises, the Vaka Cruise and Bishop's Cruises have the tourist's 'turtle spotting' around Moturakau and Rapota – tourists are always happy to spot a turtle (*pers. obs.* 2012; 2013).

Onu Hewitt spoke about the importance of maintaining turtle populations for future generations of Cook Islanders. Onu sponsors diver training of the local youth and talked about the excitement that they show when they see a turtle.

Identifying Threats

Beach development and artificial lighting

There is little beach front development on Aitutaki. Most of the beach front resorts are built on the west coast of the main island and on the motus of Akitua and Akaiami.

Main Island:

The resorts on the west coast of the main island provide the most suitable stretches of nesting habitat between Amuri and Base One as the resorts manicure the beach. A small number of sun loungers are set out on the beach but they do not obstruct access.

A light assessment was conducted between 21:30 – 22:30 on 07/03/2013 along the west coast between the Aquila Hardware Store and Etu Moana; the area where most of the resorts are located. The beach

[12] Locally extinct

was very dark and neither street nor house lights impacted the beach. The only sources of anthropogenic lighting are from:

- The bar and pool area of Pacific Resort; this was found to cast substantial light on to the beach from flood lights and flame torches. However, a majority of this lighting was extinguished when the resort was passed for a second time at 22:30. Room lighting was not considered to be a problem
- Extremely bright floodlights shone on to the beach near the Tamanu
- Bright interior lights from one of the beach bungalows shone onto the beach; however these lights are unlikely to be on during the night

Akitua:

This motu is home to the Aitutaki Lagoon Resort and Spa. Its sandy beaches are highly modified and constructed from dredged material dug out from the swimming channels adjacent to the beaches. The dredged material is fine and silty and may not provide adequate substrata for nest construction or incubation.

A light assessment was conducted between 21:00 – 22:00 on the 12/03/13 from the Ootu Peninsular overlooking the northern shore of Akitua. Considerable lighting was observed along the western point of the motu but the eastern (reef) side remained in complete darkness.

Akaiami:

There are two modest tourist accommodations set back from the beach on the western shore. They do not accommodate a lot of tourists and few people appeared to be staying there during the expedition (nesting season).

Lagoon tours and recreational activities

The lagoon tours are not considered to be a threat to the turtles and may in fact benefit them. Tours and tourists act like observers policing detrimental activities, for example; 'islanders maybe more wary about taking turtles as tourists may see them' (Richard Storey *pers. com*. 2013).

Tours are conducted during regular hours (10am – 4pm) with tourists confined to motu which the tours visit. The boats drive at a leisurely pace which minimises the chance of accidental impacts with basking turtles and the crews make sure that no litter goes overboard.

The lagoon provides the perfect environment for recreational activities such as kite surfing and wind surfing and these activities are conducted in areas where turtles may occur. However, as neither of these activities involve either heavy equipment or a motorised propeller, any impacts with turtles are unlikely to cause a major or fatal wound.

Boats travel very fast in the lagoon, the passage and on the outer-reef. Boat strikes with turtles are potentially fatal and this turtle was photographed on the outer-reef with obvious scarring from a propeller to its carapace (refer to Figure 19).

Figure 19 a turtle with propeller scars on its carapace

Traditional take

It is thought that only a few turtles are taken for food (see Gathering Local Knowledge) and that this is no longer a major threat to turtles on Aitutaki.

Natural predators

There is little or no predation of turtles or their nests on Aitutaki. There was no evidence of turtle nests having been dug up or any animals commonly associated with nest predation found near nesting areas. Sea birds were not observed near turtle nests and the reef is very narrow where the turtles nested; therefore, hatchling survival rate maybe better than average as the survival rate of hatchlings is associated to the length of shallow reef in which the hatchlings must traverse (Booth & Evans 2011).

Marine Impacts - Gill Netting

Gill netting is thought to be the biggest threat to turtles in the lagoon (see Gathering Local Knowledge) although the level of netting has been reduced in recent years.

The existing bylaws for Aitutaki concerning gill netting (MMR & SPC 2000):

- Prevents the possession of nets more than 100 metres by 4 metres in size
- A net must not be set less-than 100 metres from another net, and one person may not set more than one net.
- If setting a net between two motus (small islands on the barrier reef), the net may not extend over more than one third of the channel width.

- In addition, the person setting the net must remain "in the vicinity" for the whole time that the net is set'

Although these bylaws restrict gill netting, it is evident that some level of netting occurs both overnight and near to the passage where high turtle abundance is reported. It is unclear whether the turtles found alive in nets are released or whether they are taken (see Gathering Local Knowledge); however, some turtles will die from drowning.

A majority of netting occurs in shallow areas, between motu on the east of the island or between the main island and the fringing reef on the west. Snorkel surveys showed that neither of these areas support a high turtle abundance; however, they may support the rarer and critically endangered hawksbill.

Fisheries Bycatch

No evidence of commercial fisheries bycatch was found.

A report was made to the author of a turtle being caught on a rod and line during a recreational fishing trip on the fringing reef – the turtle was brought on board the boat and the line cut as close to the hook as possible before the turtle was released (Tokua Pera *pers. com.* 2013).

Pollution

No evidence of pollution was observed except for rubbish which washed up along the beaches. CITP in conjunction with the Aitutaki Conservation Trust conducted a beach clean with Araura College. Charley Waters (Marine Biologist) also conducted his own beach cleaning activities (January 2013).

Stranding's / Dead Turtles

Six dead turtles, or the remains of, were discovered during the habitat suitability survey along the coast of Vaipeka to Tautu (22/10/12 – 23/10/12) on the eastern side of the main island. A sub-adult green turtle was found near the jetty in Vaipeka (refer to Figure 20), the bones of three unidentified turtles were found within a fifty metre stretch of beach and quantified by the different sized plastron bones which were grouped together (refer to Figures 21 - 23). Another two turtles were found a few hundred metres further south (refer to Figure 24&25). All of these turtles were thought to be greens but only the first turtle could be confirmed from the skull being found.

No obvious cause of death was determined for any of these animals and no conclusions were drawn, however this shoreline faces the predominant east wind and any dead animals within the north-eastern part of the lagoon would likely drift here.

A hawksbill turtle was found on the beach by the Aretai Beach Villas on the west coast of the main island (26/12/12). This was a juvenile animal and already quite decomposed; no obvious cause of death was determined (refer to Figure 26).

Due to the high abundance of dead turtles found along the Vaipeka to Tautu shoreline, this shore was surveyed again on the 7th and 8th of March 2013 to look for dead turtles which have recently washed ashore. This resulted in a dead juvenile hawksbill turtle being discovered near the jetty at Vaipeka. The turtle would have died a month or more previous to the survey and no obvious cause of death could be determined (refer to Figures 27& 28).

Several hawksbill scutes (two costal and one central) were also found scattered at various points along the coast. From the size of the scutes, we believed that these were from at least two different animals.

CITP will continue to monitor this stretch of shoreline to try and gage how many turtles are dying in the lagoon annually.

Figure 20 green turtle bones found near Vaipeka

Figure 21 plastron bones of a turtle found near Vaipai

Figure 22 plastron bones of a second turtle found near Vaipai

Figure 23 plastron bones of third turtle found near Vaipai

Figure 24 bones of a turtle found near the jetty in Vaipai

Figure 25 bones of a green turtle found near Vaipai

Figure 26 Juvenile hawksbill found near Aretai Beach Villas

Figure 27 Juvenile hawksbill found near Vaipeka

Figure 28 Juvenile Hawksbill found near Vaipeka

Discussion of CITP Survey Results

The nesting and foraging turtle populations of Aitutaki, as with other rookeries, are not the same populations. Turtles are highly migratory and travel large distances between their foraging and nesting grounds with the exception of some resident males. Therefore, we establish the population status and viability of these populations separately.

Aitutaki provides suitable nesting beaches, free from anthropogenic threats, on the north of the main island as well as on several of the motu, in particular the motu situated in the southern part of the lagoon.

Turtle nesting numbers were much lower this year than anticipated; it was previously thought that nesting numbers would reach between twenty to fifty nests annually (*pers. com.* Richard Storey 2012), spread between the motu and on the beach to the north-east of the airport. However, anecdotal evidence of nesting on Maina was supported by the nest found on Honeymoon, suggesting that nesting is not restricted to the proposed nesting season (November to March). If we infer that three or more nests[13] were laid on Honeymoon and Maina, then our annual nesting numbers would likely be nine or more.

There are few threats to nesting turtles, their eggs or the hatchlings; they are not targeted as a food source; there are few natural predators or high levels of beach development or pollution.

However, nesting numbers are still low and do not suggest long-term rookery (nesting population) viability; however, we cannot draw conclusions on annual nesting numbers from one year's data due to the turtle's highly variable remigration interval. Therefore, these results justify the critical importance of data collection to monitor this turtle rookery on an annual basis.

[13]Turtles usually lay at least three nests in a season

The foraging population of turtles which inhabit the outer-reef and the lagoon are thought to have increased in number over the past ten to fifteen years. We were unable, due to the low visibility in the lagoon, to make any turtle abundance estimates; however, we have recorded a useful Index[14] of abundance to monitor trends as part of a multi-annual dataset.

All size-classes of green turtle were frequently encountered which indicates a stable population structure. The high abundance of juveniles and sub-adults imply that there is healthy recruitment whilst the still high abundance of adult turtles imply that threats to this population have been reduced; if there were still major threats, then not many turtles would be expected to live to adult size. This suggests that the green turtle foraging population will continue to increase.

Hawksbill turtles were found to be present, and anecdotal evidence suggests adult sized hawksbills are present on the outer-reef; however, within the lagoon only a low abundance of juveniles are thought to be present, which was supported by our survey data.

Local knowledge was supported by CITP survey data suggesting that all size-classes of turtle are found in the deeper areas of the lagoon particularly around Area 'A' and Turtle Hole (refer to Figure 18); however, as few surveys were conducted in the southern half of the lagoon, we cannot compare lagoon areas to determine where the highest density of turtles occur; this will be evaluated as part of a multiyear dataset. Local knowledge suggests that Area 'A' and Turtle Hole are important foraging areas for turtles as is the southern tip of Moturakau although the main food source has yet to be determined. Three suggested food items were identified but the only food item turtles were observed eating was the brittle-disc seaweed south of Moturakau; however, this seaweed was not found in a high abundance during vegetation surveys.

The main threat to turtles in the lagoon is by incidental capture in gill-nets. Bylaws are in place which should prevent a high level of turtle mortality although their implementation is questionable due to a lack of resources. It is thought that turtles which are caught in nets and found alive maybe released; turtles which have drowned maybe taken for food. There are few threats posed to turtles in the lagoon by the present levels of tourism or from lagoon recreational activities but the speed in which some boats travel could cause injury or death to turtles. It is evident that there is some level of turtle mortality in the lagoon from the number of dead turtles found along the Vaipeka to Tautu shoreline; however, this will be quantified over future survey efforts.

Although no specific protection exists for turtles on Aitutaki, it is of common belief that they are a protected species. Few people still target them for food and there are no curios made from their parts. The Environment Service Officer Bobby Bishop brought to the attention of CITP that the Aitutaki Island Council will propose full protection for turtles within their bylaws during 2013.

[14] Number of turtles observed per unit effort

Turtles are not considered to be culturally important to Aitutakians, at least not anymore but it was evident from our work with the schools that the children were very excited to learn about turtles, see photos and videos. When the children went on the field trip with CITP to observe nest excavations and they saw their first baby turtles, it was evident how happy the children were and what a real loss it would be if turtles no longer nested on this island.

Atiu

February 14th- February 28th 2013

Project Overview

The Cook Islands Turtle Project planned a five week expedition to Atiu and the nearby uninhabited coral cay and Wildlife Sanctuary of Takutea to run from February 14th until March 28th. The research team consisted of two people; the CITP Science Officer Phil Bradshaw and a research assistant.

Prior permission was obtained from Atiu Island council to conduct CITP survey work on Atiu and permission was granted to survey Takutea from the Takutea Board of Trustees during the expedition. However, due to the coinciding turtle nesting and cyclone seasons, it proved impossible to attain transportation to Takutea because of the strong religious beliefs of the community; they do not fish or put boats in the water at this time of year. The community advised us to postpone the survey of Takutea until November or December 2013 when transportation would be available.

The research team conducted beach and marine surveys to assess the current distribution, abundance and population status of marine turtles on the island. With no data available in which to compare past abundance; local knowledge was gathered to identify threats, infer population trends and assess the turtle's population viability.

Eight beaches suitable for nesting were identified around the south coast of the island from Oneroa Landing in the east to Taungaroro Landing in the West. Only one turtle track was found, at Oneroa Landing, but no signs of nesting were visible. Anecdotal evidence suggests that there has not been any significant nesting on the island for over thirty years; however the occasional tracks are still seen.

Green turtles are known to inhabit the waters off Atiu and they are encountered near the harbour and around the south of the island, albeit in low density. Turtle abundance is thought to increase seasonally around November but no turtles were observed during the marine surveys.

The team spent a day at the school on Atiu teaching students (grades 3 – 12) about marine turtle biology, life history and conservation issues as well as whale biology, evolution and behaviour. As CITP did not find signs of nesting or any old nests which could be excavated, a school excursion was not possible.

The team departed Atiu after two weeks as there was no current nesting activity to monitor and the team could not reach Takutea; therefore CITP returned to Aitutaki to continue its monitoring efforts.

Personnel and Funding

The Atiu expedition was led by CITP Science Officer Phil Bradshaw accompanied by his research assistant Theresa Kirchner. Theresa is a German National who has a lot of experience working with humpback whales with organisations such as Duke University, NOAA (National Oceanic and

Atmospheric Administration), the University of Queensland and the Whale Centre of New England; Theresa has also worked with marine turtles in Greece.

All expedition costs were self-funding by the research team including flights and accommodation. Equipment was provided by PICI with tags and tag applicators provided by SPREP (Secretariat of the Pacific Regional Environment Programme), the camera and underwater housing was provided by Panasonic New Zealand and Uniden supplied two-way radios. CITP also won a successful grant application with Idea Wild which kindly supplied a data projector and GPS units.

Study Area

Atiu [S19˚59'; W158˚06'], also known as Enuamanu (land of the birds) lies 187 kilometres northeast of Rarotonga in the southern group of the Cook Islands (www.atiu.info). Atiu is the largest of the Ngaputoru Islands with a maximum elevation of seventy two metres (Passfield & Rongo 2011). It is a raised limestone island with makatea forests (Passfield & Rongo 2011) and surrounded by a reef encircling a shallow lagoon which is usually fifty metres or less in width (Atkinson *et. al.* 2006). Engraved into the makatea are numerous small beaches which are free from anthropogenic pressure.

The island supports a population of between four and five hundred people which live in five villages that radiate out from the centre of the island on a flat topped central plateau. Between the raised central plateau and the ring of makatea surrounding the island is a low swampy area containing fertile soils which produces crops such as taro, banana and breadfruit (www.wikipedia.org). The island is famous both for its coffee production and its reputation of being the eco-capital of the Cook Islands; a haven for naturalists and bird lovers (Atkinson *et. al.* 2006).

Twenty kilometres northwest of Atiu lies the tiny uninhabited coral cay of Takutea [S19˚48'; W158˚17'] (McCormack 1994). The island is only 1.22 km^2 (120 hectare) in size, rises to six metres above sea level and is surrounded by an unbroken reef (MMR & SPC 2000). Access is only possible in calm weather on the lee side of the island (www.atiu.info).

Takutea is the only island in the Cooks to have never hosted a permanent population and is the most important seabird breeding island in the southern Cooks (McCormack 1994; MMR & SPC 2000). Takutea was gifted to the British Crown in 1903 and was referred to as a "Wildlife Sanctuary" since that time (McCormack 1994; Passfield & Rongo 2011). Takutea was then re-established as a "Wildlife Sanctuary" in 1950 when it was gifted to the people of Atiu by the family landowners (MMR & SPC 2000) and the Aronga Mana (traditional leaders) were appointed "as trustees for all the native landowners of Atiu and their descendants" and an elected committee administers the land as the Takutea Island Trust (McCormack 1994; MMR & SPC 2000). The protected status of Takutea was further endorsed when it was declared a Community Conserved Area under the Atiu and Takutea

Environment Regulations 2008 (Passfield & Rongo 2011). Special permission needs to be obtained for visits to Takutea by the Trust Chairman, High Chief Rongomatane Ariki.

Atiu and Takutea are the first of the Cook Islands to offer marine turtles full protection under the Atiu and Takutea Environment Regulations 2008 where it states in part II (Species and Habitat Protection) section 12 that:

(1) No person shall -

- (a) Possess, disturb, kill, harm, remove or damage any living wild turtle or eggs;
- (b) Disturb any nesting areas, nest or remove any eggs from nest;
- (c) Disturb any living wild turtle in any reef area or on land;
- (d) Export from Atiu any turtle, eggs or parts thereof whether living or dead.

Beach Surveys

The team contributed sixteen and a half hours of survey effort[15] conducting beach surveys. The surveys consisted of assessing the beaches in terms of suitable nesting habitat and recording nesting activity.

A rented scooter was used to transport the team around the island's perimeter road. The team then explored every possible access to the coast. All beaches were then surveyed by foot.

Assessing Beaches for Suitable Nesting Habitat

Methodology

For comprehensive methodology refer to the Cook Islands Scientific Protocol for Turtle Monitoring.

All shorelines were assessed for their suitability as nesting habitat using the following characteristics and categories:

Characteristic	Category
• Substrata type	- sand, kirikiri[16] mud or rock
• Level of beach incline	- shallow, moderate or steep

[15] Number of survey hours multiplied by the number of surveyors
[16] Coral fragments

- The extent of nesting habitat above high-water level - estimated in metres
- Obstructions to beach access - no obstruction, rocks or raised makatea
- Vegetation or beach surround - mixed forest, Pacific Ironwood, coconut, low bush, makatea or man-made structure

Dependent upon several of these characteristics; the shoreline is grouped into one of three categories of nesting suitability after White 2012a. These were as follows:

Type A – confirmed nesting; evidence of nesting found

Type B – characteristics suitable for nesting but no nesting confirmed

Type C – Unsuitable; these may include some areas which at times could support some nesting; however their general characteristics render this unlikely.

All beaches were recorded separately and delineated into different coves if the high-water level was thought to meet the makatea cliffs. GPS (Global Positioning System, Garmin GPSmap 78 www.garmin.com) positions were taken in the middle of the beach or beach section and the width and depth of the beach estimated in metres.

The data collected was used to construct the habitat suitability map (refer to Figure 29) and target monitoring efforts.

Summary of Results

For full results on the habitat suitability assessment, refer to Appendix 3.

The team surveyed forty five coastal locations which could be accessed from the road or by short walks along the shoreline. From these locations eight beaches were identified as being able to support turtle nesting; a majority of Atiu’s shoreline consists of raised makatea cliffs. All eight beaches were located on the southern half of the island. One further beach situated between Oravaru Landing and Taungaroro Landing (S19°59.235'; W158°08.473', refer to Appendix 3) does offer suitable conditions for nest construction; however, it remains heavily shaded by Pacific ironwood and it would be unlikely for nesting activity to occur here.

The eight beaches categorised as Type B beaches were:

- Taungaroro Landing [S20°00.260'; W158°08.278', refer to Figure 29] a large eighty metre wide beach which extends up to forty metres above the high water level.

- Tumai Landing [S20°00.424'; W158°08.131', refer to Figure 29] is situated in-between Taungaroro Landing and Vai Piake. The beach is forty metres wide beach and extends up to twenty metres above the high-water level.

- Two beaches in between Te Tau Landing and Maitai Landing [S20°01.670'; W20°01.670' / S20°01.218'; W158°06.405', refer to Figure 29], each of which constitutes fifty metres of suitable habitat extending five to seven metres above the high-water level.

- The north-eastern beach at Maitai Landing [S20°01.067'; W158°03.121', refer to Figure 29] which is approximately one hundred and eighty metres long offers some of the best nesting habitat on the island.

- Takau-roa Landing [S20°00.927'; W158°05.649', refer to Figure 29] is a sixty metre wide beach which extends five metres above the high-water level.

- The south-western cove [S20°00.721'; W158°05.271', refer to Figure 29] of a long thin three cove beach situated in between Takau-roa Landing and Oneroa. The beach is approximately sixty metres wide and extends for five metres above the high-water level.

- Oneroa Landing [S20°00.033'; W158°04.990', refer to Figure 29] is the most suitable nesting beach on the island with two wide beaches; the southern beach is approximately one hundred and twenty metres and the northern beach approximately eighty metres, with both bays extending more than forty metres above the high-water level. The only evidence of turtle activity was found on the southern beach.

This constitutes to approximately 680 metres of suitable nesting habitat scattered along the southern shore of the island.

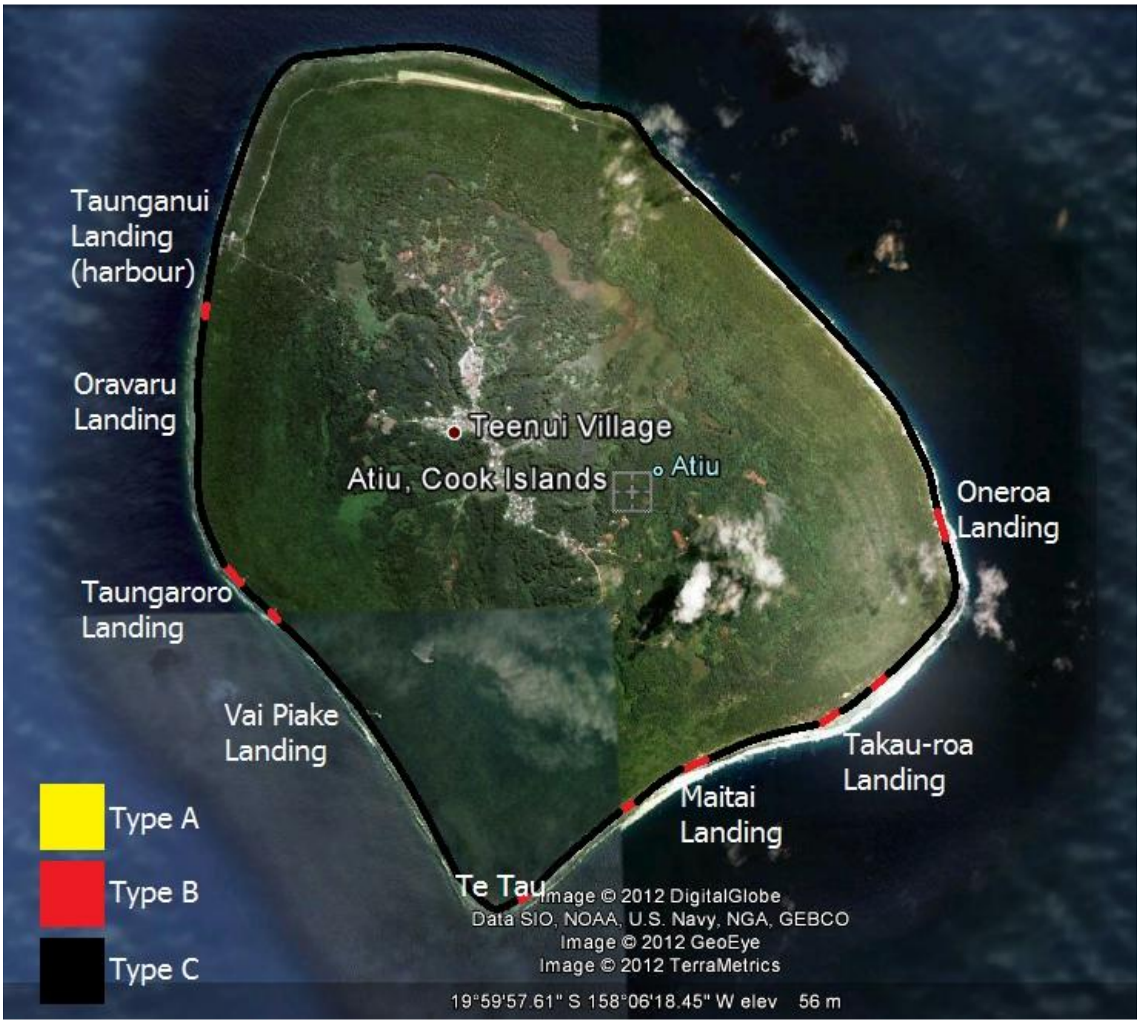

Figure 29 map of Atiu showing the distribution of suitable nesting habitat

Nesting Activity

Methodology

For comprehensive methodology refer to the Cook Islands Scientific Protocol for Turtle Monitoring.

Nesting activity surveys were conducted during the habitat suitability survey and all Type B beaches were checked every three days.

Results

Figure 30 the only evidence of turtle activity was found under an overhang at Oneroa Landing

During the two week survey period, the only evidence of nesting activity was the faint remains of an old track underneath an overhang on Oneroa Landing (refer to Figure 30); the overhang had protected the track features from the elements. No evidence of a nest was found; no signs of digging or depressions in the sand.

Therefore, current nesting cannot be confirmed.

Reproductive Success

No signs of nesting were found; therefore we cannot confirm any reproductive success this season.

Night Surveys – Tagging and DNA Sampling

Night surveys were not conducted as the research team found no evidence of current nesting.

Marine Surveys

Methodology

For comprehensive methodology refer to the Cook Islands Scientific Protocol for Turtle Monitoring.

Three marine surveys were conducted by snorkel on the outer-reef; two were conducted back-to-back totalling two hours so a larger survey area could be covered. The team entered the water from the harbour and swam out to the reef. The first two surveys (back-to-back) targeted the area south of the harbour and the third survey targeted the area north of the harbour (refer to Figure 29).

The outer-reef dropped off very sharply enabling the team to survey the whole reef area by swimming approximately fifty metres out from the fringing reef.

Results

No turtles were encountered during marine surveys.

Gathering Local knowledge and Anecdotal Evidence

Two interviews were conducted on Atiu with community members who have an interest in the natural environment. All interviews were recorded and Intellectual Property Rights were obtained for the information to be used in this report and any future reports or papers written by the author.

Interviews were conducted with:

1. 'Birdman' George Mateariki (2013): Nature walks, cave tours and Indian minor bird eradication
2. Kau Henry (2013): Environment Officer

In addition, anecdotal evidence was also collected during conversations with several members of the community. All information is summarised here[17]

1. Which species are present?

Only the green turtle is known on Atiu and Takutea (1) although nesting is not thought to have occurred on Atiu in over three decades (1 & community members' *pers. com.*2013).

[17] In the following text, references are given by the numeric value adjacent to the interviewees name

Green turtles are known to nest on Takutea every year (1 & 2).

2. Are there more turtles now than in the past?

Turtles are less abundant now on Atiu than in the past (1 & 2); the nesting population is almost obsolete (1) with just the occasional female returning to nest (2). Kau Henry said that he saw tracks on Atiu in November 2011 and a friend found a turtle in the shallow lagoon whilst crayfishing in 2012; it was thought that the turtle was returning to sea after attempting to nest.

Green turtles are still seen in the ocean surrounding Atiu (1 & 2) albeit in a much lower density than in the past. Usually medium-sized turtles are seen although large and small sizes are said to occur (1 & 2). Their numbers are thought to increase seasonally during October and November (2). Turtles are spotted around the harbour (1, 2 & community members *pers. com.*2013), an area known as 'The Cliff'; a drop-off adjacent to the shoreline (1, 2 & community members *pers. com.*2013) and around the south of the island (1).

It is unknown whether turtles are more or less abundant on Takutea as nobody goes there at this time of year (1 & 2).

3. Where do turtles nest?

Turtles were historically known to nest at Oneroa Landing (1 & 2); which was the main nesting beach, as well as Taungaroro Landing (2), Tumai Landing (2) and Maitai Landing (2). A lot of tracks are observed every year on Takutea (1 & 2), mainly along the southern coast of the island and around the western point (1 & 2). Birdman George sometimes goes to Takutea with the cruise liners, last time he went (January 2012) he saw about twenty tracks (2). George sees a lot of evidence of old nests underneath the vegetation but could not say how many nests are laid each year (1).

4. What are the main threats to marine turtles on Atiu and Takutea?

The main threat to turtles used to be from islanders taking them for their meat (1 & 2) and digging up their eggs (1). The nesting females were often found by fishermen in the early morning returning to sea across the shallow lagoon (1 & 2). The turtles would cross the reef during high-tide to come into nest and then they would be left stranded when the tide receded

(1). This is thought to be the reason why there are no turtles now - all the nesting turtles and their eggs were taken (1).

Due to new Island Regulations (2008), turtles are no longer at threat from people taking them or their eggs on Atiu and Takutea (1 & 2). No turtle has been taken for the last twenty years on Atiu (1). When a turtle is taken, the whole community would know, even if you did not tell anyone (1). Kau Henry checks boats when they come back from Takutea and has never found a turtle (2). Kau has been on Atiu radio to inform the community of the Island Regulations; telling them that they are not to catch certain animals anymore or they will be in trouble; this includes turtle (2).

Fishermen are said to still occasionally catch turtles in their nets at night-time whilst catching flying fish (2) but these animals are always released (2). There is no risk of turtles being caught in the lagoon by nets as it is too shallow, people only fish with rod or hand lines (2).

5. What techniques were / are used to hunt turtles on Atiu?

Turtles were taken from the beaches or caught in the shallow lagoon by fishermen in the early morning (1 & 2). The nests would be dug up and the eggs taken; they were considered a delicacy (1).

6. How is turtle prepared on Atiu?

There wasn’t a traditional way, the meat and intestines were all scraped out and cooked, nothing was wasted (1). Whoever killed the turtle would get to keep the shell (1). Sometimes the shell would be used as a bowl, so the meat and intestines were scraped out and put back into the shell with a bit of sea water and the whole thing put into the Umu (2).

7. Are sea turtles culturally significant to Cook Islanders?

Not now but maybe in the past (2), it is uncommon for people in the southern group to have the turtle as their ‘taura atua’[18] (2). Kau won a dance competition on Atiu using the turtle as a theme; he danced to music written about the turtle by the Penrhyn String Band, tied a turtle shell to his back and danced like a turtle (2).

[18] Family totem

Atuins used to keep turtles as pets, in a pool (2), they were never killed and some lived to they were fifty years old (2).

8. **How do you think it would affect Atuins if turtles were to become locally extinct?**

Turtles are pretty much extinct on Atiu; it's a sad story (1). Atuins are not bothered by the turtle; it's just the best meat (2).

Identifying Threats

The most prominent and only threat to turtles on Atiu was the take of both turtles and their eggs for food. The taking of nesting females is widely known to have a massive negative impact on turtle populations as the reproductive component is removed. By targeting both the females and their eggs, there would have been little or no reproductive output on Atiu for decades causing the turtle population to crash.

The outer-reef is very narrow, dropping off sharply from the fringing-reef; therefore, the outer-reef provides limited foraging habitat and could not support high turtle abundance.

There are no anthropogenic threats to the beaches through development or artificial lighting and there are no threats from natural or introduced predators, pollution or through fisheries by-catch.

Strandings / Dead Turtles

No dead turtles were found on Atiu.

Discussion of CITP Survey Results

Local Knowledge supported by CITP survey data portrays a sad story for the turtles on Atiu; the green turtle population has been reduced to a mere remnant of its former abundance and it is likely to be irrevocably lost. This is because there has been little or no nesting for thirty years or more which means that there has been little or no recruitment into the population for more than sixty years - Green turtles exhibit delayed maturity; reaching a reproductive age at between thirty and fifty years old

(Hirth 1992). If there had been any recruitment in the last sixty years, then we would still expect some level of nesting by neophytes[19] .

This emphasises the severe negative impact that the taking of nesting females and their eggs has on turtle populations through the removal of the reproductive component. It is a common misconception of people who hunt turtles that their numbers are not affected by this detrimental practise. This is because every turtle which comes to nest, and its eggs, can be taken for decades with only a small difference in nesting numbers; however after thirty to forty years, the population may suddenly crash.

The threat to turtles on Atiu has now been removed through the implementation of the Atiu and Takutea Environmental Regulations (2008) which prohibit the taking of turtles and their eggs; however, this maybe too late for the turtles on Atiu.

The rookery on Takutea is thought to still host a significant level of nesting. With the turtles protected by the Atiu and Takutea Environmental Regulations (2008), this rookery should remain stable but until sustained monitoring is initiated, we cannot presume this rookeries status.

Turtles are still thought to be present in the marine environment and are encountered at various locations around the island. The abundance of turtles is thought to be low and there is only limited habitat to support them; however they are not under threat from artisanal or commercial fisheries.

Turtles do not hold a great deal of cultural significance to the community on Atiu; however there was a feeling of sadness that the island had lost its turtles. In the past, when a turtle was caught, it was a cause for a feast and the whole community would partake. This was not because there was any custom or tradition involved with the killing of turtles but because turtle was the best and most freely available meat.

The loss of the Atiu nesting population highlights the critical need to initiate monitoring on all of the Cook Island's turtle populations before further losses occur. By informing island communities about turtle life-history strategy and their susceptibility to over-hunting, CITP aims to prevent further extirpation events through advising sustainable resource management.

[19] A turtle which has come to nest for the first time

Mauke

June 4th – June 11th 2012

Local monitoring by Basilio Kaokao

November 2012 – April 2013

Project Overview

The Mauke [S20°9'; W157°20'] expedition was conducted from the 4th to the 11th of June 2012 by a two person research team led by CITP Science Officer Phil Bradshaw accompanied by his research assistant Nerissa Bradshaw. This expedition surveyed the beaches for suitable nesting habitat and collected baseline data on species present as well as last year's nesting activity (2011 – 2012); therefore this report is only summarised here (for the full report refer to Bradshaw & Bradshaw 2012).

The expedition identified ten beaches with habitat suitable for nesting along the southern and eastern shores. Six nests were confirmed and excavated with an average clutch size of 96.5 eggs (SD± 21.4, range = 73 – 130, n = 6) and a hatching success of 93.2% (range = 82.1% - 100%, n = 6) producing 532 hatchlings.

No marine surveys were conducted during this expedition as the ocean was deemed too rough to snorkel. Local Knowledge was collected confirming the presence of green turtles in Mauke's waters and their abundance was thought to increase seasonally around October and November.

Three presentations were made at the local school to thirty six science students (grades 7 – 12) and a field trip was conducted to Anaraura Beach with the senior science class and the Environment Officer Basilio Kaokao to observe nest excavations and to discuss turtle life-cycles and conservation issues.

During the expedition, Basilio accompanied the research team to show them the beaches which supported current nesting activity and to observe the nest excavations; CITP took this opportunity to give Basilio some basic training in track interpretation.

2012 – 2013 Nesting Season

CITP and Basilio Kaokao have worked together since this expedition to facilitate the first local turtle monitoring project in the Cooks. A training document was written by Phil Bradshaw to assist local monitoring of marine turtles which included: a guide to track interpretation and recording, datasheets and a database.

During the 2012 – 2013 nesting season, Basilio has carried out nesting activity surveys on the ten beaches identified as suitable for nesting by the previous expedition (Bradshaw & Bradshaw 2013). The surveys were conducted every week from February 22nd 2013 until the end of April 2013 but no evidence of current nesting was found; therefore we cannot confirm reproductive success this season.

In addition to the monitoring, CITP worked in conjunction with NES and SPREP to design, build and erect the first turtle beach protection signs in the Cook Islands. The signs, which were requested by Basilio, were funded by SPREP after Joseph Brider (NES) and Deyna Marsh (NES) sort their assistance. CITP designed the signs with translation to Mauke's local dialect of Cook Islands Maori by Basilio. The three signs were sent, with all the necessary materials, by CITP and the signs erected by Basilio and his local scout group.

Palmerston

March 31st – May 1st 2012

Project Overview

The Palmerston [S18°03’, W163°12’] expedition ran for four weeks during the entire month of April 2012. The seven person research team was led by CITP’s former Chief Scientist Dr Michael White who was accompanied by PICI’s Programme Manager Jessica Cramp, CITP’s Science Officer Phil Bradshaw and PICI’s Aitutaki Lagoon Monitoring Officer Tina Weier. The expedition costs were partially funded through a conservation grant from the Rufford Small Grants Foundation with the remaining expenses covered by the inclusion of three paying volunteers.

The S/V Southern Cross was chartered to transport the team and all expedition equipment and supplies to Palmerston. The team stayed in a house owned by the Fisheries Officer Bill Marsters and paid a contribution to the community for their stay.

The research team was joined by five local research assistants, normally two on each survey day, to assist in conducting beach and marine surveys to assess the current distribution, abundance and population status of marine turtles on the atoll.

The team found suitable nesting habitat on nearly of all of the motu; however, one hundred and fifty three of the one hundred and eighty six nests were located on four of the major motu (Cooks Islet, Toms, Primrose and Palmerston Island) and several, of the minor motu and sand banks (Dicky Boys Sandbanks and Kitsap Bank).

As the expedition was conducted post nesting season the team did not tag turtles or collect genetic-samples and morphometric data. Ninety seven nests were excavated and were found to have been laid by green turtles. The mean hatching success of the eggs was 95.3% (SD = 9.0%, range 17 - 100%, n = 97 nests) with an average clutch size of 90 eggs (SD = 25.9, range 13 - 183, n = 97).

Marine surveys were conducted within the lagoon on fifteen days with one day spent surveying the outer-reef. Turtles were encountered on thirteen days with a total of forty two in-water encounters. Both green and hawksbill turtles were confirmed as being present, albeit greens were significantly more abundant in the lagoon; however, two of the three hawksbills encountered were found on the outer-reef. Most marine surveys targeted the southern part of the lagoon near Cook’s Islet as the visibility here was good, turtles were known to be present and there were fewer sharks.

All life-stages of green turtles were encountered but only juvenile hawksbills. The marine habitat was thought to provide foraging for both species as well as an area for juvenile development. During nesting season the lagoon and the outer-reef are thought to provide areas for green turtles to mate and rest during their inter-nesting interval.

As with many of the Cook Islands, the only threat to turtles is their consumption by the local community. Some turtles and their eggs are taken each year, normally during nesting season as this coincides with the cyclone season and boats to Palmerston are rare. However, the community here remains small in number and the turtles which are taken each year are considered to be sustainable.

For a full account of this expedition refer to White 2012b.

No monitoring was conducted on Palmerston during the 2012 – 2013 nesting season as CITP did not have the resources necessary to conduct any further expeditions or to supply additional resources to assist local monitors in data collection. During a conversation with David Marsters, one of our local research assistants, he stated that nesting numbers were very low this year, although he could not quantify this with any specific numbers.

Therefore, CITP plans to establish a locally managed monitoring team, supported by international volunteers to help provide the additional human and financial resources to sustain monitoring on Palmerston Atoll from 2013.

The Palmerston research team 2012

Photo by Jason Green

Rarotonga

September 7th 2012 – April 8th 2013

A Behavioural Study of Turtles in Papua Passage

Introduction

The four 'passages' which drain the lagoon (refer to Figure 31) are all thought to support small aggregations of juvenile and adolescent green *Chelonia mydas* and hawksbill turtles *Eretmochelys imbricata* (White 2011; *pers. obs.2012*; Steve Lyon (Pacific Divers) *pers. com.* 2012; Chris Oldham (The Dive Centre) *pers. com.* 2012). Larger turtles of both species are rarely seen within these passages although they are encountered on the fringing reef at low density (White 2011); with some individuals regularly seen by divers at popular dive sites (Steve Lyon (Pacific Divers) *pers. com.* 2012; Patrick Jaletzky (Reef 2 See) *pers.com*. 2012; Ian Wheeldon (Cook Islands Divers) *pers.com.* 2012; Chris Oldham (The Dive Centre) *pers. com.* 2012). Fidelity to foraging areas, especially developmental habitats is suggested by several studies (Meylan 1999; León & Diez 1999) and short term site fidelity was shown for juvenile and adolescent turtles within Papua Passage (White 2011) using photo-recognition (White 2006; Schofield 2008).

Direct behavioural observations of sea turtles are essential to the understanding of interactions between turtles and their ecosystems (Schofield 2006). From these observations we can infer how a variety of habitats may provide a diverse range of functions among different turtle species or influence the population structure. For this reason we used direct observation and photo-recognition to investigate the turtle abundance, habitat purpose and site fidelity within Papua Passage.

CITP conducted twenty six surveys between September 27th 2012 and April 8th 2013, specifically addressing three main questions:

1. What is the relative abundance of the two species of turtle present in Papua Passage?
2. How do the different species of turtle utilise the passage habitat?
3. Do turtles remain resident within the passage (site fidelity)?

Figure 31 the location of the four passages (Rutaki, Papua, Avaavaroa and Avana) which drain the Rarotonga's lagoon

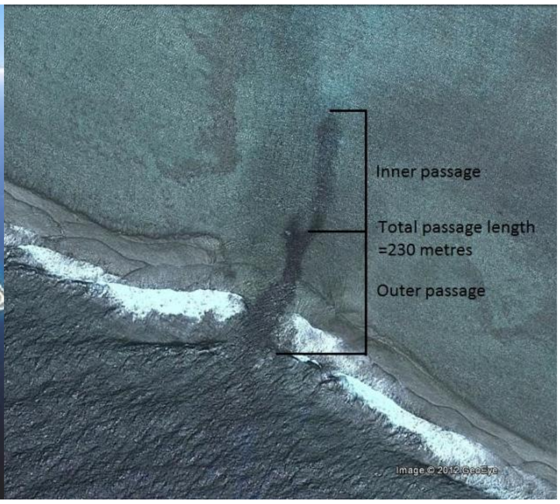

Figure 32 a close up of Papua Passage (image from Google Earth)

Study Area

Papua Passage [S21˚15.586'; W159˚45.576', refer to Figures 31 & 32] is the smallest of the four passages measuring two hundred and thirty metres in length, with a maximum width of thirty metres (in the Outer Gully) and a maximum depth of twelve metres. It consists of an inner gully, about three to six metres deep with a sandy bottom. The passage then narrows (Inner Narrows) into an area where the water rips through at high tide into a wider deeper section of the passage. This area is known as 'Middle Deep' and is about ten to twelve metres deep with a sandy bottom which, after narrowing through another section, becomes shallower (six to eight metres) with a coral bottom. The sides of the 'Middle Deep' area have good coral cover with wide shelves on the eastern side. After the 'Middle Deep' the passage narrows (Outer Narrows) again before opening out into the 'Outer Gully' where it merges with the outer-reef. The 'Outer Gully' has a sandy bottom and is about ten to twelve metres deep. The rocky sides and outcrops have good coral cover and extend out to form a fringing reef wall with a shelf reef ranging out until it sharply drops off several hundred metres further south

Methodology

For comprehensive methodology refer to the Cook Islands Scientific Protocol for Turtle Monitoring.

All surveys were conducted at low tide as the passages are dangerous during high tide or during large swells. Conducting surveys at low tide meant that surveys were conducted at different times during the day. Surveys always began at the northern end of the passage, and then slowly proceeded in a southerly direction carefully checking for turtles hidden within the passage walls.

All turtle behaviour was assessed upon first sighting and categorised as one of seven behaviours; Swimming (Su), Resting (Ru), Foraging (Fo), Eating (Ea), Cleaning (Cl), Crawling (Cu), and Breathing (Br).

The turtle species was identified, its size-class assessed (juvenile, adolescent or sub-adult and adult) based on TREDS (Turtle Research and Monitoring Database; http://sprep.org/treds/TREDSnews.aspx) and gender determined upon tail morphology (Casale *et. al.* 2005). Photographs (Panasonic Lumix DMC-FT4 in underwater housing Panasonic DMW-MCFT3) were taken focusing on both sides and the top of the turtles head to allow photo-recognition using head scales (White 2006; Schofield 2008). Photo-recognition has been shown to be an effective method to identify individual turtles (Schofield 2008).

Data Analysis

Two hundred and fifteen turtle encounters were recorded; however, only first encounters from each survey were used in these analysis (n=158). All turtles were classified to a species and size-class with their behaviour recorded. Some unidentified turtles (n = 39) could have been re-encountered; however, due to timing, behaviour and location of sighting, they are thought to be first encounters.

All statistical analysis was conducted in R version 2.11.1 (http://cran.r-project.org). Population estimates were made using a Jolly-Seber Population Estimate Applet (http://people.hws.edu/ryan/Ryan/Pages/Jolly.html).

1. What is the relative abundance of the two species of turtle present in Papua Passage?

Data for turtle encounters was not found to follow a normal distribution; however, transformation of the data was not possible due to the differences between distributions; total turtle encounters and green turtle encounters were positively skewed and followed a Poisson distribution whilst hawksbill data followed a Negative Binomial distribution, therefore, the Mann Whitney Two Sample Test for non-normally distributed data was used to compare the two sample means (green turtle encounters and hawksbill turtle encounters).

Population estimates were made using the Jolly-Seber method for mark and recapture on open populations on all turtles identified using photo-recognition (n =124). The population estimates were only conducted on twenty one surveys because photos were not taken during the first three surveys, and the first and last population estimates (from the remaining twenty three surveys) are classified as inaccurate due to estimation parameters; therefore, these were not included in the calculations.

Nearly all turtles encountered were juveniles and so size-class was not analysed.

2. How do the different species of turtles utilise the passage habitat?

For the purpose of this report the behavioural observations were pooled from seven categories (Swimming, Resting, Foraging, Eating, Crawling, Cleaning and Breathing) down to four (Swimming, Resting, Foraging and Cleaning) as the sample number was low. Turtles observed breathing were pooled with swimming; crawling with resting and eating with foraging. Fisher's Exact Test for count data was used to investigate the behavioural differences between the two species.

3. Do turtles remain resident within the passage (site fidelity)?

All turtles which could not be identified (n = 34) were omitted from these analysis. The remaining one hundred and twenty four encounters were identified to one of twenty one individuals and were used to analyse site fidelity. The Mann Whitney Two Sample Test was used to investigate any differences in site fidelity between the two species.

Results

1. What is the relative abundance of the two species of turtle present in Papua Passage?

Turtles were seen on 100% of the twenty six surveys with a total of one hundred and fifty eight turtle encounters. This is an average of 6.1 turtles encountered per survey (SD± 2.4, range = 3 – 13, n = 158, refer to Figure 33).

One hundred and twenty encounters were with green turtles and thirty eight were with hawksbill turtles. Green turtles were encountered on all twenty six surveys whilst hawksbills were only encountered on eighteen (refer to Figure 34).

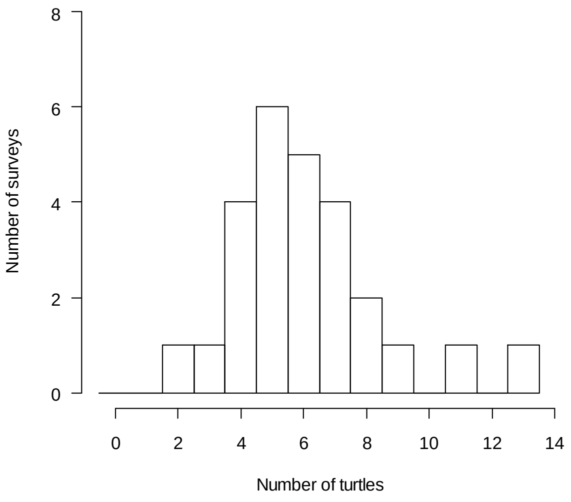

Figure 33 histogram of turtles encountered per survey (surveys =26, mean = 6.1, SD± 2.4, range = 2 – 13, n =158)

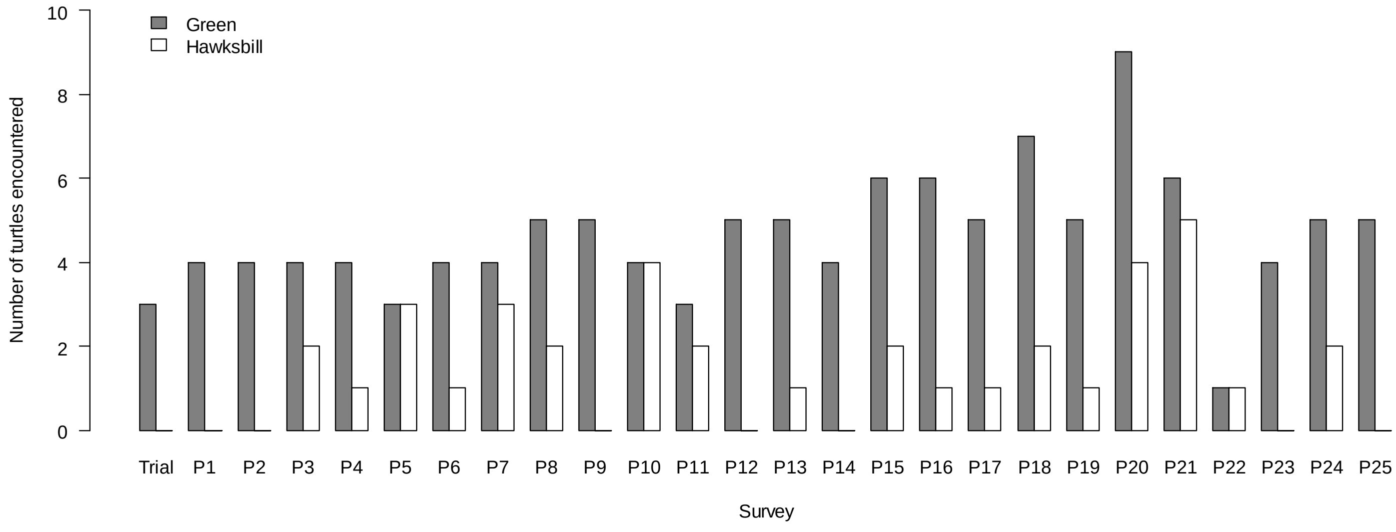

Figure 34 histogram of turtles encountered per survey by species (green turtles = 120, hawksbill turtles = 38, n = 158)

Green turtles were significantly more abundant than hawksbills (Mann Whitney Two Sample Test, p = <0.001, highly significant, refer to Figures 35 & 36) and were encountered on a ratio of three green turtles to one hawksbill.

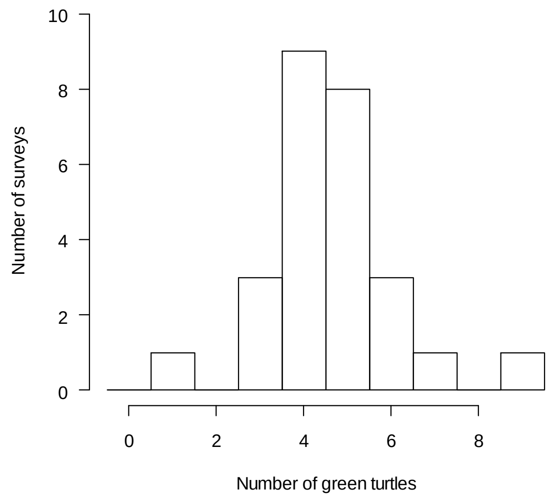

Figure 35 histogram of green turtles encountered per survey (median = 4.5, interquartile range = 5 – 7, range = 1 – 9, n = 120, surveys = 26)

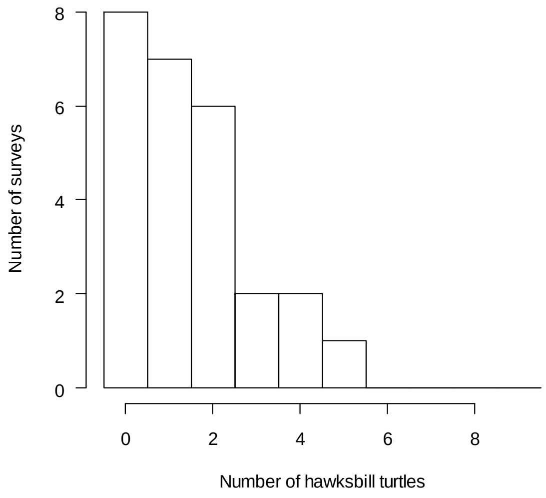

Figure 36 histogram of hawksbill turtles encountered per survey (median = 1, interquartile range = 0 – 2, range = 0 – 7, n = 38, surveys = 26)

Population estimates were made using the encounter data from the twenty one identified turtles (n = 124). Ninety six encounters were with green turtles and twenty eight were with hawksbills. Average population estimates were thirty nine for green turtles (median = 39.4, inter-quartile range = 28.1 – 50.0, range = 14.0 – 62.5, n = 21 surveys, refer to Figure 37) and nine for hawksbills (median = 9.4, inter-quartile range = 7 – 12, range = 7 – 45, n = 21 surveys, refer to Figure 38)

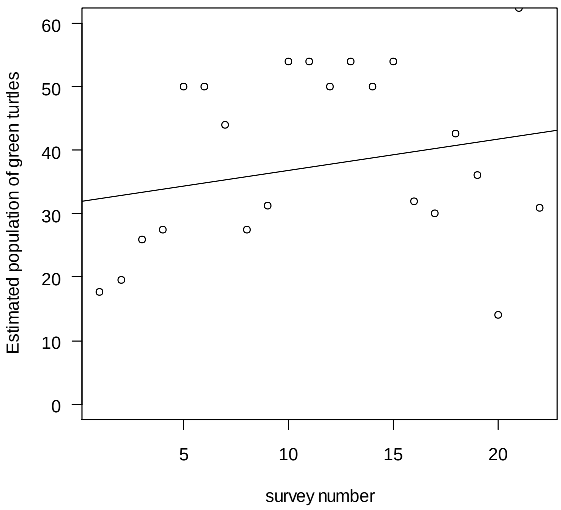

Figure 37 population estimates for green turtle using the Jolly-Seber method for open populations (median = 39.35, inter-quartile range = 28.13 – 50.0, range = 14.0 – 62.5, n = 21 surveys)

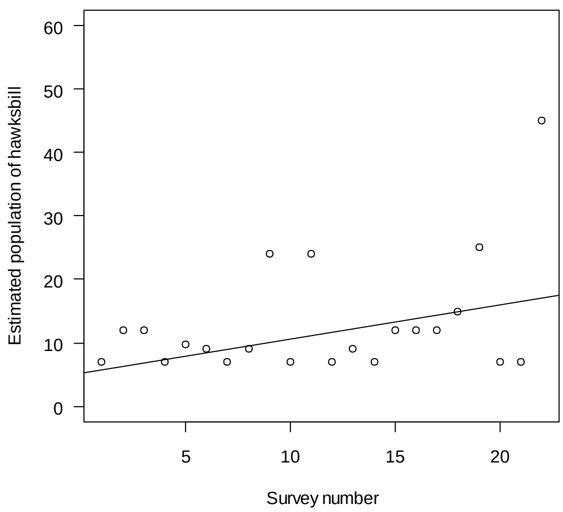

Figure 38 population estimates for hawksbill turtle using the Jolly-Seber method for open populations (median = 9.35, inter-quartile range = 7 – 12, range = 7 – 45, n = 21 surveys)

All of the turtles encountered were juveniles with two exceptions; a sub-adult male green whose tails was growing both proximally and distally and whose shell length measured more than sixty five centimetres (refer to Figure 39) and a hawksbill turtle would have been on the cusp of being a sub-adult sized turtle.

Figure 39 the only sub-adult green turtle observed in Papua Passage

2. How do the different species of turtles utilise the passage habitat?

The green and hawksbill turtles were shown to exhibit significantly different behaviours from each other indicating that they utilise the passage habitat for different purposes (Fisher's Exact Test, p= <0.001, highly significant, refer to Table 1 & Figure 40). Both species were encountered swimming and resting in the passage as expected values would predict; however, green turtles were found at 'cleaning stations' which hawksbills were not and hawksbills were common to see foraging which was rarely observed with green turtles.

Table 1 the observed behaviours for green (n = 120) and hawksbill turtles (n = 38)

Behaviour	Green	Hawksbill
Cleaning	6	0
Foraging	1	12
Resting	42	8
Swimming	71	18

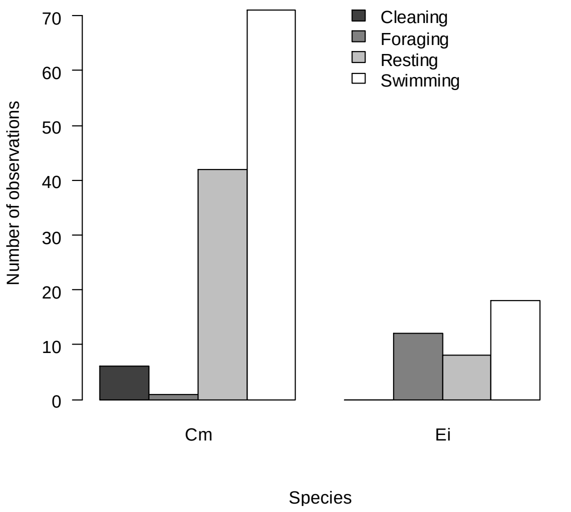

Figure 40 histogram highlighting the significantly different behaviours exhibited by greens (Cm) and hawksbills (Ei) (Fishers Exact Test p = <0.001, n = 158, green = 120, hawksbill = 38)

3. Do turtles remain resident within the passage (site fidelity)?

The use of photo-recognition proved to be very effective with twenty one turtles identified accounting for 78.5% of encounters (n=158). No significant difference was found between the two species in terms of site fidelity (Mann Whitney Two Sample Test, p = 0.94, not significant, refer to Figures 41 & 42). However, the median encounter rate for hawksbills (median = 4, inter-quartile range = 2 – 4, range = 1 – 8, n = 7 identified hawksbill turtles) was higher than for greens (median = 3, inter-quartile range = 1 – 13.35, range = 1 – 20, n = 14 identified green turtles).

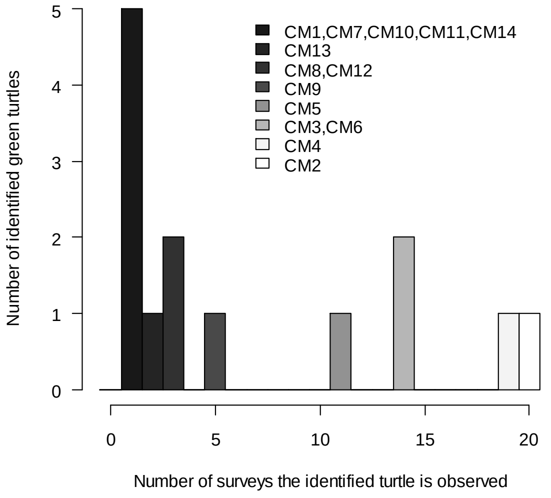

Figure 41 site fidelity of green turtles (median = 3, inter-quartile range = 1 – 13.35, range = 1 – 20, n = 14)

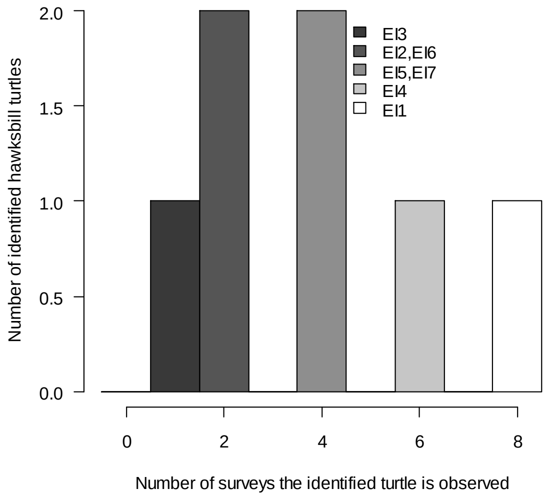

Figure 42 site fidelity of hawksbill turtles (median = 4, interquartile range = 2 – 4, range = 1 – 8, n = 7)

Discussion

1. What is the relative abundance of the two species of turtle present in Papua Passage?

This study found that both species of turtle occurred in a higher abundance now than during the 2009 study conducted by White (2011). White reported turtle encounters on thirty six out of forty seven surveys (77%) with a maximum of seven turtles encountered per survey, a mean encounter rate of 3.01 (SD± 1.77) and a total of one hundred and ten encounters. White encountered green turtles during thirty five surveys (74%) and hawksbill turtles during fifteen (32%) despite his survey period lasting for two to three hours in contrast to the one hour survey time of the present study.

During this study, green turtles were encountered on all twenty six surveys (100%) and hawksbill turtles were encountered on eighteen (69%). A maximum of thirteen turtles (nine green and four hawksbill) and a minimum of two (one green and one hawksbill) were encountered per survey with a mean encounter rate of 6.1 (SD± 2.4) and a total of one hundred and fifty eight encounters. This suggests that the abundance of both species have increased in Papua Passage over the last two years.

The median population estimate for green turtles was thirty nine (refer to Figure 37); substantially higher than the number of turtles seen per survey would suggest or we would think could be resident within the passage. This would indicate that green turtles utilise habitat outside of the passage and that passages do not host discrete populations; individuals come and go but may remain resident within the passage for various lengths of time. The median population estimate for hawksbills was nine (refer to Figure 38) which contrasts with the much higher estimate obtained for greens. This would indicate that hawksbill turtles not only occur in a lower abundance but may also be less transient than greens, remaining resident within the passages at least in the short term.

Green turtles were found to be significantly more abundant than hawksbill turtles with three greens to one hawksbill ratio of encounter (one hundred and twenty green turtle encounters to thirty eight hawksbill encounters) which concurs with the population estimates. The previous ratio of encounter suggested by White (2011) was two greens to one hawksbill which implies that green turtle abundance is increasing more rapidly than hawksbill.

Nearly all turtle encounters were with juveniles with the exception of a sub-adult male green and a sub-adult hawksbill. The near absence of larger size-classes of turtle suggests that the Passage provides a developmental habitat for these species offering them some protection from potential predators or competition from larger conspecifics. The lack of larger turtles may also represent an artefact of past exploitation (León & Diez 1999) but some studies (Meylan 1999; Bellini *et. al.* 2000;

Grossman *et al.* 2007; Whiting & Koch 2006) suggest turtles may migrate from juvenile to adult foraging grounds.

2. How do the different species of turtles utilise the passage habitat?

The behaviour exhibited by green and hawksbill turtles was found to be significantly different (Fisher's Exact Test, $p = <0.001$). The two species were most commonly encountered whilst swimming and both species were encountered whilst resting. However, green turtles were frequently observed at cleaning stations and only observed foraging once. This is in contrast to hawksbills which were never observed at cleaning stations and frequently observed foraging.

Green turtles were found to rest in relatively open locations on the passage floor or on the wide shelves protruding from the passage walls. Some green turtles had regular resting spots where they could be found on numerous occasions. For example; a single turtle (CM6) was observed resting on 'The Pinnacle' on eight occasions and three turtles (CM2, CM3, and CM4) were frequently encountered resting on the 'Coral Pavement' or the shelf protruding from the eastern wall of 'Middle Deep'. Green turtles would often remain at rest for the entire duration of the survey although they may move between spots if disturbed. There were several occasions when two or three turtles were observed resting in close proximity (refer to Figure 43) to each other although social interaction was rare. On one occasion a green turtle attempted to steal the resting place of another turtle, however, the intrusion was rebuked (refer to Figure 44).

Figure 43 two turtles resting in close proximity to each other

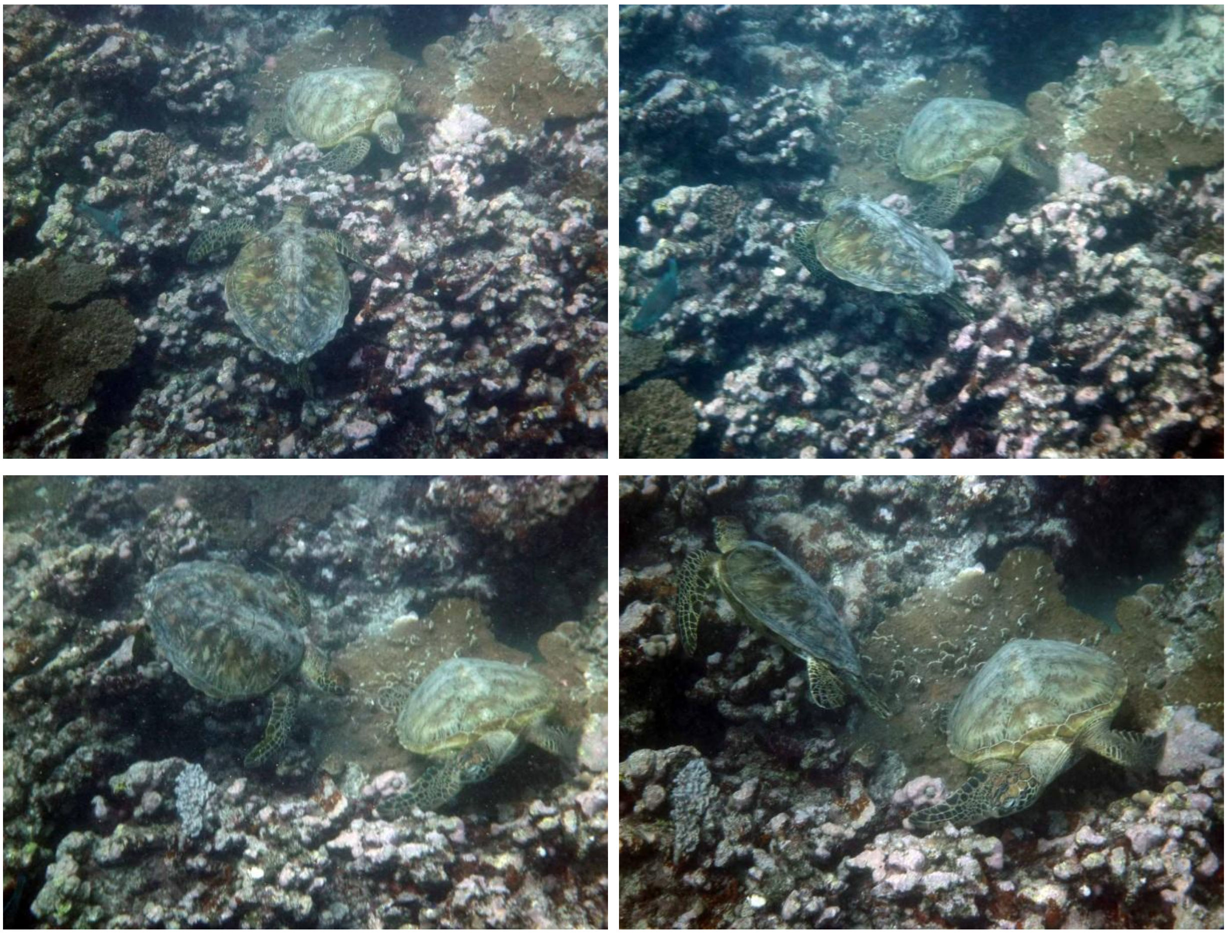

Figure 44 a sequence of behaviour depicting a green turtle trying unsuccessfully to steal the resting place of another larger green turtle

Hawksbills were generally found at rest in small grottos along the passage walls where they were difficult to locate and easily missed by observers. The preference of hawksbills to rest in these grottos may be to maximise dive duration through assisted resting (Houghton *et. al*. 2003, Blumenthal *et. al.* 2009) or for protection. The resting depths and fidelity to resting spots for both species were found to correspond with those reported by Hirth (1992a).

Foraging by green turtles was rare and only observed once when a green turtle had its head buried in a floor crevice. However, on close inspection the green turtle was not seen to be eating and no potential food was located. Green turtles were observed swimming between the passage and the outer-reef on numerous occasions and were often followed by the researcher. On several occasions, turtles were observed leaving the passage in pairs or congregating in small groups of threes and fours in the 'Outer Gully'; however, they would usually disperse and swim in indiscriminate directions out across the reef where they forage for algal species (Steve Lyon 'Pacific Divers' *pers. com.* 2012). Eating was not observed by green turtles during this study or the previous Papua Passage study (White 2011) and so it is presumed that the passage does not provide a foraging habitat but a refuge for juvenile green turtles to rest in-between forays to the outer-reef in search of food. This would mean that the abundance of green turtles within the passage is not limited by food resources.

Hawksbill turtles were observed foraging on twelve occasions (32% of hawksbill observations) along the passage walls and along the shallow reef habitat adjacent to the passage. Hawksbills were never observed eating and so the author cannot elaborate on food preferences; however, it is evident that the passage offers suitable foraging for this species. The high density of hawksbill within the passage, as opposed to the outer-reef, would concur with Limpus (1992), van Dam & Diez (1996) and Leon & Diez (1999) who suggested that coral wall habitat greatly increases the foraging potential for hawksbills and that they are more likely to be found in habitats that have vertical faces to coral formations.

Self-cleaning was not observed for either turtle species although fish cleaning symbiosis was frequently observed for green turtles. Two cleaning stations were regularly visited, the 'Rubble Slope' and another in the 'Middle Deep'. Turtles would hold a posture with their head raised, flippers spread apart and their body slightly raised off the ground to actively solicit cleaning by fish (Schofield 2006). Three fish species; lined bristletooth *Ctenochaetus striatus*, lemonpeel angelfish *Centropyge flavissimus* and speckled damsel *Pomacentrus bankanensis* were observed cleaning turtles with bristletooth focusing mainly on the carapace whilst the smaller fish species targeted the softer epidermal areas (*pers. obs*. 2012; 2013).

Hawksbills were not observed in cleaning symbiosis with fish; however, on one occasion a hawksbill was observed leaving a grotto where fish associated with cleaning symbiosis were located. This may be either cleaning fish visiting a grotto where a hawksbill was resting or a hawksbill using a more discrete cleaning station; however, hawksbill turtles may be deterred from using cleaning stations utilised by greens due to interspecific competition.

3. Do turtles remain resident within the passage (site fidelity)?

The frequent encounter rate of certain individuals would indicate that site fidelity, at least in the short term is exhibited within Papua Passage. It is also fair to assume that during the one hour survey time, not all individual turtles utilising the passage would be present or necessarily encountered even when present; therefore, we can take the encounter rate of individual turtles to be the minimum. Consequently, our data supports other studies which show fidelity to both foraging (Limpus 1992, Whiting & Koch 2006) and resting sites (Hirth *et. al.* 1992; van Dam & Diez 1997).

There was no significant difference between species in regards to site fidelity (Mann Whitney Two Sample Test, p = 0.94). The data shows a distinct bimodal split in site fidelity by green turtles suggesting that some individuals remain resident in the passage; at least during the short term, while other individuals may be more transient. This theory is supported by the population estimate which rose constantly during subsequent surveys. If the passage serves as a refuge for turtles which forage on the outer-reef then there is likely to be movement between the passages whilst the presence of a smaller resident population would indicate that there is adequate forage near-by.

Hawksbill abundance was much lower than for green turtles with a median population estimate of nine which remained relatively constant. However, the median encounter rate of individual hawksbills was higher than it was for greens suggesting that the hawksbill turtles maybe less transient than greens (although sample sizes are small) and that some individuals maybe resident.

A particularly conspicuous hawksbill, which was both easily approached and identifiable due to a notch in the carapace, was observed on eight occasions during this study and was also identified in White's report (2011). This means that this individual has shown long-term site fidelity spanning at least two years corresponding with Limpus (1992) and Whiting & Koch (2006) who suggest that hawksbills show fidelity to localised areas for extended periods of time after initial recruitment from their early pelagic life-stage.

Conclusion

It is clear that the passages are an important refuge and developmental habitat for both green and hawksbill turtles. Where the hawksbills may remain resident within the passage and utilise it both as a resting and foraging ground they may become resource limited and their population growth restricted. Green turtles do not seem limited by resources within the passage as they forage on the outer-reef and are content to rest in close proximity to each other; therefore there populations may increase without constraint. Greens are likely to move between the passages as they forage further in search of food; however, some individuals do exhibit site fidelity to the passages at least in the short term.

SCUBA Diver Sighting Surveys

The SCUBA diver sighting survey was initiated in 2009 to investigate how marine turtles utilise Rarotonga's reefs and lagoons. The data was collected by five dive operators up to 2010 which facilitated the survey of multiple dive sites, simultaneously and throughout the year. Data was collected on which species were present and at which life-stage, where they were found and what they were doing. This was to produce quantifiable data on:

- the distribution, and marine ecology of sea turtle species

- how the turtles are using the available habitat

This survey showed that green and hawksbill turtles are present in Rarotonga's water throughout the year, that they occur at a ratio of two green turtles to one hawksbill and that both populations mainly consisted of juveniles and sub-adults. This report did not summarise the findings of the behavioural observations. For the full results of this survey refer to White (2011; 2012a)

Since March 2012, the SCUBA diver sighting survey was re-initiated to investigate changes in the relative abundance of the two species, to assess population structure, observe behaviour and to record where turtles commonly occur.

Methodology

Two dive operators assisted in the study during the course of this year (March 2012 – April 2013); Pacific Divers and the Dive Centre. For every turtle encountered during a dive, the dive leader recorded the following data:

- Date
- Location (dive site)
- Species (green, hawksbill or unidentified)
- Behaviour (Swimming, Breathing, Resting, Foraging, Eating, Cleaning)
- Size-class
    - green turtles: Shell lengths = small (20.0 – 64.9 cm), medium (65.0 – 84.9 cm), large (85.0 – 115 cm)
    - hawksbill turtles: shell lengths = small (20.0 – 49.9 cm), medium (50.0 – 64.9 cm), large (65.0 – 100 cm)
- Tail visible (extending past the posterior edge of the carapace)
- Method (boat, SCUBA, snorkel)
- Observer

Results

Between March 26th 2012 and April 11th 2013 one hundred and forty five turtle encounters were recorded (refer to Table 2), 52% of encounters were with green turtles and 43% were with hawksbills; the species was unidentified on 5% of encounters.

Table 2: number of encounters with different turtle species

Greens	Hawksbills	Unidentified
76	62	7

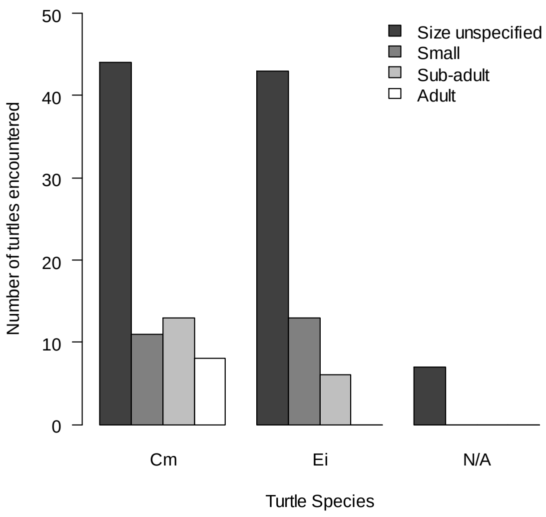

Figure 45 the size-classes of turtles encountered by species; Cm = green, Ei = Hawksbill (n = 145).

All size-classes of green turtle were regularly encountered; however, adult sized hawksbills were not encountered (refer to Figure 45).

Seven of the eight adult green turtles were recorded as having a long tail extending past the posterior edge of their carapace; indicating that they were males. The data suggested that there were more female sub-adult sized turtles for both species; however, the tail may not yet have started to grow if they were on the cusp for becoming classed as a sub-adult (refer to Table 3).

Table 3 the assumed gender for sub-adult sized turtles based on tail morphology

	Green	Hawksbill
Female	7	4
Male	2	1
Unspecified	4	1

There was no significant difference in the behaviour of the two turtle species (Mann Whitney Two Sample Test, $p = 0.75$, refer to Figure 46) with a majority of turtles encountered whilst swimming. Green turtles were also commonly encountered whilst resting in contrast to the hawksbill which was commonly encountered foraging and eating.

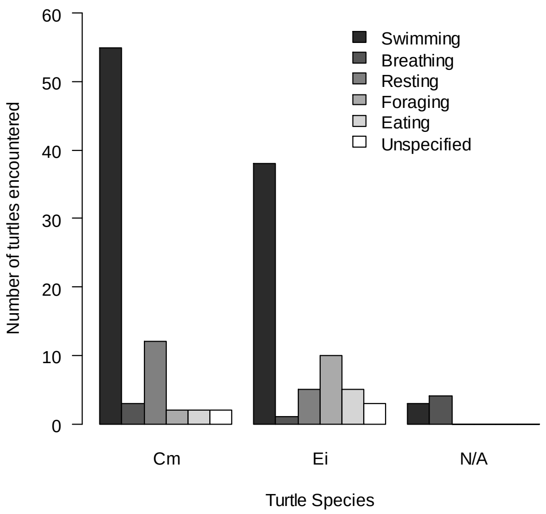

Figure 46 no significant difference in behaviour was observed (Mann Whitney Two Sample Test, p = 0.75)

Turtles were encountered at many different dive sites; however, we cannot determine which sites turtles are most likely to be encountered as we do not know how many dives were made at each dive site; presence and absence data (refer to Figure 47).

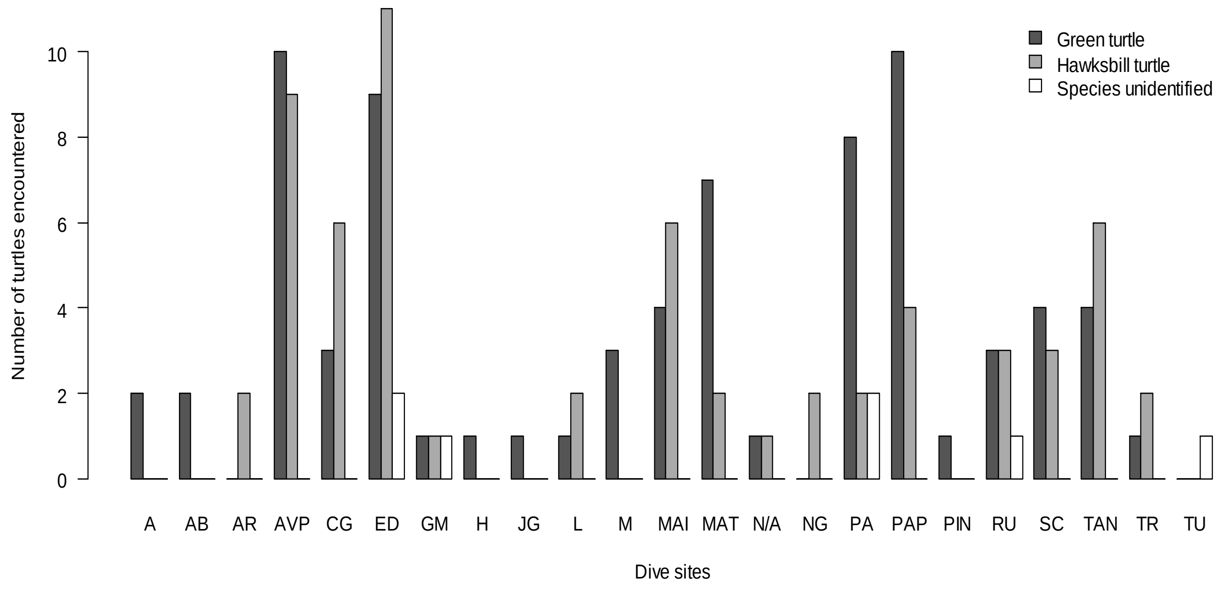

Figure 47 the number of turtles encountered by dive site (dive-site abbreviations: A = Avaavaroa; AB = Abyss; AR = Aroa Lagoon; AVP = Avaavaroa Passage; CG = Coral Garden; ED = Edna's Anchor; GM = Goldmine; H = Harbour; JG = Japanese Garden; L = Lagoon; M = Matervera; MAI = Maitai; MAT = Mataora; N/A = not specified; NG = Ngatipia; PA = Papua Drop-off; PAP = Papua Passage; PIN = Pinnacles; RU = Rutaki Reef; SC = Smurf City; TAN = Tangaroa's Rock; TR = Trader's Reef and TU = Tupapa)

Discussion

Divers regularly encounter turtles throughout the year in Rarotongan waters. The ratio of encounter suggests a two green to one hawksbill ratio which is a marked change from the previous study which recorded a three green to one hawksbill ratio (White 2012). However, without any identification of individuals or data on presence and absence for every dive, we cannot suggest whether there has been an increase or decrease in the abundance of either species or whether the same individuals are being commonly encountered.

The regular encounters of all size-classes for green turtle suggest that the population structure is stable; however, there is a near absence of adult females. Adult hawksbill turtles were not encountered during this survey which contrasts to the previous study (White 2012) and may indicate that adult hawksbills migrate to other foraging habitats (Meylan 1999; Bellini *et. al.* 2000; Grossman *et al.* 2007; Whiting & Koch 2006) or that hawksbill populations maybe recovering from past exploitation (León & Diez 1999). However, the encounter rate for this species is encouragingly high and suggests Rarotonga provides an area safe from exploitation and may provide crucial habitat to aid in the regional recovery of this critically endangered species.

There was no significant difference between the observed behaviours of the two species (Mann Whitney Two Sample Test; $p = 0.75$) as a high number of the turtles encountered were swimming, which is to be expected as this is when they are at their most conspicuous. However, this category is likely to have masked any more subtle differences such as the interesting difference between the number of green and hawksbill turtles encountered foraging. From the Papua Passage survey (refer to the Behavioural Study of Turtles in Papua Passage section) green turtles were thought to forage on the outer-reef whereas this was rarely observed during this survey. In addition, hawksbills were commonly observed in the passage foraging and it was thought that they may not need to spend much time foraging on the outer-reef, which was not found to be the case. Therefore, this highlights two questions for future research:

1. Where are green turtles foraging and what are they eating?
2. Is the food available for hawksbills rare, increasing their foraging time, or are they highly selective?

The graph depicting dive-sites where turtles are commonly encountered (refer to Figure 47) does not tell us very much without data on both the presence and absence of turtles during all dives. The only dive sites where more than two turtles were encountered during a single dive was on the south of Rarotonga near or within the passages (Avaavaroa, Rutaki and Papua). Some of the dive sites on the north of the island (Coral Garden, Edna's Anchor, Maitai, Mataora, Smurf's City and Tangaroa's Rock) appear as though turtles are commonly spotted; however, these sites are dived significantly more frequently than the other dive sites. In order to draw any accurate conclusions on where turtles are commonly encountered; we need to record all dives whether turtles are encountered or not.

Limitations of study:

The Diver Sighting Survey has provided useful data on species population structure and behaviour; however, without presence and absence data we are not able to draw any conclusions on relative abundance between species or between years. With presence and absence data we could identify dive-sites where turtles are frequently encountered (turtles encountered / number of dives at that site), the abundance of each species encountered over successive years (number of green or hawksbill turtles / total number of dives) and this could be refined to density of turtles to particular dive-sites or areas around the island (north / south / east /west).

The classification of size-class for turtles can be highly subjective, especially between different species and observers; an adult sized hawksbill may seem small in comparison to an adult green turtle and two different observers may class the same turtle differently. This can also be true for tail length classification in sub-adult sized turtles. It is quite obvious whether an adult turtles is male or female;

however, when a turtle becomes of a sub-adult size its tail may have only marginally distended past the end of it's carapace; therefore, even though the turtle is male, to the untrained eye, the turtle may be classed as female.

Conclusions from CITP 2012 – 2013 surveys

The surveys conducted by CITP since September 2012 suggest that foraging turtle populations around Rarotonga and Aitutaki are healthy and are thought to be increasing. Both islands have a stable population structure of green turtles with the abundance of juveniles suggesting high levels of recruitment and the abundance of adults suggesting that they suffer few threats. Mauke and Atiu also report the presence of green turtles in their waters, including all life-stages, albeit in a much lower density.

Rarotonga has been shown to provide important develpmental habitat for hawksbills and this species was also enocuntered on Aitutaki and Palmerston but remains unknown around Mauke or Atiu. Adult hawksbills were conspicuously absent from all CITP surveys this year, despite anecdotal evidence suggesing their presence around Aitutaki and previous surveys recording them around Rarotonga. We can at this stage only speculate to why this maybe and try to increase our survey efforts next year to locate these animals of conseravtion concern.

Nesting numbers for the 2012 – 2013 nesting season were very low throughout the southern group islands surveyed. No evidence of nesting was found on Mauke or Atiu, nesting numbers were reported to be low on Palmerston (David Marsters *pers. com.* 2013), although unquanitifed, and six nests were laid on Aitutaki (during the survey period). These numbers are worrying but it may be a natural fluctuation in the highly variable remigration intervals that turtles exhibit; however, only a long-term dataset will reveal these trends and allow any accurate assessments to be made.

There are few threats to turtles or their habitats on the islands which have been surveyed so far with the exception of hunting. The hunting of turtle, if done sustainably, can provide an important source of protein for remote island communities. However, if nesting turtles are targeted then this can cause huge impacts to nesting rookeries and may lead to their extirpation. Therefore, CITP advises a more sustainable take of turtle by:

- Targeting male turtles as opposed to females
- Avoid taking females of a reproductive size, especially between October and December
- Target turtles in the water as opposed to turtles on the beach; however, if turtles are to be taken from the beach, allow them to nest first
- Do not take all the eggs from a nest

Atiu and Takutea offer full protection for turtles through local Island Regulations and CITP have been informed that Aituaki and Mauke are considering to enforce their own protection for turtles. Communities on most of the southern group islands no longer rely on turtle as a food resource (except Palmerston) or have use of the turtle in traditional practises. Therefore, protection through local Island Regulations can be considered by Island Councils and implemented if it is supported by their community.

Capacity Building and Training

CITP's mission is to form local monitoring teams on each island and to identify and train community members to sustain monitoring and manage projects.

Palmerston

CITP trained five local research assistants during the Palmerston expedition and worked with a further three members of the community. Research assistants were trained in habitat suitability surveys, track interpretation and nest identification, nest excavations, marine surveys and the use of a GPS (White 2012b). CITP plans to return to Palmerston in the 2013 – 2014 nesting season to establish an annual monitoring project working with the community. One of the Palmerston research assistants (David Marsters) has been approached and has expressed his interest for further training in track interpretation, working with nesting females and data recording so he may manage this project in the future. Therefore, CITP and the Palmerston community will work together to sustain monitoring on this rookery and initiate a community-led international volunteer programme to assist the community with the human and financial resources.

Mauke

CITP worked with Basilio Kaokao (Mauke's Environment Officer) during the June expedition to survey last year's nesting activity. During this expedition, we discussed some features of track interpretation and nest identification as well as demonstrating nest excavation techniques. Before this year's nesting activity began, a training manual was devised and sent to Basilio by CITP to assist in the local monitoring of nesting activity.

CITP plans a return trip to Mauke in the 2013 -2014 nesting season to offer further training to Basilio as well as several other members of the community who have shown interest.

Aitutaki

CITP trained eight international volunteers in conducting habitat suitability surveys, track interpretation, nest identification and nest excavations. Volunteers were also involved in all outreach activities including our school work, beach cleans and community presentations. All of the volunteers brought unique skills to the project and will hopefully return in future seasons to carry on our work.

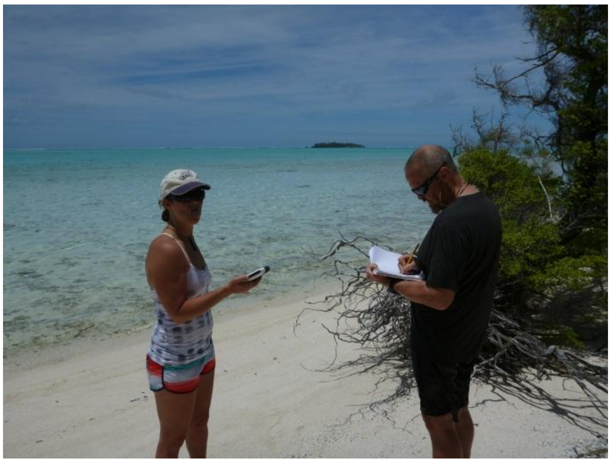

Figure 48 Veronica and Leo conducting a habitat suitability assessment

Figure 49 Phil Bradshaw teaching Jane Wesson how to identify a turtle nest

Atiu

Training of local monitors was not possible during this expedition as no turtle activity was found. CITP will look at training local monitors during its return to Atiu in November or December 2013 when it conducts its survey of Takutea.

The idea of initiating nest monitoring as a school project was broached with the Takutea Trustees as they were keen for their younger community members to learn our survey techniques. Therefore, CITP's research team should include two or three local research assistants, probably from the school or volunteers from the community to survey Takutea later this year.

Marine Turtle Education and Awareness-Raising

CITP's Education goals:

Environmental education is the most fundamental conservation tool and offers perhaps our best hope to preserve the future of endangered species and habitats. It is critical to raise the awareness for environmental protection and endangered species management to the younger generation of Cook Islanders so that they can continue to manage their resources and habitats sustainably. Due to the 'shifting baseline syndrome' (Pauly 1995) younger generations do not always understand how bountiful the oceans were historically and think that some species (such as the turtle) are naturally rare as opposed to being in danger of extinction. By educating children to the rare and amazing wildlife around them, CITP hopes to inspire their respect for the environment and all the creatures which dwell in it, to only take what they need and to dispose of their waste in a responsible manner.

Between April 2012 and April 2013, CITP taught over 450 children on the outer-islands.

CITP presentations were focused to the age range of their target audience and covered topics such as:

Marine Turtle Biology, Life-cycles and Conservation Issues:
Taught on Palmerston, Mauke, Aitutaki and Atiu

- The differences between family groups (for the younger children)
    - Tortoises, terrapins and sea turtles
- Sea turtle adaptations
    - Shell
    - Flippers
    - Salt glands
- The different species of sea turtle
    - In the Cook Islands
    - Globally
- Life cycles of turtles
    - Migrations
    - Nesting
    - Hatchling and adult life-stages
- The importance of turtles
    - Culturally
    - Biologically
    - Protein source
    - Economically
- Why turtles are endangered
    - Sustainable resource management
    - Habitat destruction
    - By-catch
    - Responsible disposal of rubbish
- Turtle conservation measures (for the older children)
- How we can help turtles

Whale Biology and Behaviour:

Taught on Aitutaki and Atiu

- Different types of whales
    - Toothed or baleen whales
- Different species of whales
- Whale evolution
  (for the older children)
- Whale species in the Cooks
    - Humpbacks
- Whale morphology
- Whale identification
- Whale migrations
- Specialised whale hunting behaviour
- Critter-cam footage of whales underwater and breaching

Coral Reefs; Life-Cycles and Diversity:

Taught on Aitutaki

- How sandy beaches are formed
- Reef diversity
- Life-cycle of corals

A BBC documentary 'The Blue Planet – Coral Reefs' was used as a teaching aid

The schools CITP have taught at include:

Palmerston - CITP taught ~ 25 children (grades 3 – 12) at Palmerston Lucky School for a day on marine turtles.

The older children (grades 6 – 12) were also taken on to the beach to observe turtle nest excavations performed by local and international volunteers. The younger children drew turtle posters which supported a conservation theme.

Mauke – CITP taught three science classes (grades 6 – 12) totaling 36 children on marine turtles. The senior science class was taken to the beach to observe turtle nest excavations with the Environment Officer Basilio Kaokao.

Aitutaki – CITP taught ~265 children between the four schools conducted a series of presentations, each of which lasted between one and two hours on marine turtles, whales and coral reefs.

- Vaitau Primary (grades 3 – 6, ages 9 – 11) = 30 children
- Tekaaroa Primary (grades 1 – 6, ages 6 – 11) = 75 children
- Araura Primary (grades 3 – 6, ages 9 – 11) = 35 children
- Araura College (grades 7 – 12, ages 12 – 17) = 130 children

The Primary school children drew turtle conservation posters which the CITP volunteers judged for the schools prize giving days. CITP arranged a day trip for the four schools (grades 5 & 6 from the Primary Schools and grade 7 from the College), with the assistance of the Aitutaki Conservation Trust, to the beach to observe turtle nest excavations and conduct beach cleaning activities.

Atiu – CITP taught ~ 130 children about marine turtles and whales.

Primary (grades 3 – 6, ages 9 – 11) = 65

Secondary (grades 7 – 12, ages 12 – 17) = 65

A field trip could not be arranged as there was no nesting activity and no nests to excavate. We hope to involve some of the senior students in our survey of Takutea next season.

Figure 50 CITP teaching on marine turtles at Araura Primary

Figure 51 CITP teaching on marine turtles at Tekaaroa Primary

In addition to the work in outer-islands schools, CITP is committed to writing a locally focused environmental module on 'Marine Turtle Biology, Life-Cycles and Conservation Issues' as part of PICI's Conservation Education Project. The module will be written in conjunction with the Ministry of Education (MoE) to be aligned with specific curriculum and learning objectives as set forth by the MoE and New Zealand NCEA[20] framework. The module will be designed to be used as a teaching aid in all Cook Islands schools to highlight an area of local concern and to increase student interest. The module will include a field activity linked with local monitoring teams, where applicable, to inspire young scientists in becoming involved with local monitoring projects.

[20] National Certificate of Educational Achievement

Community Presentations

Four community presentations were given this year, two on Palmerston and one each on Aitutaki and Atiu.

Palmerston

The initial presentation on Palmerston was conducted to introduce the team and the project's objectives to the community as well as to encourage participation in surveys. The team was made to feel very welcome and the community put on an amazing kaikai.

A second community presentation was given before the research team departed to inform the community of the expedition's findings. Two of our local research assistants helped with presenting the research data and the community had a lot of interesting questions.

(For a full account refer to White 2012b).

Aitutaki

A presentation of the Aitutaki expedition findings was given at Ureia Hall on the 30th of January. The presentation was advertised on the radio, thanks to Charlie Waters, and people were personally invited by the research team. Unfortunately for CITP, the heavens opened and the rain flooded roads and buildings and attendance was lower than expected. However, despite the rain, fourteen people still attended and the results were very positively received.

An information hand-out was made by CITP on the 'Ten most frequently asked questions about turtles'. This was printed by Charlie Waters and distributed to the people at the presentation. Interested community members engaged the team with questions about turtle biology and our future plans. They were keen to know how they could help the turtles and whether they should be protected by Island Bylaws.

Atiu

A presentation was given to the Takutea Board of Trustees about the planned surveys to be conducted on Takutea and why they are important. The Trustees granted CITP permission to and we discussed different initiatives to get the younger community members involved. It was agreed that CITP will give a presentation to the wider community when the team returns in November 2013 so that interested community members can accompany the team to Takutea and learn survey techniques.

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Tamanu
Bubble's Below

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To the island communities of Palmerston, Mauke, Aitutaki and Atiu

Meitaki!

To all of our good friends, we will look forward to seeing you again!

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Appendix 1

Nesting Habitat Suitability Assessment of Aitutaki

Main Island

Arutanga to Ureia [S18˚51.857'; W159˚47.982' – S18˚51.445'; W159˚47.723']

Type C– the substratum is very muddy and would be unlikely to provide adequate incubation conditions for nesting. The beach incline is very shallow with man-made structures or vegetation to the high-water level. Access is unobstructed but nesting would not be possible.

Amuri to Base One [S18˚51.445'; W159˚47.723' – S18˚49.676'; W159˚46.643']

Type B / C – This coastline consists of interchanging short sections of suitable and unsuitable nesting habitat. The most suitable sections of nesting habitat were typically in front of resorts / holiday accommodations where the beach has been manicured and vegetation cut back (refer to Figure 1). The beaches were generally sandy although some areas were highly congested with roots making nest construction a challenging prospect. In general, the beaches had a very shallow incline with vegetation within a few meters of the high-water level (refer to Figure 2). Access was unobstructed from the lagoon which was about one kilometre wide to the outer-reef and one to two metres deep.

Base One to the Boatshed Bar and Grill (north and east of the airport) [S18˚49.676'; W159˚46.643' – S18˚50.844'; W159˚45.382']

Type A – Current nesting was confirmed along this stretch of beach. The sandy beach was layered by a thick layer of kirikiri covering much of its area. The beach incline was moderate although the beach profile changed a lot during the expedition's duration. Access was obstructed by a wall of raised makatea running along much of the shoreline; however there were gaps where turtles could access the beach and the beach incline was generally shallower at these points. The beach was accessed via a short stretch of shallow lagoon (~1 metre deep) where the outer-reef bordered within 100 - 200 metres. The beach was backed by low bush with the airport runway situated behind. The airport does not affect nesting as there are no night flights; however this beach is used by off-road vehicles (refer to Figure 3). The beach end, near the Boatshed Bar and Grill is obstructed by rocks with the beach incline becoming steeper and the kirikiri larger preventing successful nesting here.

<u>Boatshed Bar and Grill to Ranganui's</u> (eastern end of the Ootu Peninsular) [S18˚50.844'; W159˚45.382' – S18˚50.888'; W159˚45.393']

Type C –The shoreline here has been modified recently by heavy digging equipment. The beaches are made from fine silty sand and they have a shallow incline. There are man-made structures (holiday accommodations and the boat landing area for the Aitutaki Lagoon Resort and Spa) and some scattered coconuts bordering this beach. Access to the northern shore is via a short stretch of lagoon (<100 metres) from the outer reef or via the channel between the Peninsula and Akitua. This channel has been modified and the water can be fast moving through here during certain tides or swell conditions.

<u>Ranganui's to Arutanga</u> [S18˚50.888'; W159˚45.393' – S18˚51.857'; W159˚47.982']

Type C – A majority of this coast line consists of muddy or silty-sand which would not provide adequate conditions for either nest construction or incubation (refer to Figure 4). The beach incline was very shallow with mixed forest to the high-water level. Access was unobstructed from the lagoon although the western shore south of Arutanga had some volcanic rocks preventing access to the shoreline.

<u>Arutanga</u> [S18˚51.857'; W159˚47.982' – S18˚51.857'; W159˚47.982']

Type C – Arutanga is the location of the main wharf and consists of concrete down to the water; therefore, no suitable nesting areas.

Figure 1 Pacific Resort beach north of Amuri (Type B)

Figure 2 western shore from Amuri to Base One (Type C)

Figure 3 north east shore on the Ootu Peninsular (Type A)

Figure 4 Ranganui's to Arutanga, the eastern shore (Type C)

The Motu:

When only one GPS position is given then this has been recorded on the north of the motu.

Akitua [S18˚50.949'; W159˚45.268']

Type B – The Aitutaki Lagoon Resort and Spa is located on this motu which has highly manicured and modified beaches. The sand surrounding the motu is scraped back on to the beaches to create deep water swimming channels and to replenish the sand on the motu. The beaches are continuously raked clean by Resort staff which would eradicate any signs of turtle emergence. The beaches consist of fine silty sand with a moderate to steep incline bordered by scattered coconuts or beach huts (refer to Figure 5). Beach access is unobstructed for most of the island from either the lagoon or the outer-reef via a short stretch (<100 metres) of shallow (~1 metre) lagoon.

Type C – The north east section [S18˚50.949'; W159˚45.268' – S18˚50.949'; W159˚45.268', refer to Figure 56] is quite rocky which would prevent access.

Figure 5 west beach of Akitua (Type B)

Figure 6 rocky section on the north-east side (Type C)

Angarei [S18˚51.336'; W159˚45.200'], Ee [S18˚51.557'; W159˚45.211'] and Mangere [S18˚52.071'; W159˚45.134']

Type B – The southwest coast of Ee [S18˚51.020'; W159˚45.175' – S18˚52.035'; W159˚45.112', refer to Figure 7] has several hundred metres of sandy beach which extend five to twenty metres above the high-water level. The beach has a shallow incline and is bordered by scattered coconut trees with unobstructed access from the lagoon.

Type C – There are two other beaches on these motu - The southern beach on Ee [S18˚52.180'; W159˚44.968' – S18.52.178; W159.45.001] has two to five metres of sandy beach extending above the high-water level on a very shallow incline. The beach is bordered by ngangie and access is unobstructed. When a test hole was dug at the back of the beach (~ 60 cm deep) the hole became waterlogged; therefore, this beach would not support nesting.

The southern tip of Mangere [S18˚52.178'; W159˚45.001' – S18˚52.180'; W159˚44.968', refer to Figure 8] has a fifty metre stretch of sandy beach extending approximately five metres above the high-water level. The beach has a shallow incline and is bordered by ngangie vegetation. Access is unobstructed from the lagoon but the beach is unlikely to support nesting as nests are likely to become waterlogged.

The east coast of all three motu [S18˚52.180'; W159˚44.968' - S18˚51.336'; W159˚45.200', refer to Figure 9] consists of raised makatea which would impede any emergence attempts by turtles, there are no sandy areas and ngangie vegetation bordered the makatea.

The northern and western shore of Angarei [S18˚51.336'; W159˚45.200' – S18˚51.531'; W159˚45.205'], Ee [S18˚51.557'; W159˚45.211' – S18˚51.906'; W159˚45.123'] and Mangere

[S18˚51.336'; W159˚45.200' – S18˚52.178'; W159˚45.001'] have a sandy substratum; however the ngangie vegetation meets the high-water level with a few sandy bays in between. These bays are congested with tough roots and nest construction would be difficult if not impossible. The incline of the beach is shallow and access is unobstructed from the lagoon (refer to figure 10).

Figure 7 south-west of Ee (Type B)

Figure 8 south beach of Mangere (Type C)

Figure 9 east shore of all three motu was makatea (Type C)

Figure 10 northern and western shores of Angarei and Ee and Mangere (type C)

Papau [S18˚52.876'; W159˚45.058']

Type A – The eastern beach [S18˚52.911'; W159˚44.967' – S18˚53.028'; W159˚44.921', refer to Figure 11] does not constitute a typical nesting beach as access is very difficult through numerous rocks to reach the short stretch of sandy beach. The beach had a layer of large kirikiri on its surface and ngangie vegetation within five to ten metres of the water's edge; however an old nest (~1 year old) was located and excavated (PA01, refer to Figure 12).

Type B – The northern beach [S18˚52.911'; W159˚44.967' – S18˚52.876'; W159˚45.058', refer to Figure 13] constitutes the best nesting habitat on Papau although no evidence of nesting was found. The sandy beach had a thin layer of kirikiri and extended five to ten metres from the high-water level on a shallow incline. Low bush vegetation bordered the beach and there was no obstruction to access from the lagoon or the outer reef; which is situated within a couple of hundred metres and accessed via a passage.

Type C – The south eastern corner of Papau [S18˚52.911'; W159˚44.967' - S18˚52.911'; W159˚44.967', refer to Figure 14] consisted of raised makatea for a short section before the sandy beaches started again. The southern and eastern shores have ngangie vegetation coming to the high-water level with some sandy bays in between. These bays are unlikely to support nesting as they have a shallow incline, they are congested with tough roots and they do not extend far enough from the high water level to prevent waterlogging of the nests. Access would be unobstructed from the lagoon.

Figure 11 eastern shore of Papau (Type A)

Figure 12 nesting confirmed on the eastern shore of Papau

Figure 13 northern shore of Papau (Type B)

Figure 14 southern and eastern shore of Papau (Type C)

Tavaeruaiti [S18˚53.428'; W159˚44.623'] and Tavaerua [S18˚53.564'; W159˚44.536']

Type B – Both motu had suitable nesting areas on the their northern shores (Tavaerua [S18˚53.557'; W159˚44.546' – S18˚53.554'; W159˚44.522'] and Tavaeruaiti [S18˚53.443'; W149˚44.457' – S18˚53.431'; W159˚44.605'], refer to Figure 15) which provide ten to twenty metres of sandy beach extending above the high-water level on a shallow incline. These beaches were bordered by mixed forest with unobstructed access from the lagoon; however both of these beaches were fifty metres or less in length.

Tavaerua had a suitable nesting beach on the south eastern shore [S18˚53.745'; W159˚44.357' – S18˚53.715'; W159˚44.344', refer to Figure 16] which was similar to the northern spits in size, substrata and amount of sand available above the high-water level although the access along the reef side was obstructed by rocks.

Type C – The southern beach of Tavaeruaiti [S18˚53.508'; W159˚44.457' – S18˚53.443'; W159˚44.627', refer to Figure 17] was sandy with a shallow incline and bordered by ngangie vegetation; however, there was only two to three metres of sand above the high-water level which would be insufficient to support nesting. As the beach proceeded westerly the ngangie vegetation bordered the high-water level and the substrata became rockier (refer to Figure 18).

The long southern beach of Tavaerua [S18˚53.745'; W159˚44.357' – S18˚53.715'; W159˚44.344'] was sandy with low bush and mixed forest bordering it; however, due to the shallow incline and only two to three metres of sand extending above the high-water level, nesting would be unlikely.

The eastern shore of both motu (Tavaeruaiti [S18˚53.431'; W159˚44.605' – S18˚53.508'; W159˚44.457', refer to Figure 18] and Tavaerua [S18˚53.715'; W159˚44.344' – S18˚53.554'; W159˚44.522']) consisted of raised makatea with ngangie vegetation and no suitable areas for nesting.

The western shore of Tavaerua [S18˚53.557'; W159˚44.546' – S18˚53.709'; W159˚44.499'] consisted of ngangie vegetation down to the high-water level with sandy bays congested with roots. Access to the western shore was unobstructed from the lagoon but nesting would not be possible except for a short stretch of narrow beach [S18˚53.672'; W159˚44.525' – S18˚53.652'; W159˚44.546'] which had five metres of sand extending above the high-water level, nesting may be possible here although unlikely.

Figure 15 northern beach of Tavaeruaiti (Type B)

Figure 16 southern beach of Tavaerua (Type B)

Figure 17 southern beach of Tavaeruaiti (Type C)

Figure 18 eastern shore of Tavaeruaiti (Type C)

Akaiami [S18˚54.119'; W159˚43.910' – S18˚54.651'; W159˚43.886']

Type A – Evidence of nesting was discovered on the beach stretching from the north-west around to the north-east of Akaiami [S18˚54.227'; W159˚44.000' – S18˚54.186'; W159˚43.734'] where ten or more old nests (≥ 1 year old) and several attempts were situated in amongst the vegetation. The sandy beach had varying quantities of kirikiri on the surface and a shallow to moderate incline. Vegetation on the western shore was mainly mixed forest fronted by low bush (refer to Figure 19) which changed through to a dominance of ngangie as the beach rounded the north and continued along the eastern shore (refer to Figure 20). The access to some of the north-eastern shore was obstructed by rocky outcrops; however, these were short sections and could be easily navigated around. The northern beach is accessed from the lagoon or the outer-reef via a short stretch (<100 metres) of shallow lagoon (~1 metre).

Type B – The east beach continued south from the northern 'Type A' beach [S18˚54.186'; W159˚43.734' – S18˚54.369'; W159˚43.666', refer to Figure 21] and is differentiated by sections of raised makatea (up to 1 metre high) bordering the shore intersected with gaps of varying lengths enabling beach access. The sandy beach extends five to fifteen metres above the high-water level; however, some sections are covered by a thick layer of kirikiri which may prevent nest construction. The beach has a moderate incline which becomes steep at its southern end. The beach is bordered by ngangie and some low bush vegetation. Access from the outer-reef would be via a short stretch (<100 metres) of shallow lagoon (~1 metre).

The southern beach [S18˚54.583'; W159˚53.683' - S18˚54.657'; W159˚43.813'] provides adequate nesting habitat although the approach is quite rocky and the beach incline steep. The extent of the nesting area is narrow; however, due to the steepness of the incline it could support nesting. The substratum is sandy with some kirikiri and it is bordered by low bush vegetation. Access could be either from the lagoon or from the outer reef.

The south-western beach where Gina's Beach Lodge and Akaiami Paradise are situated [S18˚54.583'; W159˚53.683' - S18˚54.657'; W159˚43.813', refer to Figure 22] consists of five to ten metres of sandy beach extending above high-water on a shallow incline and bordered by a sparse mixed forest; access is unobstructed from the lagoon. The accommodations are situated far enough back from the beach so as not to cause problems to nesting turtles although no assessment on lighting has been attempted (due to their location on the motu). As the beach extends north, it becomes narrower with the mixed forest becoming denser.

Type C – The western shore in-between the south-western (Type B) and northern (Type A) beaches [S18˚54.320'; W159˚43.898' - S18˚54.227'; W159˚44.000'] has vegetation bordering the high-water level which changes from mixed forest to ngangie as it proceeds northward. The few sandy coves were congested with roots and the access became rockier.

The eastern beach declined in suitability as it continued south [S18˚54.369'; W159˚43.666'; S18˚54.583'; W159˚53.683', refer to Figure 23] until raised makatea formed a continuous barrier obstructing access. The sandy beach disappeared completely and the ngangie vegetation bordered the makatea. This section continues until the southern (Type B) beach.

Between the southern beach and the south-western beach, where the accommodation are situated, [S18˚54.657'; W159˚43.813' – S18˚54.651'-W159˚43.886', refer to Figure 24] there is a moderately inclined sandy beach where ngangie vegetation borders the high-water level offering no suitable areas for nesting; access would be unobstructed from the lagoon.

Figure 19 west shore of Akaiami's north Type A beach

Figure 20 east shore of Akaiami's north Type A beach

Figure 21 a makatea free section on Akaiami's eastern beach (Type B)

Figure 22 Akaiami's south west beach in front of Gina's Beach Lodge (Type B)

Figure 23 solid makatea on the south-east shore (Type C)

Figure 24 south shore with ngangie vegetation meeting the high-water level (Type C)

Muritapua [S18˚54.857'; W159˚43.853']

Type B – The northern beach [S18˚54.857'; W159˚43.853' – S18˚54.855'; W159˚43.809', refer to Figure 25] has approximately ten metres of suitable sandy beach above the high-water level with a shallow incline. The beach is bordered by mixed forest and has unobstructed access from either the lagoon or the outer-reef close by.

The southern beach [S18˚54.936'; W159˚43.769' – S18˚54.925'; W159˚43.845'] is sandy with a shallow incline and bordered by ngangie vegetation. Along much of the beach length there are only a few metres of sand above the high-water level except on the spit where there is more than five metres of suitable nesting area (refer to Figure 26). The incline on the narrower stretch of the beach is steeper than on the spit and so nesting may be possible along the back edge. Access is unobstructed from either the lagoon or from the outer-reef close by (<200 metres).

Type C – The eastern shore [S18˚54.855'; W159˚43.809' – S18˚54.936'; W159˚43.769', refer to Figure 27] consists of raised makatea bordered by ngangie vegetation.

The western shore [S18˚54.936'; W159˚43.769' – S18˚54.857'; W159˚43.853', refer to Figure 28] has sandy beaches with ngangie vegetation bordering the high-water level. The few sandy bays were congested with roots preventing nest construction; access is unobstructed from the lagoon.

Figure 25 northern beach (Type B)

Figure 26 widest section on the southern beach (Type B)

Figure 27 east shore (Type C)

Figure 28 west shore (Type C)

Tekopua [S18˚55.212'; W159˚43.776' – S18˚56.165'; W159˚43.967']

Type B – There is a small spit on the north of Tekopua which is about thirty metres in length with fifteen metres of sand extending above the high-water level. The beach has a shallow incline, is bordered by ngangie vegetation and has unobstructed access from either the lagoon or from the outer-reef close by (~250 metres).

The eastern shore [S18˚55.599'; W159˚43.677' – S18˚56.055'; W159˚43.706', refer to Figure 29] has a stretch of beach in amongst the Type C raised makatea sections where the makatea is lower or completely absent permitting beach access. The sandy beach is quite wide in places (> 10 metres) and there is some kirikiri on the surface. The beach incline is shallow and it is bordered by low bush vegetation; access is from the outer-reef via a short stretch (<100 metres) of shallow (~1 metre) lagoon.

The beach on the southern end of the western shore [S18˚56.132'; W159˚44.101' – S18˚56.007'; W159˚43.921', refer to Figure 30] has more than 10 metres of sand above the high-water level and a shallow incline. The beach is bordered by low bush and mixed forest with unobstructed access from the lagoon or from the reef via the channel between Tekopua and Tapuaetai.

Type C – The majority of the shoreline of Tekopua is unsuitable for nesting. The western shore and around the north of the island [S18˚56.007'; W159˚43.921' – S18˚55.212'; W159˚43.776', refer to Figure 31] consists of ngangie vegetation bordering the high-water level with a few sandy bays congested with roots; access is unobstructed from the lagoon.

As this beach continues to the eastern shore [S18˚55.212'; W159˚43.776' – S18˚55.599'; W159˚43.677', refer to Figure 32], beach access is prevented by raised makatea which is fifty metres wide and bordered by ngangie vegetation. As this section continues south the makatea becomes thinner with a sandy beach behind, although this remains inaccessible. The vegetation starts to comprise of low bush along its front edge with ngangie behind. The makatea eventually breaks down to the Type B beach described above.

The makatea starts again [S18˚56.055'; W159˚43.706' – S18˚56.207'; W159˚43.772'] south of the Type B beach again preventing access with ngangie vegetation bordering behind.

At the south eastern tip the makatea stops and thick ngangie vegetation borders the high-water level [S18˚56.207'; W159˚43.772' – S18˚56.165'; W159˚43.967', refer to Figure 33] barring any access to the land. As the shore proceeds westerly the vegetation turns to mixed forest.

There is a small motu [S18˚56.180'; W159˚43.786'] just off the southern tip of Tekopua which consists mainly of makatea with some sand on the western tip and mostly ngangie vegetation.

The vegetation thins along the southern coast and a sandy beach with a very shallow incline starts [S18˚56.165'; W159˚43.967' – S18˚56.132'; W159˚44.101', refer to Figure 34]. The vegetation, a mixture of ngangie and coconut, borders the high-water level; however, there are many sizeable gaps in-between the vegetation allowing beach access but the incline is so shallow that nests would become waterlogged at high- tide. This beach joins the Type B beach on the south-western shore.

Figure 29 eastern beach (Type B)

Figure 30 south-western beach (Type B)

Figure 31 north-western shore (Type C)

Figure 32 north-eastern shore (Type C)

Figure 33 southern shore (Type C)

Figure 34 southern beach (Type C)

Tapuaetai (One-Foot Island) [S18˚56.188'; W159˚44.238]

Type B – The north-western beach [S18˚56.188'; W159˚44.238' – S18˚56.196'; W159˚44.146', refer to Figure 35] is sandy and extends for ten to twenty metres above the high-water level with scattered coconut and a few buildings bordering the back of the beach. The beach incline is shallow and access is unobstructed from the lagoon or from the outer-reef via the channel in-between Tapuaetai and Tekopua. The lagoon cruises disembark on this section of beach but this is unlikely to have an impact on turtles nesting.

The southern beach [S18˚56.305'; W159˚44.084' – S18˚56.188'; W159˚44.238', refer to Figure 36] has ten metres of sandy beach extending above the high-water level which narrows as it continues west to just a few metres. The beach has a shallow incline with dense mixed forest bordering it; access is unobstructed from the lagoon.

Type C – The northern shore east of where the lagoon cruises disembark [S18˚56.196'; W159˚44.146' – S18˚56.246': W159˚43.997', refer to Figure 37] is unsuitable for nesting except for a short section (~30 metres) of sandy beach extending five to eight metres above the high water level. The main stretch; however, has mixed forest either bordering the high-water level or within a couple of metres with roots congesting the accessible sand. Access is unobstructed from the lagoon via the channel in-between Tapuaetai and Tekopua.

The eastern shore [S18˚56.246'; W159˚43.997' – S18˚56.305'; W159˚44.084', refer to Figure 38] is rocky with a high berm (~1 metre) topped by thick mixed forest vegetation a few metres from the high-water level.

There is a short section (~50 metres) on the west coast in-between the southern and the north-western Type B beaches where it narrows, becomes thick with roots and a small berm borders the beach a few metres from the high-water level preventing access.

Figure 35 north-western beach (Type B)

Figure 36 southern beach (Type B)

Figure 37 northern shore (Type C)

Figure 38 eastern shore (Type C)

Sand bar west of Tapuaetai

Type B – The sand bar bordering the sand flats to the west of Tapuaetai provides suitable nesting habitat with a shallow incline leading flat topped area (50 x 80 metres) of suitable nesting habitat which has a sparse cover of young coconut trees.

Small Island south of Tapuaetai [S18˚56.390'; W159˚44.128']

Type B – The whole of this small motu (100 metres x 50 metres) is suitable for nesting with a good sandy substratum, some undeveloped bushy vegetation in the middle and unobstructed access from the lagoon

Motukitiu [S18˚56.752'; W159˚44.019']

Type B – The western shore [S18˚56.971'; W159˚44.051' – S18˚56.752'; W159˚44.019', refer to Figure 39] has a sandy beach with five to ten metres of sand extending above the high-water level bordered by mixed forest. The access is unobstructed from the lagoon although shallow (< 0.5 metres) for several hundred metres. This beach could support nesting underneath the overhanging vegetation.

There was a small section of beach on the north-eastern shore [S18˚56.868'; W159˚43.877'] about sixty metres in length, which provided up to ten metres of sandy substrata above the high-water level and bordered by ngangie vegetation. Access is unobstructed from the outer-reef close by but the incline is very shallow and this beach may become inundated if large swells breach the east reef.

The sandy beach on the south-eastern shore [S18˚57.011'; W159˚43.929' – S18˚57.017'; W159˚43.979', refer to Figure 40] is about one hundred metres in length and extends for twenty metres or more above the high-water level. The beach incline is shallow and is bordered by mixed forest. Access is difficult as there is a lot of rocky obstructions.

Type C – The northern shore [S18˚56.752'; W159˚44.019' – S18˚56.805'; W159˚43.933', refer to Figure 41] consisted of a narrow sandy beach with mixed forest growing to the high-water level and access would be difficult across a shallow rocky pavement.

After the north-east (Type B) beach [S18˚56.805'; W159˚43.933' – S18˚56.868'; W159˚43.877'] the shoreline became inaccessible due to a raised section of makatea bordered by ngangie vegetation.

The southern coast [S18˚57.017'; W159˚43.979' – S18˚56.971'; W159˚44.051', refer to Figure 42] was unsuitable due to a very thick layer of kirikiri which would prevent nest construction and the steep incline of the beach. This beach is bordered by mixed forest and access would be unobstructed from the very shallow lagoon.

Figure 39 the western beach (Type B)

Figure 40 the south-eastern beach (Type B)

Figure 41 the northern shore (Type C)

Figure 42 the southern shore (Type C)

Moturakau [S18˚55.532'; W159˚45.032']

Type B – Both the northern [S18˚55.532'; W159˚45.032' – S18˚55.462'; W159˚44.962', refer to Figure 43] and the southern [S18˚55.560'; W159˚44.983' – S18˚55.581'; W159˚45.028', refer to Figure 44] shore had suitable sandy beaches with shallow inclines, the northern beach was wider (2 - 20 metres) than the southern beach (5 – 10 metres); however, both were bordered by mixed forest with unobstructed access from the lagoon.

Type C – The eastern shore [S18˚55.462'; W159˚44.962' – S18˚55.560'; W159˚44.983', refer to Figure 45] had thick mixed forest vegetation growing to the high-water level for a short span which was then displaced by a solid cliff of rock completely obstructing access.

The western shore [S18˚55.581'; W159˚45.028' – S18˚55.532'; W159˚45.032', refer to Figure 46] was also very rocky preventing access to the beach which is bordered by mixed forest.

Figure 43 the wide northern beach (Type B)

Figure 44 the southern beach (Type B)

Figure 45 the rocky eastern shore (Type C)

Figure 46 the rocky western shore (Type C)

Rapota [S18˚55.702'; W159˚45.515']

Type C – Rapota did not provide any areas suitable for nesting except for a short stretch of beach on the south-west shore [S18˚55.722'; W159˚45.499' – S18˚55.702'; W159˚45.515', refer to Figure 47]. This short sandy beach (~50 metres) was about five to seven metres wide on a shallow incline and heavily shaded by large trees. There was a thick layer of leaf litter on the ground and no direct sunlight. Access would be unobstructed from the lagoon.

The eastern and southern shores [S18˚55.671'; W159˚45.447' – S18˚55.722'; W159˚45.499', refer to Figure 48] consisted of large volcanic rocks preventing any access onto the motu. There was a small sandy beach located on the south-east shore but this would be submerged at high tide (refer to Figure 49).

The western shore [S18˚55.702'; W159˚45.515' – S18˚55.671'; W159˚45.447', refer to Figure 50] was rocky for about thirty metres after the south-western shady beach (see above) until it rounded onto the north shore where the substratum was sandy; however, the incline was very shallow with thick mixed forest bordering the high-water level. Fallen coconut trees, thick leaf litter and dense vegetation would prevent access from the lagoon and preclude nesting.

Figure 47 south-western shady beach (Type C)

Figure 48 south and eastern shore (Type C)

Figure 49 small beach in the south east (Type C)

Figure 50 northern beach (Type C)

Honeymoon [S18˚54.784'; W159˚49.682']

Type A – This motu is a large sand bar with mixed forest in its centre. It provides ideal nesting habitat for most of its length with only the extremities on the northern section becoming inundated at high tide. The incline along the southern section, surrounding the vegetation, is moderate leading to a flat-topped sand bar. There is about forty metres of suitable nesting habitat surrounding the mixed forest and access is unimpeded from all sides (refer to Figure 51). An old nest (HM01) was found on the southern side and excavated (refer to Figure 52).

Figure 51 the northern sand spit looking south (Type A)

Figure 52 the southern beach where a nest was situated (Type A)

Maina [S18˚54.801'; W159˚49.933']

Type B – All of the beach area on Maina is suitable for nesting [S18˚54.874'; W159˚49.969' - S18˚54.801'; W159˚49.933']. The southern beach consists of five to ten metres of sand with a moderate incline and backed by thick low bush vegetation (refer to Figure 53). As the beach continues west and round to the north of the motu the beach becomes wider (> 10 metres), the incline shallower and the vegetation sparser (refer to Figure 54). Access to the beach is unobstructed for its whole length with the outer-reef situated about 300 – 500 metres from the southern and western shores of the motu.

Type C – The eastern shore [S18˚54.801'; W159˚49.933' – S18˚54.874'; W159˚49.969'] is rocky with a high berm (~ 1 metre) preventing access on to the motu. The vegetation here is thick mixed forest and the ground is congested with roots.

Figure 53 southern beach (Type B)

Figure 54 northern beach (Type B)

Appendix 2

Nesting Activity and Reproductive Success Data

Table 1 nesting activity data for Aitutaki

Date	Beach	Nest code	Lat	Long	Track type	Attempts	Nesting Activity
09/11/2012	Ootu north	ON1	18.50.284	159.45.538	NEST	3	AEC - 2 x BP - Nest
21/11/2012	Ootu north	N/A	18.50.052	159.45.656	NA	0	
21/11/2012	Ootu north	N/A	18.50.123	159.45.632	AEC	8	2 x AEC - 4 x BP - AEC - BP
21/11/2012	Ootu north	ON2	18.50.095	159.45.648	NEST	4	2 x BP - 2 x AEC - Nest
04/12/2012	Ootu north	ON3	18.50.122	159.45.632	NEST	2	BP - AEC - Nest
14/12/2012	Ootu north	ON4	18.50.104	159.45.645	NEST	5	BP - AEC - BP - 2 x AEC - Nest
25/12/2012	Ootu north	ON5	18.50.081	159.45.655	NEST	0	Nest
06/01/2013	Ootu north	ON6	18.50.027	159.45.689	NEST	7	3 x AEC - BP - 2 x AEC - BP - Nest

Table 2 excavation data for Aitutaki

Date	Nest code	Beach	Dist to sea	Dist top egg	Dist bot EC	Hatched shells	Unfert	Eye spot	Early	Mid	Late	Total embryos
27/11/2012	PA01	Papau	6.2	20	50	22	48	0	0	3	16	19
29/11/2012	AK01	Akaiami	16	33	47	67	7	0	0	0	0	0
05/12/2012	HM01	Honeymoon	47.1	48	70	85	0	0	0	0	0	0
11/01/2013	ON1	Ootu north	23.15	32	53	97	4	0	0	0	0	0
30/01/2013	ON2	Ootu north	28.5	34	50	98	3	0	0	0	0	0
14/03/2013	ON3	Ootu north	23.5	38	50	119	4	0	1	0	1	2
15/03/2013	ON4	Ootu north	26.7	29	40	94	4	0	0	0	1	1
14/03/2013	ON5	Ootu north	28.7	28	39	101	3	0	0	0	0	0
14/03/2013	ON6	Ootu north	35.8	22	38	90	3	0	0	0	1	1

Table 3 excavation data (continued)

Nest code	Dead pipped	Live pipped	Un-hatched	DH[1]	DH top 10cm	LH[2]	LH top 10cm	Clutch	% success	Researcher	Notes
PA01	2	0	69	0	0	0	0	91	24.2	Phil	Old nest ~ 1 year
AK01	0	0	7	0	0	0	0	74	90.5	Phil	Old nest ~ 1 year
HM01	3	0	3	0	0	0	0	88	96.6	Phil	Old nest ~ 3 months
ON1	4	2	10	1	0	10	2	107	90.7	Amanda	
ON2	1	0	4	0	0	1	0	102	96.1	Karissa	
ON3	0	0	6	0	0	0	0	125	95.2	Theresa	
ON4	2	0	7	1	0	0	0	101	93.1	Theresa	
ON5	0	1	4	0	0	3	0	105	96.2	Theresa	
ON6	0	0	4	0	0	3	0	94	95.7	Theresa	

[1] Dead hatchling
[2] Live hatchling

Appendix 3

Nesting Habitat Suitability Assessment on Atiu

The nesting habitat suitability assessment was conducted anti-clockwise from the harbour. Each of the following data points was accessed by paths leading to shore from the islands perimeter road. A majority of the coastline consisted of high makatea cliffs lined with Pacific ironwood *Casuarina equisetifolia* with no suitable habitat for nesting turtles (refer to Figure 1). Scattered in amongst the makatea cliffs were numerous small coves and beaches; some of which were suitable for nesting and are accessed by turtles traversing the narrow and very shallow lagoon.

Type C – The harbour - Taunganui Landing [S19°58.751'; W158°08.372'] is surrounded on both sides by high makatea cliffs. The harbour is a concrete construction with high walls and a boat ramp leading into it.

Type C – [S18°59.055'; W158°08.462'; - S19°59.144'; W158°08.498', refer to Figure 2] two small sandy bays which would be inundated at high tide. The bays were surrounded on both sides by high makatea cliffs lined with Pacific ironwood. The shallow lagoon is approximately eighty metres wide.

Type B – [S19°59.235'; W158°08.473', refer to Figure 3] A small sandy bay about ten metres wide with a shallow incline leading to fifteen metres of suitable nesting sand extending above the high-water level; a test hole was dug to the required depth (50 – 60cm). The beach is surrounded by makatea cliffs lined with Pacific ironwood which heavily shades the beach. The lagoon is approximately sixty metres wide. Nesting here is possible although unlikely.

Type C – Oravaru Landing [S19°59.396'; W158°08.499', refer to Figure 4] is a small sandy beach about twenty metres wide. Most of this beach would be inundated at high tide except for a small area ten metres wide which extends for three to four metres above the high-water level. The beach has a moderate incline and is surrounded by makatea cliffs lined with Pacific ironwood. Nesting is possible here but nests are likely to become inundated during large swells; the lagoon is approximately sixty metres wide.

Type C – [S19°59.515'; W158°08.498' refer to Figure 5] consists of two small sandy bays which extend two metres above the high-water level. The beach is bordered by makatea cliffs lined with Pacific ironwood and the lagoon is approximately sixty metres wide.

Type B – Taungaroro Landing [S20°00.260'; W158°08.278', refer to Figure 6] is a large sandy beach about eighty metres wide extending ten to forty metres above the high-water level. The beach has a steep incline along the water's edge which then levels out. The beach is bordered by makatea cliffs lined with Pacific ironwood. This beach offers the most suitable nesting habitat along this section of coast.

Figure 1 Atiu's shoreline mainly consisted of high makatea cliffs lined with Pacific ironwood (Type C)

Figure 2 a small sandy bay just south of the harbour (Type C)

Figure 3 a small sandy bay suitable for nesting (Type B)

Figure 4 Oravaru Landing, nesting maybe possible but unlikely (Type C)

Figure 5 the northernmost of two sandy bays (Type C)

Figure 6 Taungaroro Landing (Type B)

Type B – Tumai Landing [S20°00.424'; W158°08.131', refer to Figures 7 & 8] is a small sandy beach about forty metres wide and extending fifteen to twenty metres above the high-water level. The beach has a shallow incline and is surrounded by makatea cliffs with scattered Pacific ironwood and low bush vegetation. Access from the narrow lagoon which is approximately forty metres wide is partially obstructed by rocks.

Type C – [S20°00.528'; W158°08.004', refer to Figure 9] a small rocky bay with a shallow sand layer. The bay is about thirty five metres wide and extends two to three metres above the high-water level. A test hole was dug to thirty centimetres when solid rock prevented digging any deeper, therefore, this bay would not support nesting. The beach was surrounded by makatea cliffs lined with Pacific ironwood.

Type C – Vai Piake Landing [S20°00.788'; W158°07.786'] did not constitute any beach area; only raised makatea cliffs lined with Pacific ironwood. The lagoon is approximately thirty metres wide.

Type C – [S20°00.865'; W158°07.708', refer to Figures 10 & 11] consisted of a double cove beach. The northern cove was six metres wide with three metres of sand extending above the high-water level. The beach was steeply inclined with rocks partially obstructing beach access, nesting maybe possible on this beach; however it is unlikely. The second cove was much larger; about fifty metres wide and extending twenty five metres above the high-water level on a shallow incline. Rocky outcrops protruded from the sand in the middle of the beach and two test holes were dug (on either side of the bay) to about forty centimetres deep before solid rock was struck; therefore, this beach would not support nesting. Both beaches were surrounded by makatea lined with Pacific ironwood.

Type C – Te Tau Landing [S20°01.706'; W158°07.148', refer to Figures 12 & 13] the southern tip of Atiu had small scattered sandy coves with moderate to steep inclines. Most of the beaches had makatea along the water's edge preventing access; however, there were very narrow access points to one or two of the small beaches which would make them a Type B. The beaches with access extended five to ten metres above the high-water level and were surrounded by makatea with very low scrub vegetation. Nesting would have been possible if access points are found; therefore nesting is unlikely.

Type B – [S20°01.670'; W158°06.970', refer to Figure 14] a small sandy beach approximately fifty metres wide and extending about five metres above the high-water level on a shallow to moderate incline. This beach is bordered by high makatea cliffs with low scrubby vegetation. Nesting is possible but unlikely due to the beach becoming heavily 'washed' or inundated during high swells. The lagoon is approximately sixty metres wide.

Type C – [S20°01.454'; W158°06.705', refer to Figures 15 & 16] a one hundred metre wide rocky bay with a shallow layer of sand. The bay extends about fifteen metres above the high-water level and is surrounded by flat makatea and some rocks obstruct beach access form the lagoon.

Figure 7 Tumai Landing a wide sandy beach south of Taungaroro Landing (Type B)

Figure 8 rocks partially obstructing access to one of the bays at Tumai Landing (Type B)

Figure 9 a small rocky bay (Type C)

Figure 10 the northernmost of two small beaches (Type C)

Figure 11 the southern bay with a shallow sand layer covering rock (Type C)

Figure 12 Te Tau Landing; a beach suitable for nesting but with a very narrow access from the lagoon (Type B)


Figure 13 the main beach at Te Tau Landing; access from the lagoon is obstructed by the makatea (Type C)


Figure 14 a small beach situated east of Te Tau Landing (Type B)


Figure 15 wide rocky bay with little sand (Type C)


Figure 16 looking north-east from the rocky bay

Type C – [S20°01.391'; W158°06.635', refer to Figure 17] a fine kirikiri beach which is approximately one hundred metres long and extends four to six metres above the high-water level. The beach is on a steep incline and when test holes were dug; they constantly collapsed. The beach is surrounded by makatea cliffs and low bush vegetation.

Type C – a series of three small bays; the first [S20°01.290'; W158°06.497', refer to Figure 18] and second [S20°01.290'; W158°06.497'] bays are rocky with a thin layer of sand. The first bay is approximately thirty five metres wide and extends for eight metres above the high-water level. Both bays are surrounded by makatea cliffs covered in low bush vegetation.

Type B – the third bay [S20°01.218'; W158°06.405', refer to Figure 19] is a sandy beach which is approximately one hundred metres wide of which fifty metres extends seven metres above the high-water level; the other fifty metres would be inundated at high tide. The beach has a moderate incline and a test hole was dug to sixty centimetres. Beach access is unobstructed across the lagoon which is approximately forty metres wide.


Figure 17 a long narrow beach with a steep incline and a fine kirikiri substratum. Test holes were difficult to dig (Type C)


Figure 18 the first bay only has a thin layer of sand over a rocky substratum (Type C)


Figure 19 the third bay has suitable nesting habitat (Type B)


Figure 20 south-western bay of Maitai Landing (Type B)


Figure 21 north-eastern bay of Mai Tai Landing (Type B)


Figure 22 north-eastern bay of Mai Tai Landing (Type B)

Type B – Mai Tai Landing consists of two sandy bays separated by a makatea overhang. Both beaches are surrounded by makatea and low bush vegetation. The south-western beach [S20°01.123'; W158°06.227', refer to Figure 20] is thirty metres long and extends for four to five metres above the high-water level on a steep incline. This beach may support nesting; however, it is unlikely. The north-eastern beach [S20°01.067'; W158°03.121', refer to Figures 21 & 22] is one hundred and eighty metres long and extends five to fifteen metres above the high-water level on a moderate incline. This beach is one of the most suitable nesting beaches on the island.

Type C – [S20°01.037'; W158°06.064', refer to Figure 23] is a small bay with a thin layer of sand and kirikiri covering a visibly rocky substratum. The beach is approximately forty metres wide and extends about eight metres above the high-water level on a shallow incline. The beach is surrounded by makatea and low bush vegetation.

Type C – [S20°00.942'; W158°05.730', refer to Figure 24] a small sandy cove surrounding by makatea with low bush vegetation. The beach is likely to be inundated at high-tide.

Type B – Takau-roa Landing [S20°00.927'; W158°05.649', refer to Figure 25] is a small sandy beach approximately sixty metres wide and extending up to five metres above the high-water level. The access from the fifty metre wide shallow lagoon is partially blocked by rocks at its northern end.

Type C – [S20°00.885'; W158°05.514' refer to Figure 26] a small rocky cove with very little sand, surrounded by makatea cliffs with no vegetation.

Type B – [S20°00.721'; W158°05.271', refer to Figure 27] the first of three coves which form a long thin beach surrounded by makatea. The first south-western cove is about sixty metres wide and extends about five metres above the high-water level. There are a few boulders obstructing access at the southern end but these would be easily navigated around.

Type C – [S20°00.721'; W158°05.271'] the second cove is approximately twenty metres wide and extends 2-3 metres above the high-water level. Access is nearly completely obstructed by boulders along the water's edge.

Type C – [S20°00.721'; W158°05.271', refer to Figure 28] the third north-eastern cove is five metres wide and extends two to three metres above the high water level. There are a couple of boulders on the northern end of the beach but these would not obstruct access. A test hole was dug at the back of the beach and solid rock was struck at a depth of twenty five centimetres.

Type C – [S20°00.614'; W158°05.152'] a small sandy cove approximately seventy metres wide and extending one to two metres above the high-water level. The beach is surrounded by makatea cliffs and the lagoon is about fifty metres wide.

Type C – [S20°00.464'; W158°05.010' **-** S20°00.386'; W158°04.952', refer to Figures 29 & 30] a long thin beach divided up into three coves which are all surrounded by makatea cliffs. The first cove (south-easterly) is about forty metres wide and extends one to two metres above the high-water level on a shallow incline. The second and third coves (middle and north-westerly) are both about twenty five metres wide and extend three to four metres above the high water-level on a moderate incline. There are no obstructions to any of the beaches and the shallow lagoon as approximately fifty metres wide.

Figure 23 small rocky bay north-east of Maitai Landing

Figure 24 a small sandy cove which is likely to be inundated at high tide (Type C)

Figure 25 Takau-roa Landing (Type B)

Figure 26 small rocky cove with little sand (Type C)

Figure 27 the south-western bay (Type B)

Figure 28 the north-eastern bay (Type C)

Figure 29 the south-easterly of the three bays (Type C)

Figure 30 the middle of the three bays (Type C)

Type B – Oneroa Landing [S20°00.033'; W158°04.990', refer to Figures 31 & 32] is a large wide sandy beach surrounded by makatea with low bush vegetation. The beach is split into two distinct sections with the southerly section approximately one hundred and twenty metres wide and extending up to fifty metres above the high-water level. A turtle track was found underneath an overhang but no sign of nesting was found. The second section is approximately eighty metres wide and extends forty metres above the high-water level. There is no obstruction to access from the lagoon which narrows from eighty metres to thirty metres as it proceeds north.

Type C – [S19°59.951'; W158°05.026', refer to Figure 33] a long narrow sandy beach split into three coves. The beach is one hundred and thirty metres wide and extends four to five metres above the high-water level in three areas although most of the beach is only one to two metres above high-water. All of the coves are surrounded by makatea with low bush vegetation.

Type C – Tarapaku Landing [S19°59.124'; W158°05.572', refer to Figure 34] a sixty metre wide narrow sandy beach which extends two to three metres above the high-water level. The beach is surrounded by high makatea cliffs and access is unobstructed from the forty metre wide lagoon.

Type C – [S19°58.634'; W158°06.067', refer to Figure 35] a small very narrow sandy beach which would be inundated at high tide. The beach is surrounded by high makatea and access would be across the one hundred metre wide lagoon.

Type C – All of the shoreline north of Tarapaku Landing until the harbour (with the exception of the small beach listed above) consists of high makatea cliffs with a very narrow or non-existent lagoon (refer to Figure 36).

Figure 31 southern cove of Oneroa where a turtle track was found (Type B)

Figure 32 the northern cove of Oneroa (Type B)

Figure 33 long thin beach split into three coves (Type C)

Figure 34 Tarapaku Landing (Type C)

Figure 35 a small beach north of Tarapaku Landing

Figure 36 the shoreline along the north of the island