Pacific Islands Conservation Initiative

Cook Islands Turtle Project

Nesting Suitability Survey of Rarotonga, Cook Islands

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Contents

1 Summary

Undertaking beach surveys to determine suitability of nesting habitat is vital in ensuring the long-term conservation of marine turtle species and their habitats within the Cook Island archipelago and nearby Pacific Islands. The following beach and Marine surveys of Rarotonga were undertaken from the 28th of January to the 7th of February 2015 to assess suitability of habitat for nesting. Marine surveys were randomly undertaken at Papua passage and local knowledge was gathered from various companies around the island to determine which species of turtles and size-class were present. No nesting activity or signs of turtle tracks were located during the survey. Beaches were also categorised for nesting suitability and mapped accordingly. In total 30 km were surveyed. Of the 30km surveyed, 15 km of beach was considered suitable for nesting. These beaches were located on the southern side of the island and on average 13 meters wide, with a moderate incline, consisting primarily of sand or kirikiri substrata. They were well vegetated beaches with little or no disturbance.

Most of the beaches surveyed were in close proximity of resorts and in areas of high recreational use by tourists and tourist operators. Artificial lighting from resorts, proximity of roads to beaches and people walking on the beaches at night could also pose as another issue for nesting females because they respond negatively to white light. As a result, bright lights often disorient turtles causing them to abandon their nests or completely deter them ascending ashore to lay their eggs. This could explain why no nesting activity currently occurs on the beaches of Rarotonga.

To accommodate for nesting activity in the future, a human impact assessment of suitable beaches is advised to determine if human habitat alterations have influenced nest-site selection or microenvironments within nest chamber. It is also recommended that the beach characteristics of all fifteen islands be compared and correlations between successful and unsuccessful nesting attempts be identified. This will enable researchers to determine if turtles within the Cook Island archipelago select nest sites based on particular beach characteristics and to which variables are higher nest densities and improved hatching success rates associated with.

2 Introduction

The Cook Islands Turtle Project (CITP) was established in 2009 as part of a collaborative research effort between Dr. Michael White and the Pacific Island Conservation Initiative (PICI). Since its establishment, nesting activity, turtle sightings and/or anecdotal evidence has been reported in Aitutaki, Manihiki, Nassau, Palmerston Atoll, Pukapuka, Rakahanga, Suwarrow, Tongareva, Manuae, Rarotonga and Mauke. In water behavioural studies have taken place primarily in Papua passage, Rarotonga and Aitutaki (White, 2011; 2012; Bradshaw, 2013b). By identifying index beaches where turtles prefer to nest and understanding how turtles in the Cook Islands utilise their nearby habitats and surrounding waters, implementation of appropriate management strategies will allow for improved hatching success rates and the long-term survival of turtle populations. Marine surveys will also help scientists to determine which species and size-class of turtles are present in surrounding waters and how they utilise available habitat. It is envisioned that as research continues, in-water and beach assessment data will be available for all fifteen islands.

2.1 Importance of sea turtles

Marine sea turtles are culturally, economically and environmentally important to the Cook Island community and identity of Pacific Islanders. Culturally sea turtles are considered ocean ambassadors, symbolising longevity, stamina and tranquillity (Logan, 2006). Sea turtles are a must see for tourists who visit the island and are economically beneficial to small local businesses such as dive companies and tourist boat operators. Environmentally turtles are known as key indicator species in many coastal ecosystems (Jackson et al. 2001). Due to their herbivorous diet, adult green sea turtles play an important role in ocean ecosystems by maintaining healthy sea grass beds (Bjorndal, 1980; Thayer et al. 1984). When grazing on sea grass, green turtles prevent the accumulation of older portions of sea grass blades which are often overgrown with microorganisms, algae, invertebrates and fungi (Jackson, 2001). On the contrary, the sponge diet of hawksbill turtles helps them to maintain productivity of coral reef ecosystems (Leon & Bjorndal, 2002). During nesting and oviposition, turtle eggs provide nutrient-deficient beaches with an increased concentration of high quality nutrients which help vegetation to grow and dunes to stabilise (Bouchard & Bjorndal, 2000; Hannan et al. 2007). Turtles have also developed a symbiotic relationship with many species of fish and shrimp providing them with barnacles, algae and epibionts to feed on (Wilson et al. Unknown). Despite their importance, sea turtles around the world are becoming endangered and research concerning marine turtle populations in the Cook

Islands is lacking and data deficient (Meylan & Donnelly, 1999; Woodrom-Rudrud, 2010; White 2011, 2012).

2.2 Biology of sea turtles

Prior to nesting, females will spend several years foraging in preparation for their next migration to natal nesting beaches. Although the minimum breeding size and age at which a turtle reaches sexual maturity differs between individuals, species and populations, most nesting females will become sexually mature between the ages of 30-50 years (Miller et al. 2003). Once mature, females are believed to use the earth's magnetic field to navigate from their feeding grounds to breeding grounds. This phenomenon is referred to as natal homing and explains how turtles are able to imprint on magnetic features (i.e. angle of inclination and intensity of total field) of their natal beach as hatchlings, allowing them to return to breed and nest within the general geographical region from which they hatched (Meyland et al, 1990; Bowen et al, 1993, 1994, 1995; Lochmann et al. 1999). Due to the gradual change of the earth's geomagnetic field over time, females have been known to return to natal regions rather than to highly specific natal sites (Lochmann et al. 1999). Limpus (1985) also noted that during the same breeding season, loggerhead turtles returned to their regions of birth and selected nesting beaches that were of close proximity to one another (0-5km). This further supports strong site fidelity of nesting females to nesting beaches (Allard et al. 1994; Limpus et al. 1992) and emphasises the importance and need to identify and protect key nesting beaches in the Cook Island region to ensure that the overall aim of the project is met. Traditionally nesting is known from all of the Cook Islands except Mitiaro (Woodrom-Rudrud 2010).

As the process of migration, mating and nesting demands a high amount of energy, females will lay several clutches over a period of several months rather than nesting on a yearly basis (Miller et al. 2003). The reproductive effort of a sexually mature female involves the following stages; vitellogenesis, migration, egg production, oviposition and return migration (Miller et al. 2003). Commencement of vitellogenesis is highly dependent on quality and quantity of food source in foraging grounds (Bjorndal, 1997) and is linked to a combination of endogenous (hormone levels and fat reserves) and exogenous factors (Wibbels et al. 1990, 1992). Reproductive success is thus dependent on a number of variables and is not only limited by beach structure. Nevertheless, accessibility of beach and suitability for nesting are crucial to the long-term survival of turtle populations around the world, as site of oviposition is known to affect hatching and emergence success rates.

Four of the seven species of marine turtles are known to nest and inhabit waters surrounding the Cook Islands. The two most common species include the green turtle and hawksbill turtle. Nesting activity and in water behavioural observations are more prevalent for green turtles than hawksbills (White, 2011, 2012; Bradshaw, 2013b).

3 Study sites

3.1 Beach Surveys

The Cook Islands consists of 15 islands spread over approximately 2 million km2 of ocean from latitude 09°S to 23°S and longitude 156°W to 167°W. Geographically, these islands are divided into two groups. The northern group consists of islands which are mostly low-lying coral atolls, while the southern group generally consist of higher islands that are volcanic in origin.

The mountainous island of Rarotonga, Cook Islands, is surrounded by a fringing coral reef, which encloses shallow tidal lagoons (Spalding et al. 2001). The northern coastline is mostly rocky with the reef being close to shore; there is a small lagoon with sandy beaches near to Toa Motu. The eastern coastline is mostly coral boulders and rubble; in some places the reef drop-off abuts the land, and access from seawards is difficult (e.g. Ngatangiia and Matavera). Sandy beaches and the widest lagoons are located in the southeast at Muri; south (Vaima'anga); southwest (Aro'a); and west (Aorangi). The beaches at Blackrock, in the northwest, are mainly gravel or stones; although beach access from the lagoon is good.

In the tidal southern lagoon at Vaima'anga there are three passages through the coral reef: Ava'araroa, Papua and Rutaki. These passages provide the outflows back into the ocean for the waves that are continually breaking over the reef into the lagoon; consequently the current flow in these passages can be considerable dangerous at times.

Rarotonga is part of the southern group and is the youngest island within the Cook Island archipelago. Despite its age, Rarotonga is the largest of all islands having a circumference of 32km and stands 4,500m above the ocean floor with the highest peak on the island is 658m above sea level.

Rarotonga is divided into three main districts or tribes. Te Au O Tonga on the northern side of the island (Avarua is the capital), Takitumu on the eastern and southern side and Puaikura on the western side. Land districts are also used to divide the island. The Land District of Avarua is represented under vaka Te Au O Tonga, The Land Districts of Matavera, Ngatangiia and Titikaveka are represented under vaka Takitumu and the Land District Arorangi is represented under vaka Puaikura.

Figure 1. Map of Rarotonga

3.2 Marine Surveys

Papua Passage (S21˚15.586'; W159˚45.576') is the smallest of the four passages measuring two hundred and thirty metres in length, with a maximum width of thirty metres and a maximum depth of twelve metres in the outer gully (Bradshaw, 2013b). The passage consists of three sections; (1) the inner gully, (2) middle deep and (3) outer gully. The inner gully is the shallowest of all sections with a depth of about three to six metres. This section then narrows (Inner Narrows) into a wider deeper (ten to twelve metres) section of the passage referred to as the 'Middle Deep' (White, 2010). Majority of the bottom of the passage is sand whilst the sides of the 'Middle Deep' area and the rocky sides and outcrops of the 'Outer Gully' offer ideal conditions for coral to grow growth with wide coral shelves present on the eastern side. The 'Outer Gully' extends out to form a fringing reef wall with a shelf reef ranging out until it sharply drops off several hundred metres further south (Bradshaw, 2013b).

4 Methodology

Beach surveys were conducted after low tide which meant that surveys occurred at different times of the day. Specific sections of the beach were surveyed for presence of turtle tracks and nests. Beaches were also categorised for their suitability for nesting and mapped accordingly. Free swimming surveys were randomly undertaken in Papua passage. Although size of survey area and survey length was not defined, in-water observations enabled the researcher to determine what species, gender and size-class of turtles inhabited the waters south of Rarotonga. The following data was collected for each beach or sub-section of beach:

- Beach suitability for nesting;
- Identification of species of turtle from tracks left in the sand;
- Presence of nesting activity including both successful nests and non-nesting emergences (false crawls).
- Identification of predation and other threats (poached, human, marine) in area.

For comprehensive methodology refer to the Cook Islands Scientific Protocol for Turtle Monitoring (Bradshaw, 2013a).

4.1 Beach Surveys

Each beach or section of beach was assessed for its nesting suitability using the following criteria; beach length, width, elevation, incline, substrate type, accessibility from open water, sand softness and presence/absence of obstructions and vegetation.

The beaches were then categorised as either:

- Type A – Confirmed nesting
- Type B – Suitable for nesting but no nesting was confirmed (red)
- Type C – Mostly suitable but some sites not suitable (blue)
- Type D – Unsuitable for nesting (yellow)

The beach name (if applicable), and its location was recorded using a Garmin GPS (MAP 78). GPS coordinates and data was used to create a nest suitability map (refer to Figure 2).

4.2 Nest Activity Surveys

No nest activity or tracks were visible during the survey.

4.3 Marine Surveys

A limited number of marine surveys were conducted during this study. Free swimming surveys were randomly undertaken in Papua passage at low tide to assess which species, gender and size-class of turtles were present. Gender of adult sized turtles were assigned based on tail morphology (Casale et al. 2005). Although size of survey and length of survey time were not defined, photos of turtles were taken when sighted to verify sex, species and individuality of turtle. In order to gain a better understanding of relative abundance, population structure, distribution and status of marine sea turtles in the area, in-water behavioural studies with designated size and time limits are recommended for future marine surveys carried out in Papua passage and surrounding waters.

4.4 Anecdotal Evidence

Interviews were conducted with people who were considered to have a good knowledge of the lagoon, turtles and interactions with turtles. Interview questions were tailored to the interviewee; However a majority of the questions were the same or similar in nature (Refer to appendix 8.3a and 8.3b for comparison). 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.

Local knowledge of turtle sightings and anecdotal evidence was collected from the following people;

- Josh Dorton bran (2015) – Dive staff (Pacific Divers)
- Hue (2015); Owner of Reef Sub – Semisubmersible tours
- Staff of Captain Tama's Lagoon Cruizers (2015)
- Patrick Jaletzky (2015); Co-Owner of Adventure Cook Island.
- Jackie (2015); Marine Biologist and Co-owner of Marine Parks

5 Results

5.1 Nest Suitability

A total of 30 km of beach was surveyed. No evidence of nesting was found however, 15 km of beach was determined to have suitable characteristics for nesting (Fig 2). This beach was located between Arorangi and Muri beach districts along the southern end of the island. These beaches were on average 12 m wide with a moderate beach incline. They also had minimal human disturbance and were lightly vegetated with primarily palm trees and low lying shrubs. The substrata included sand and kirikiri, and there were minimal to no obstructions to the beach access.

The eastern coastline consists mostly of coralline rocks/fossils with little or no sand; also access from seawards is very difficult. Parts of the northern coast are also rocky and the lagoon is narrow or non-existent, but there are a few small sandy areas, particularly near to the airport. Much of the western coast has resorts on the sandy beaches. The best places however, are along the southern coast; where the lagoon is also widest.

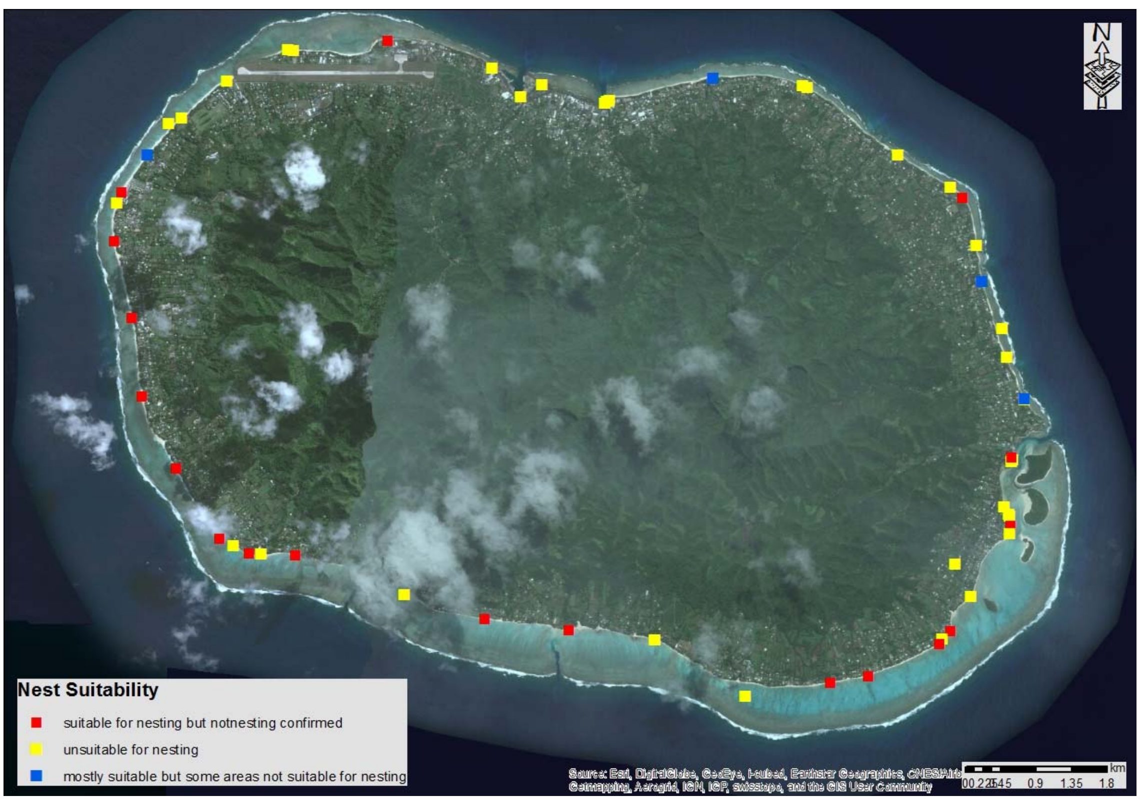

Figure 2. Nesting suitability map of Rarotonga.

5.2 Marine Surveys

Photos collected in Papua passage verified the presence of green and hawksbill turtles (Appendix 9.2). On average, 6-7 turtles were sighted on all occasions with one adult sized male encountered every survey. Nearly all the turtles encountered were either swimming (Figure 3,5 and 7 in Appendix 9.2)or resting (Figure 4 and 6 in Appendix 9.2) in the passage with the exception of the adult male green turtle who was often seen swimming close to the 'Outer Gully' (Figure 3 in Appendix 9.2). Majority of turtles observed were of juvenile or sub-adolescent size.

Previous in-water behavioural studies undertaken in Papua passage suggest that green turtles were significantly more abundant than hawksbill. The previous ratio of encounter suggested by Bradshaw (2013b) was three greens to one hawksbill whilst White (2012) reported a ratio of two greens to one hawksbill. Implementing regular scuba diver sighting surveys with local dive companies would enable researchers to gain a better understanding of how marine turtles utilise Rarotonga's reefs and lagoons and provide useful data on species population structure and behaviour. Despite lack of marine data, the high abundance of juveniles in Papua passage could indicate that it is an important developmental habitat for green and hawksbill turtles.

5.3 Anecdotal Evidence

Through communicating with local tourist boat operators and diving companies it is indicated that turtles are resident year round and are most abundant in Papua, Avarua and Rutaki passage (Hue (Reef Sub) pers. com. 2015). Turtles are often sighted by divers swimming in and out of the passages, resting on coral bommies or feeding on algae to the eastern side of the 'Middle Deep' section of Papua passage (Josh Dorton bran Pacific Divers) pers. com. 2015). Co-owner of Adventure Cook Island and Staff of Captain Tama's Lagoon Cruizers have also observed turtles on the peripheral edge of the lagoon to the South of the island. Green turtles of all size classes including large adult males and females were reported by a number of the interviewees, with the majority of adult sized green turtles observed swimming in the 'Outer Gully' of Papua passage which merges with the outer-reef (Josh Dorton bran (Pacific Divers) pers.com.2015). Although sightings of adult sized hawksbill turtles are rare, juveniles are often observed to the north of the island close to Avatu harbour and Traders Jacks (Hue (Reef Sub) pers. com. 2015; Patrick Jaletzky (Adventure Cook Island) pers. com. 2015). Both Hue and Patrick noted that overall more turtles are sighted in winter to north of the island whilst a greater abundance of turtles are encountered to the south of the island in summer. Jackie, Hue and staff of Captain Tama's Lagoon Cruizers reported an increase in turtle sightings in waters surrounding Rarotonga. The presence of turtles of all size-classes thus indicates that the reef which surrounds Rarotonga provides adequate resources for both foraging and refuge and sustains a resident population.

5.4 Capacity Building, Training and Education

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. During this survey, CITP did not train any local volunteers. However, a detailed outline of CITP's work plan was forwarded to relevant local government and environmental agencies. All interested parties were given the opportunity to partake in the surveys and data collection process. Due to the time of day at which the surveys were conducted (i.e. during working hours) and everyone's busy schedule, no-one was able to attend these field surveys. Training of local monitors was not possible during this expedition as no turtle activity was found. CITP has organised to present an educational talk to the Year 13 Biology class at Tereora College after the April school holidays. This presentation will cover the following:

- Goals and objectives of CITP (Cook Island Turtle Project);
- The differences between family groups -tortoises, terrapins and sea turtles;
- Sea turtle adaptations – shell, flippers, salt glands;
- The different species of sea turtle in the Cook Islands and globally;
- Life cycles of turtles – migrations, nesting, hatchling and adult life-stages;
- The importance of turtles culturally, biologically and economically;
- Conservation issues & management.

6 Discussion

No nesting activity, evidence of turtle tracks or nesting females were encountered whilst surveying the beaches of Rarotonga. These results further support the survey carried by White (2012). The absence of marine encounters with adult sized females and low abundance of adult sized males could explain why nesting activity on the island was absent. The characteristics and beach structure of the island and the development of infrastructure that is of close proximity to the beaches may also be unfavourable to support successful mating and nesting activity.

The high abundance of juvenile and adolescent turtles could mean that the waters and nearby habitats surrounding the island offer adequate food supply and protection of predators for juveniles to develop and forage. Nevertheless, how sea turtles in the Cook Island utilise nearby habitat for certain stages of their life-cycle remains unclear due to limited research in the area having been conducted.

A crucial part of a turtle's life-cycle involves females ascending to shore at night to lay their eggs. On average females will lay between two to four clutches within the season with a 10-20 day interval (Miller et al. 2003; Kamel & Mrosovsky. 2005). During this stage, females can be easily distracted by movement and presence of white light (White 2011). Once oviposition has occurred, eggs will incubate in the nest for approximately 60days before hatching. Time of incubation however is dependent on sand temperature as development is known to occur much quicker with an increase in temperature (Miller et al. 2003). Other variables such as elevation, distance from high tide mark, temperature, moisture, humidity, salinity and sand particle size are also vital to ensuring that embryos develop into healthy hatchlings (Spotila et al. 1987;Ackerman, 1997; Miller et al. 2003). As parental care is absent in this species, site of oviposition is thus important as it largely influences the developmental microenvironment of a nest which in turn affects hatching and emergence success, sex ratio, fitness and vulnerability of hatchlings to nest predation (Miller et al. 2003). Although females are known to nest in the geographical region to which they are born, nest site selection on a beach may be crucial for optimum offspring survival. Surveying beaches for nesting suitability and identifying which beach characteristics on a beach encourage nesting is thus vital to the long-term conservation of turtle populations around the world.

Chemical and physical characteristics of beach sand can influence nesting behaviour and clutch survival of green turtles. Studies undertaken in the French Frigate Shoals, Great Barrier Reef, Sarawak and Malaysia noted a higher frequency of aborted digging attempts when females dug egg chambers in coarse, dry sand due to the sand easily caving in (Mortimer, 1990). Clutch mortality was also higher on beaches with low substrate water potentials and drier conditions (Mortimer, 1990) as gas exchange between egg and surrounding sand is known to be influenced by water content and particle size of sand (Miller et al. 2003). The drier the sand, the more water the egg loses to the surrounding sand. Desiccation will occur if change in eggs initial mass is more than 40% (Miller et al. 2003).

Although several studies have attempted to determine the forces behind pattern of nesting site selection, results often contradict each other or conclude that nest placement on a beach is largely non-random (Kolbe & Janzen, 2002). Despite ongoing research efforts, successful reproduction of marine turtles is known to be influenced by the following variables; availability and quality of food in foraging grounds, presence of nearby inter-nesting habitat, low predation rates and appropriate offshore currents (Georges et al, 1993). Environmental conditions of a nesting beach (i.e. modest temperature fluctuations, low salinity, high humidity and well drained and aerated sand) and suitability of beach structure for digging (e.g. substrate type, slope etc.) are also vital to ensuring successful reproduction and optimum hatching survival and emergence rates of hatchlings from nests (Mortimer, 1990).

Some studies suggest that preference for characteristics of nesting beaches depends on the rockery and the species of turtle (Miller et al. 2003). For instance, studies on loggerhead turtles showed that loggerheads nesting in South Africa preferred beaches with adjacent reefs or rocky outcrops whilst those needing in the Mediterranean preferred sandy beaches. In general most loggerhead turtles prefer sandy, wide, open beaches with a flat sandy appearance when viewed from sea (Miller et al. 2003). Hays and Speakman (1993) also reported an increase in hatching success rates when nests were laid away from the sea, but not in vegetation as roots often invaded the nest chambers and interfered with the successful development of embryos (Hays & Speakman, 1993).

On the other hand, major green turtle nesting beaches are characterised by moderately sorted sand with mean particle diameters ranging from 0.2-1.0mm, high spherical values and low levels of organic carbon (Mortimer, 1990). Higher rates of mortality has also been reported for eggs incubated in volcanic sands compared to sands which have similar size distributions and composed of biogenic parental material (Mortimer, 1990). It could thus be expected that turtles may use sand texture as a criteria in nesting site selection. As a result, it is recommended that once index beaches within the Cook Island archipelago are identified, texture, structure and composition of sand should be analysed and compared to the hatching success rates of nests excavated.

It is not entirely clear if oviposition site choice is based on specific beach characteristics, the following nest beach characteristics are crucial to embryo development. To increase hatching and emergence success rates beaches need to be easily accessible to nesting females and sand needs to be cohesive enough to allow for building of egg chamber (Mortimer, 1990). Nests must also be high enough above the high tide mark to prevent inundation or erosion of nests while sand characteristics such as temperature, humidity/water potential, salinity and respiratory gases are also important factors to consider for successful incubation of eggs (Miller et al. 2003). Nevertheless, little is known about how physical characteristics of beach influence microclimate of sea turtle eggs during incubation.

Despite the extensive wealth of knowledge regarding the biology of marine sea turtles, lack of data from past turtle emergence and nesting events on Rarotonga makes it hard to predict when the next laying event will occur on the island. Has laying ever occurred on the island? If so, nesting activity would most likely occur on the island as a result of natal homing and the ability for marine turtles to imprint magnetic features of their natal beach as hatchlings so that they are able return to nest within the general geographic region from which they were born (Lochmann, 1999).

By collecting data on the beach characteristics of successful and unsuccessful nesting attempts and categorising suitability of habitat for nesting, it is hoped that in the long-term beach characteristics to which turtles respond to both positively and negatively will be identified for key index sites so that turtle populations of the Cook Islands can be monitored and trends assessed.

7 Conclusions and Recommendations

Although no nesting activity was recorded in Rarotonga, a total of 15km of beach was categorised as suitable for nesting. The remaining 15 km of beach was categories as unsuitable, mainly due to inaccessibility of beach due to the presence of large rock boulders, mere absence of beach or presence of substrata which would prove otherwise difficult for nesting females to dig a successful nest chamber. Although 15 km of beach was categorised as suitable, most of this was in close proximity of resorts and in areas of high recreational use by tourists and tourist operators. Artificial lighting from resorts, proximity of roads to beaches and people walking on the beaches at night could also pose as another issue for nesting females as they respond negatively to white light as they are adapted to sight underwater. As a result, bright lights often disorient turtles causing them to abandon their nests or completely deter them ascending ashore to lay their eggs. This could explain why no nesting activity currently occurs on the beaches of Rarotonga.

To accommodate for nesting activity in the future, a human impact assessment of suitable beaches is advised to determine if human habitat alterations have influenced nest-site selection or microenvironments within nest chamber. It is also recommended that the beach characteristics of all fifteen islands be compared and correlations between successful and unsuccessful nesting attempts be identified. This will enable researchers to determine if turtles within the Cook Island archipelago select nest sites based on particular beach characteristics and to which variables are higher nest densities and improved hatching success rates associated with. This is important as the micro-environment of the nest is known to affect gas-water exchange and temperature of eggs which in turn can in turn influence rate of development, size, sex, speed of locomotion, behaviour, thermoregulation, growth rates and phenotypes of hatchlings (Janzen, 2002). Direct behavioural observations of sea turtles are also essential to the understanding of interactions between turtles and their ecosystems (Schofield 2006). Success within nest areas will also provide clues for habitat needs of species. Due to their slow growth rate, the evolutionary response of marine turtles to natural selection in rapidly changing environments is extremely slow. As a consequence, ongoing research in this field is important to ensure the long-term survival of turtle populations with the Cook Island and Pacific region.

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9 Appendices

9.1 Raw Data

Island/motu	beach code	beach length (m)	beach width (m)	beach elevation (m)	beach incline	substrata type	beach access	sand softness	sea defence/obstruction	vegetation	other observations	beach type
Rarotonga	10		9.5	2	Moderate	Sand	Lagoon	4.5m - Med (rocks	N/A	sheoak	quiet close to oval and church, dogs pres	B
Rarotonga	11	301	11.5	11	Moderate	Sand	Lagoon	5.5m - Easy	N/A	palm trees	motu in front of beach	B
Rarotonga	12	146	8.2	10	Moderate	Sand	Lagoon	4m - Easy	Rocky outcrops eit	palm trees and low lying sl	private villas in close proximity	B
Rarotonga	RV	565	13	10	Moderate	Sand/small pebble	lagoon	Easy	N/A	palm tress, shrubs	little human disturbance, close to house	B
Rarotonga	Rocks	837	9.3	11	Moderate	kirikiri	lagoon	Easy	low rocky platforn	palm trees, shrubs	little human disturbance, close to house	B
Rarotonga	13	1000	13	11	Moderate	kirikiri/small pebb	lagoon	Easy	N/A	palm trees	close to helicona - provate villas	B
Rarotonga	ROY	1000	8.1	11	Moderate	kirikiri	lagoon	Medium - some r	N/A	palm trees	infront of roya. Tahitienns	B
Rarotonga	AV	117	17.1	11	Moderate	kiri, rocks, pebbles		Easy	Rocks - covered at	palm trees	low disturbance	B
Rarotonga	17	1000	13.1	15	Moderate	kirikiri/small pebb	passage	Easy	concrete revetme	sheoaks, low-lying shrubs	low disturbance, houses	B
Rarotonga	18	1000	12.2	14	Moderate	kirikiri	lagoon	Easy	N/A	palm trees, she oaks	low disturbance, houses	B
Rarotonga	SCH	183	23.4	28	Moderate	sand/rocks	ocean/reef	Med-some rocks	N/A	goats foot, palm trees	reef close, low disturbance, evidence of	B
Rarotonga	AR	405	10.7	14	Moderate	kirikiri	lagoon/reef	Easy	N/A	palm trees, sheaoaks, gras	little disturbance, sandy beach	B
Rarotonga	RBR	202	17.2	13	Moderate	kirikiri	lagoon/reef	moderate - some	N/A	palm trees, sheoaks	little vegetation, infront of resort	B
Rarotonga	DC	1030	11.8	14	Moderate	kirikiri	lagoon/reef	Easy	N/A	palm trees, sheoaks, other	exposed root system at vegetation line,	B
Rarotonga	24	1000	11.7	17	Moderate	sand/kirikiri	lagoon/reef	Easy	N/A	palm trees, sheaoaks, othe	little disturbance, close to house	B
Rarotonga	25	1010	10.8	15	Moderate	sand/kirikiri	lagoon/reef	Easy	N/A	palm trees, sheoaks, other	little disturbance	B
Rarotonga	26	1010	13.2	11	Moderate	sand/kirikiri	passage	Easy	N/A	palm trees, goats foot	little disturbance on beach, close to boat	B
Rarotonga	ENDAIR	1120	11.4	18	shallow	kiri/small pebbles	ocean/reef	moderate - some	N/A	palm trees, grass	little disturbance on beach but close to a	B
Rarotonga	28	447	10.6	22	Moderate	kiri	ocean/reef	Moderate (some	N/A	palm trees, goats foot	little disturbance	B
Rarotonga	EDGEW	545	14.3	20	Moderate/ste	kiri	ocean/reef	Easy	low rocky platforn	palm trees	close to resort but wide beach	B
Rarotonga	15	1000	19.5	10	Moderate	N/A	ocean/reef	Medium - some r	Large rocks scatter	palm trees, pig face, low lying shrubs & pioneer plants		B & C
Rarotonga	16	370	12.8	9	Moderate	small to medium p	ocean/reef	Difficult large roc	N/A	Succulant, pioneer plants e.g. pigface, beach bean		B & C
Rarotonga	REEFCOM	517	10.6	15	Moderate	kiri/small pebbles	ocean/reef	Moderate (some	N/A	sheoaks	beach closest to high tide is covered in p	B/C

9.2 Sea Turtles observed in Papua Passage recorded during the Marine Surveys (photos provided by Josh Dortan Brand 2015)

Figure 3. Adult male Green Turtle swimming close to Outer Gully.

Figure 4. Sub-adult Green turtle resting on coral platform in 'Middle-deep' area.

Figure 5. Adolescent Hawksbill turtle swimming in 'Middle-deep' area .

Figure 6. Adolescent Hawksbill turtle resting on coral platform.

Figure 7. Sub-adolescent Green Turtle swimming within passage.

9.3 Example of Sea turtle Questionnaire used for interviewing dive operators

Name:

Occupation:

1. How long have you been operating for?
2. What do you feel most attracts people to dive in Rarotonga?
3. Where do you normally go diving on the island?
4. At which dive sites have you seen turtles?
5. At which dive sites do you normally frequent the most turtles? I.e. the passages?
6. At which dive site do you normally frequent the least amount of turtles?
7. Are there some spots on the island where you never see turtles? I.e. the lagoon?
8. Do you have favourite dive sites which you target to find turtles?
9. How often do you see turtles whilst diving? Never/Sometimes/Likely/Always

a. On average how many turtles do you see during your dives?

b. Species?

c. Size and gender?

d. More or less turtles now than in the past?

e. Time of year that you see most turtles?

10. How do divers react around the turtles?

a. How do the turtles react around the divers?

11. Do environmental conditions affect seeing turtles?
12. Do turtle sightings have a noticeable impact on the diver’s experience?
13. Do you use turtles to help market dives?
14. How do you think it would affect your dive company if turtles became locally extinct?
15. What threats do you think turtles may encounter around the island
16. How do you see the community perceives turtles and or conservation.

9.4 Example of Sea Turtle Questionnaire used for interviewing Government organisations

Name:

Occupation:

1. Do you think sea turtles have any cultural significance to Cook Islanders?

• What do they symbolise?

2. Do sea turtles have any official protection on the island?

a. What?

b. When was it established?

c. How is it enforced?

d. Is it widely accepted?

3. Are turtles an important resource to any segments of the community?

4. Do you think people still intentionally hunt turtles on the island?

a. What methods would they utilise?

b. If turtles are caught incidentally, do you think they are still kept for food?

c. Are turtles still shared amongst the community when they are killed?

5. Are there other traditional uses of sea turtles despite being a food resource that are still practised?

6. Do you know if turtles are present around the island?

7. Where are they commonly found?

8. What species do you see?

9. Size-class?

10. Do you think that there are more or less turtles around now than in the past?

a. Time scale

11. Do you know where or if turtles nest on island?

a. If so which species

12. Are there any traditional forms of management for turtles which are still practised?

13. What does ……………………. do in terms of monitoring or management for turtles on the island?

14. Do you know of any local people who may be interested in turtles / monitoring them?

15. Would you like to see the turtle project continue to collect data long-term? Why?

16. What threats do you think sea turtles might face?

17. How do you think it would affect Cook Islanders if turtles became locally extinct.