Turtles and their habitats on Mauke, Southern Cook Islands.

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Abstract

The survey of Mauke was undertaken from the 4th to the 11th of June 2012 to assess the abundance, distribution and population status of marine turtles. This involved beach surveys to evaluate the habitat and categorise its suitability for nesting, recording all nesting activity and excavating the hatched nests. Marine surveys could not be undertaken due to rough seas, however local knowledge was gathered concerning which turtle species and life-stages were present and the time of year in which turtles were encountered. Through observations and anecdotal information, threats were assessed to turtles, their eggs and their habitats.

In total 1.1 km of beach was classified as suitable nesting habitat with two beaches identified as hosting the majority of turtle activity and classed as Index beaches. However ten beaches (including Index beaches) were classified as good turtle nesting habitat and should be regularly surveyed during nesting season. A small active rookery was confirmed with both current and successful nesting. Hatching success was found to be high, averaging 92.4% with an average clutch size of 92. Five of the six nests excavated were confirmed as green turtles nests and this was further supported with photographic evidence.

Some take of turtles and their eggs were identified; however steps have been made by the Environmental Officer to ameliorate these. No other threats were identified which may impact this rookery.

The Environmental Officer and other community members are keen to continue future monitoring work although further advice and technical support is necessary.

Introduction

Sea Turtles are highly evolved marine reptiles that have existed in their present form for at least 110 million years (Hirayama 1998). They have survived several mass extinctions and are keystone species (Bjorndal & Bolten 2003). In the last century, global sea turtle populations have been reduced to a fraction of their former numbers through anthropogenic actions (Allen 2007, Balazs 1975, 1983a, 1983b, 1995, Eckert 1993, Fraizer 2003, Groombridge & Luxmoore 1989, FAO 2009, Geermans 1993, Kinan 2002, 2005, Kinan & Dalzell 2004, McCoy 1974, 1997, Meylan 1999, Meylan & Donnelly 1999, Pritchard 1995a, 1995b, Woodrom-Rudrud 2007, 2010) and are presently listed by the IUCN *Red List of Threatened Species* as either threatened, endangered or critically endangered (www.iucnredlist.org) throughout their distribution.

The Cook Islands consists of 15 islands or atolls spread over some 2 million km^2 of ocean from latitude 09°S to 23°S and longitude 156°W to 167°W (White 2012). There are very few scientific or contemporary data concerning sea turtles in the Cook Islands and as such they have been listed as data deficient (Meylan & Donnelly 1999, Maison *et al*. 1999, Woodrom-Rudrud 2010, White 2011; 2012). The only studies conducted were in the 60's and 70's by Dr Pete Pritchard and George Balazs

(Maison *et al.* 1999, White 2012) and the study conducted by Cetacean Research (Unpublished) on Palmerston in 2000. Since 2009 the Cook Islands Turtle Project (CITP), under the leadership of Dr Michael White, have surveyed and recorded baseline data on habitat suitability, nesting frequency and nest distribution on Rarotonga, Aitutaki, Palmerston (accompanied by the author) and Tongareva. Nesting is traditionally known from all of the Cook Islands except Mitiaro (Woodrom-Rudrud 2010) however until all of the islands and atolls have been surveyed, the status of marine turtles within the Cook Islands remains unknown.

In February 2012, nesting by green turtles (*Chelonia mydas*) was reported from Mauke by Basilio Kaokao (the Environment Officer), June Hosking and Catherine Siota. These were the first reports of confirmed nesting on Mauke (Basilio Kaokao *pers. com.* 2012), therefore CITP proposed a short focused research trip. This was undertaken from the 4th to the 11th of June 2012 by the author and his wife Nerissa (a long-term turtle researcher) with the primary research aim to:

Assess the current distribution, abundance, and population status of marine turtles on Mauke.

In order to achieve this we specifically addressed the following research objectives:

1. **Assess all beaches:**
    - To categorise beaches in terms of suitable nesting habitat.
    - To quantify the extent and distribution of nesting.
2. **Excavate hatched nests:**
    - To measure the level of hatching success
    - To confirm the nesting species (if dead embryos are found).
3. **Conduct reef surveys:**
    - Assess which species of turtle and life-stages are present, and their abundance.
    - Identify foraging preferences and habitat use
4. **To identify and quantify impacts and threats to sea turtles and their habitats:**
    - Marine impacts (e.g. pollution, fishery bycatch, reef degradation)
    - The level of traditional take (of both turtles and their eggs)
    - Predation
    - Threats to nesting habitat
5. **To raise awareness about the conservation issues of sea turtles:**
    - Through community presentations
    - Lecture on sea turtle biology, life history and threats at the local school
6. **Gather anecdotal information:**
    - Concerning past nesting abundance
    - Species regularly seen
    - Traditional practices involving sea turtles

Methods:

The study area: Mauke

Mauke [20° 9'S, 157° 20'W] is the most easterly island of the Cook Islands and has a population of about 280 - 300 people (Tangata Ateriano *pers. com*. 2012) The island consists of a low-lying central volcanic plateaux surrounded by raised fossilised coral reef –'*makatea'* - (Spalding *et al.* 2001, White 2012) with isolated sandy bays. The sandy bays are easily accessed by a road which runs the circumference of the island and there are paths to many of the bays. Most bays are clearly named by

signs at the road side. Only the bays with clear access paths were surveyed so they could be easily located in future surveys.

Mauke is surrounded by a shallow lagoon which is typically less than a couple of feet deep with the fringing reef about 30 - 40 metres from shore. The lagoon does not provide adequate habitat for marine turtles, therefore the lagoon must be traversed for each individual nesting emergence.

The reef drop-off is close to the fringing reef around much of Mauke which limits the extent of habitat available for marine turtles. In the south-east of Mauke, an under-water shelf extends outwards and is the traditional fishing grounds; however it may provide the greatest area of suitable habitat.

Beach surveys

This was the first survey to be conducted on Mauke therefore it was important to assess all beaches for nesting suitability, identify Index beaches and record all nesting activity.
Beaches were surveyed from the harbour in the north-west of the island in an anti-clockwise direction using a moped to cover the distances in between the bays. Bays were located either by signs or through clear access paths.

Each bay was then assessed for its nesting suitability using the following criteria:

- Accessibility from open water
- Substrata type
- Sand depth
- Quantity of sand above the high water mark

The beaches were then categorised as either:

- Type A – Confirmed nesting
- Type B – Suitable for nesting (same as Type A) but no nesting was confirmed
- Type C – Unsuitable for nesting

The beach name (if applicable), and its location using a Garmin GPS (MAP 78) were recorded and the length of Type A/B beaches were estimated to quantify the length of suitable nesting habitat.

Nesting activity surveys
Beach surveys are the most commonly used population index for monitoring marine turtles (Schroeder & Murphy 1999).
This survey was conducted post nesting season therefore no tracks were visible and all activities were recorded as separate events unless activities were connected with no uncertainty.
All turtle activities were identified as either attempts (body pits or abandoned egg chambers) or nests and their locations recorded by GPS . The top egg was located in all nests and recorded as confirmed nests. Nests which the eggs could not be located were recorded as possible nests.

All confirmed nests were then excavated using standard Marine Turtle Specialist Group (MTSG) guidelines (Miller 1999). Measurements were taken from the existing sand level down to the top egg and again to the bottom of the egg chamber once the contents had been removed. Shells over 50% in tact where counted as hatched and if less than 50% they were discarded. Unsuccessful eggs were opened to assess at which stage the egg failed. These were recorded as:

- Unfertilised – no visible sign of an embryo
- Dead embryo – this is recorded in four separate categories
    - Eyespot embryo – only the black eyespots are visible
    - Early stage embryo – the embryo is smaller than its yolk sac
    - Middle stage embryo – the embryo is of equivalent size to its yolk sac
    - Late stage embryo – the embryo is larger than its yolk sac or is full term
- Pipped hatchling – the hatchling has opened the egg and sits in side it with head and flippers visible. This is then sub-divided as alive or dead.

If hatchlings are found in the nest they are categorised as alive or dead. This is then sub-divided by its position in the nest:

- Within the top 10 cm of the nest
- Lower than the top 10 cm of the nest

From excavations we calculate the clutch size (hatched shells + unsuccessful eggs, hatchlings are not counted as they have already been recorded as a hatched shell) and the hatching success (number of hatched shell / clutch size * 100). If dead hatchlings or late-stage dead embryos are found then the nesting species can be confirmed.
By recording nesting activity, clutch size and hatching success, we can estimate the reproductive success.

Marine surveys

Unfortunately marine surveys were not conducted as the sea state was too rough. A boat should be considered in both the planning and the budget for future surveys to enable marine surveys.

Identifying threats and impacts

As marine surveys were not conducted or any turtles encountered, we could not identify any in-water impacts. We observed no visual signs of turtle harvesting or egg poaching although these issues were raised by community members. Observations were made on feral pigs which are rife on the island, although no attempt was made to quantify them. Similarly observations were made concerning sand extraction however this was not on a damaging scale and so not quantified. All evidence relating to other threats was gathered anecdotally.

Results

Beach assessments

We surveyed 38 beaches (refer to Table 1 in Appendices) however some of which could be termed more accurately as gullies. Fourteen of these were categorised as Type C and were predominantly along the west coast of the island. The Type C beaches were characterised by either rocky substrata or being enclosed by makatea where the high tide would submerge or frequently wash the entire beach. Two further beaches were categorised as Type B* as they had similar features to Type C beaches however there were small pockets of suitable nesting habitat, although this would be unlikely.

Eighteen beaches were categorised as Type B, which equated to approximately 860 metres of beach (estimated width of beaches at the edge of the lagoon). These were predominantly located from the

south west point of the island and covered both the south and the east coasts. Some of these beaches provide good turtle nesting habitat with large areas of accessible sand above the high water level. Nesting on all beaches is thought only possible at high tide due to access over the fringing reef and traversing the shallow lagoon which can be entirely exposed at low tide. Only two beaches (Te Oneroa and Anaraura) had mixed forest at the back as opposed to makatea.

Four beaches were categorised as Type A (confirmed nesting) and equated to approximately 280 metres of beach with 17 activities recorded (refer to Table 2 in Appendices). There were seven confirmed nests (one on Poutukava, three on Anaraura, and three on Anaiti), three possible nests (all of which were on Anaraura), five abandoned egg chambers and two body pit attempts. Some nests had previous attempts made but were recorded as a single activity.

Quantifying nesting success

Six nests were excavated (refer to Table 3 in Appendices), the egg chamber of the seventh nest was not located but four freshly hatched shells were found within the sand and was still counted as a confirmed nest. The hatching success was high, ranging from 82.1% to 100% with a mean of 92.4%. Clutch size varied from 73 – 130 with a median of 92. In total there were 579 eggs of which 532 hatched, 23 were unfertilised, 15 contained dead embryos and 9 dead pipped hatchlings. Five of the six nests were confirmed as green turtle nests by embryos or hatchlings being found.

Discussion

Habitat suitability

Mauke has an active rookery of turtles nesting a long approximately 1.1 km of suitable nesting habitat. This habitat is situated along both the south and east coast. Two important beaches were responsible for the majority of nesting, Anaraura and Anaiti (refer to Figures 5 – 8 in Appendices) and should be used as Index beaches to follow trends in nesting abundance. There were however six other beaches north of Anaiti (Te Pari Aanga, Aanga, Noname 11, Te Unu, Arap Aea and Ana Takapua, refer to Figures 9 – 14 in Appendices) and two west of Anaraura (Te Oneroa and Takoto, refer to Figures 3 & 4 in Appendices) which also had ideal nesting habitat. Therefore these beaches should also be regularly surveyed in future years as nesting distribution varies.

Beaches are dynamic habitats and over subsequent years the sand levels will change altering which beaches provide suitable nesting habitat. The majority of beaches surveyed on the west coast had limited habitat due to the makatea surrounding them and even if sand levels were higher, there would still be limited habitat for nesting and inundation would be likely. Therefore these beaches do not need to be included in regular survey efforts however all beaches should be surveyed on a five to ten year basis to assess habitat change.

The northern shore was not surveyed from Uriuriata at the eastern end of the runway until Patito south of the harbour as there is no access to the bays, however we were informed that nesting is not known to occur along the north coast (Basilio Kaokao *pers. com.* 2012).

Nesting distribution, species and activities

Turtle nesting was initially reported in February 2012; however we were informed that nesting occurs every year on Mauke (Basilio Kaokao *pers.com*. 2012). Basilio also informed us that nesting tends to start in December at the northern end of the east coast and then move south over the next few months

until March when it concludes. From our nest excavations we could not verify this trend however we did find a range of decaying embryos or dead hatchlings which would support this time frame as the egg-laying period.

All evidence at present indicates that green turtles are the species responsible for the nesting activities. The excavations disclosed both dead hatchlings and dead embryos of green turtles in five out of the six nests. This was also reinforced by photographs from Basilio (refer to Figure 1 in Appendices) which clearly shows a nesting green turtle. Another photo (refer to Figure 2 in Appendices) shows a green turtle upside down which local residents discovered in the makatea where it had got lost after emerging to nest (it is not known if nesting was successful or not).

In total we recorded 17 individual activities on four different beaches. Some of which involved multiple nesting attempts before successfully nesting (refer to Table 2 in Appendices). In total, there were seven confirmed nests and three possible nests which probably accounts for two or three nesting females.

The first beach which had confirmed nesting (Poutukava) had very different features to the other three beaches with nests. It was a small cove (20 metres wide) surrounded by makatea, however there was a 6 metre wide gap allowing access to a further sandy section at the back of the beach. The gap was rock (no sand) with a shallow incline allowing the turtle to pass and nest approximately 30 metres from the water's edge. The nest was laid in shallow sand with both the side and the bottom of the egg chamber partially encased in solid rock. There were two previous attempts, suggesting that the sand depth may not be adequate to support a high abundance of nests.

Anaraura (refer to Figure 5 in Appendices) hosted twelve activities in total (two of which were recorded as one activity) with three confirmed nests, three possible nests, three abandoned egg chambers and three body pits. There were mixed anecdotal reports about how many emergences occurred therefore all activities (except the one previously stated) were recorded separately. The beach was both deep and, for a wide section, backed by mixed forest allowing nesting in amongst the vegetation, which is a preference for green turtles. One of the nests and a body pit were laid in a small cove, west of the main beach. All nests were laid at least 30 metres from the water therefore inundation would be unlikely.

Anaiti consists of three separate bays which all had reports of nesting (Basilio Kaokao *pers.com.* 2012). The most southerly cove (refer to Figure 6 in Appendices) was shallow and surrounded by makatea with approximately 2 – 3 metres of suitable nesting habitat above the high water mark. This beach had three nests anecdotally; however no signs were observed or found despite extensive searching.

The second bay (Terua Okea, refer to Figure 7 in Appendices) had a large area of disturbed sand along the back of the beach, close up to the makatea, where a single emergence had resulted in two nesting attempts before successfully nesting. The sand here was coarse and whilst excavating the nest the sand would cave in easily. This was noted as a possible reason for the two failed attempts as the sand depth was adequate.

The most northerly cove of Anaiti (refer to Figure 8 in Appendices) had four separate activities, two of which were confirmed nests. Although both nests were recorded as confirmed, one nest only revealed four hatched shells and the egg chamber was not located. The nest was heavily disturbed with few features to aid in egg chamber location however the four hatched shells were fresh (from this

year) and the shells could not have been from the other nest due to the distance between their locations. It was thought that the nest may have been predated or poached and these four eggs were missed, although this is speculative. In general this cove had more suitable nesting habitat than the other two coves (of Anaiti).

Hatching success

Clutch sizes were average for green turtles and hatching success was high (refer to Table 3 in Appendices). There were no signs of bacteria or inundation in the nests (some nests may have been inundated but we failed to locate them due to no visible evidence of nesting). The only nest which had a lower hatching success (MKH03 – 82%) was on Anaraura. Ants and roots were found within the nest and had perforated some eggs which may have caused them to be unsuccessful. All other nests had a hatching success of 90% or higher.

It was noted during nest excavations that sand temperature was very cool. This has important implications for hatchlings as their sex is determined by sand temperature; with lower temperatures yielding males. A major problem for sea turtle populations, exacerbated by global climate change, is feminisation of sea turtle populations (Hays *et al.* 2003, Hawkes *et al.* 2007, 2009, Fuentes 2010, Booth 2011). If Mauke produces a predominance of male hatchlings, then a higher significance is placed on this rookery as it may be important for producing males within the Cook Islands nesting population. This may also explain why the nesting population remains low despite there being suitable nesting habitat and few natural or anthropogenic threats. Future research should include investigating incubation temperatures on Mauke and all of the Cook Islands.

Species present and habitat use

Through communicating with local residents it is indicated that turtles are resident year round and are more numerous near the egg-laying period (December to March). The species recollected as being present were green turtles however there was no confirmation as to whether hawksbills were present or not. Turtles of all sizes (life-stages) were said to be present including very large turtles. This means that the reef which surrounds Mauke provides adequate resources for both foraging and refuge and sustains a resident population. We cannot however quantify abundance, site fidelity or which areas of the reef are most frequented until a marine survey is conducted.

Identifying threats to sea turtles and their habitats

It was raised on several occasions that sea turtles and their eggs are still used as a food resource. Basilio has taken steps to raise awareness about sea turtles and has included their protection in the Mauke Regulations. He appeared on television three times asking local residents to stop eating them; received with a mixed response. The community members that we spoke to stressed that turtles were still killed and they thought this was unnecessary as food is not in short supply. There was no quantification as to how many turtles may be killed or whether this is a regular occurrence. The turtle in the photograph (refer Fig. 2 in Appendices) was nearly killed; however Basilio and other community members persuaded them to release it. No information was gathered about direct or incidental capture of turtles at sea and so we cannot quantify this threat.

There were several reports of a single person who takes turtle eggs and several digging attempts could, speculatively, have been poached nests (these were recorded as abandoned egg chambers, one on Anaurura and two on Anaiti, Bay 3). It should be stated that any nests poached or nesting females

taken would impact highly on this population as it is conceivable that only two or three females were responsible for this year's nesting. By Basilio raising awareness and turtle protection being included in the Mauke Regulations, the level of take will hopefully be reduced. All of the community members spoken to were very enthusiastic about turtle conservation on Mauke.

The beaches on Mauke were free from anthropogenic pressure except for a low level of sand extraction at the back of Noname 8 (a 20 metre wide, Type B bay in between Tukumi and Te Oneroa) and Anaraura Bay 1 (an 80 metre wide, Type B bay north east of the main beach of Anaraura). In both cases this was not thought to have a major impact. There are very few people utilising the beaches, no artificial lights shining on them and the only buildings in close proximity were at Anaraura. The buildings at Anaraura (Ri's Hideaway) are built at a respectable distance from the beach and would have little influence on nesting turtles. It should however be advised that tourists staying here may use the beach at night and could disturb nesting turtles. Therefore information could be posted advising tourists not to go on the beach at night between December and March.

Some of the beaches were polluted with plastics and also foam from a boat which has been wrecked on the reef (refer to Figure 8 in Appendices). In its present quantities neither the foam nor the plastics would cause problems to nesting turtles and it is regularly cleared by Basilio and his scout group. Through quick action from Basilio and other community members the diesel and other potential pollutants from the wreck were removed, however the boat should be removed before it causes any further pollution or damage to the reef.

Feral pigs on the island are rife and are known predators of turtle nests, however, no direct evidence of this was observed here. Basilio has appealed to community members to not feed their pigs near the beaches and has stated that if he sees pigs on the beach he will take measures to eradicate the problem.

Education and raising awareness

A community presentation was not given at the request of Basilio Kaokao as he had recently been on Mauke television enforcing the Mauke regulations protecting sea turtles. He felt that the community had heard enough about sea turtle conservation for one year; however he did say that on a future visit this would be desirable.

We made three 50 minute presentations at Mauke School to about 36 children from the science classes aged 11 through to 16. This encompassed sea turtle biology, life-cycles, threats and conservation issues. We were also able to take the senior class (15-16 year olds) on to the beach with the Principal Josephine Ivirangi and Basilio to conduct two nest excavations. During this time we were able to engage with the children further on sea turtle life cycles and survival strategies and show them some hands-on fun science.

Capacity building

Basilio is keen to make reports about sea turtle nesting and to provide protection for them, their nests and their habitats. Unfortunately due to the survey being conducted post-nesting season we could not give detailed explanations about turtle nest identification. Basilio did witness two excavations, however due to the survey week being through Environment Week, Basilio did not have more time to conduct an excavation himself. It is hoped that a repeat visit can be made during March 2013 to

survey the 10 beaches suggested, record nesting activities, excavate any hatched nests and train Basilio in turtle monitoring so that he can continue the work.

In addition to Basilio, Tangata Ateriano the local Police Officer has volunteered to assist any monitoring work and June Hoskings name has also been put forward by other parties. Unfortunately June was not on Mauke during our visit and so we were unable to meet her or to confirm her enthusiasm.

Further anecdotal information

Before leaving Mauke it was brought to our attention by Tangata Ateriano (*pers. com.* 2012) that nesting also occurs on Mitiaro after he spoke with the visiting police officer from that island.

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References

Allen, M.S. (2007) Three millennia of human and sea turtle interactions in remote Oceania. *Coral Reefs* 26: 959-970.

Balazs, G.H. (1975a) Green turtle uncertain future: Protection vial if remnant population is to survive. *Defenders; v.* 50(6): 521-523.

Balazs, G.H. (1983a) Subsistence use of sea turtles at Pacific Islands under the Jurisdiction of the United States. Southwest Fisheries Center, Honolulu Laboratory, Administrative Report H-83-17.

Balazs, G.H. (1983b) Sea turtles and their traditional usage in Tokelau. *Atoll Research Bulletin* 279:1-30

Balazs, G.H. (1995) Status of sea turtles in the central Pacific Ocean. In: Bjorndal, K. (*ed*.). *Biology and Conservation of Sea Turtles*. Smithsonian Institution Press. Washington D.C., 615 pp.

Booth. D.T., Evans. A. (2011) Warm Water and Cool Nests Are Best. How Global Warming Might Influence Hatchling Green Turtle Swimming Performance. PLoS ONE 6(8): e23162. doi:10.1371/journal.pone.0023162

Bjorndal, K.A., Bolten, A.B. (2003) From Ghosts to Key Species: Restoring Sea Turtle Populations to Fulfil their Ecological Roles. *Marine Turtle Newsletter*. 100: 16-21.

Eckert, K.L. (1993) The biology and population status of marine turtles in the North Pacific. NOAA-TM-NMFS-SWFSC. 186pp.

FAO Fisheries Department. (2009) Guidelines to reduce sea turtle mortality in fishing operations. Rome, FAO. 128p.

Frazier J (2003) Prehistoric and ancient historic interactions between humans and marine turtles. In: Lutz PL, Musick JA, Wyneken J (*eds.*) *The Biology of sea turtles, vol 2*. CRC Press, Boca Raton, Florida, 1–38.

Fuentes MMPB, Hamann M, Limpus CJ (2010) Past, current and future thermal profiles of green turtle nesting grounds: Implications for climate change. *Journal of Experimental Marine Biology and Ecology* 383: 56–64.

Geermans, S. (1993). Summary of traditional usage of turtles within the SPREP region. 23pp.

Groombridge, B., Luxmoore, R. (1989) The Green Turtle and Hawksbill (Reptilia: Cheloniidae): World Status, Exploitation and Trade. CITES Secretariat, Lausanne, Switzerland. 601 pp.

Hawkes LA, Broderick AC, Godfrey MH, Godley BJ (2007) Investigating the potential impacts of climate change on a marine turtle population. *Global Change Biology* 13: 923–932.

Hawkes LA, Broderick AC, Godfrey MH, Godley BJ (2009) Climate change and marine turtles. *Endangered Species Research* 7: 137–154.

Hays GC, Broderick AC, Glen F, Godley BJ (2003) Climate change and sea turtles: a 150-year reconstruction of incubation temperatures at a major marine turtle rookery. *Global Change Biology* 9: 642–646.

IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. <www.iucnredlist.org>. Downloaded on 24 May 2012.

Kinan, I. (*ed.*) (2002). Proceedings of the Western Pacific Sea Turtle Cooperative Research and Management Workshop. February 5–8, 2002, Honolulu, Hawaii, USA. Honolulu, HI: Western Pacific Regional Fishery Management Council. 300 pp.

Kinan, I. (*ed*.) (2005) Proceedings of the Second Western Pacific Sea Turtle Cooperative Research and Management Workshop. Vol. 1: West Pacific Leatherback and Southwest Pacific Hawksbill Sea Turtles. 17-21 May 2004, Honolulu, HI. Western Pacific Regional Management Council: Honolulu, HI, USA. 119pp.

Kinan, I., Dalzell. P. E. (2004) Turtle conservation and fisheries development in the Pacific Islands: Different perspectives create conflicts between developed and developing economies. Sea turtles: Flagship species for conservation and fishery management. *Maritime Studies.* 3(2): 195-212.

Maison, K.A., Kinan Kelly. I., Frutchey. K.P. (2010) Green turtle nesting sites and sea turtle legislation throughout Oceania. US Dept of Commerce. NOAA Technical Memorandum. NMFSF/ SPO-110. 52 pp.

McCoy, M.A. (1974) Man and Turtle in the Central Carolines. *Micronesica* 10(2): 207-221.

McCoy, M.A. (1997) The traditional and ceremonial use of the Green sea turtle (Chelonia mydas) in the Northern Mariana Islands: With recommendations for its use in cultural events and education. A report prepared for the Western Pacific Regional Fishery Management Council & University of Hawai'i, Sea Grant College Program.

Meylan, A.B. (1999) Status of the Hawksbill Turtle (*Eretmochelys imbricata)* in the Caribbean Region. *Chelonian Conservation and Biology.* 3(2): 177-184.

Meylan, A.B., Donnelly. M. (1999) Status justification for listing the Hawksbill turtle (*Eretmochelys imbricata*) as Critically Endangered on the 1966 IUCN *Red List of Threatened Animals*. Chelonian Conservation and Biology 3(2): 200-224.

Miller, J.D. (1999) Determining Clutch size and nesting success. In: *K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois, M. Donnelly (eds.)* Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4.

Pritchard, P.C.H. (1995a) Marine turtles of the south Pacific. In: Bjorndal, K. (*ed.*) *Biology and Conservation of Sea Turtles*. Smithsonian Institution Press. Washington D.C., 615pp.

Pritchard, P.C.H. (1995b) Marine turtles of Micronesia. In: Bjorndal, K. (*ed.) Biology and Conservation of Sea Turtles*. Smithsonian Institution Press. Washington D.C., 615pp.

Schroeder, B., Murphy, S. (1999) Population Surveys (ground and aerial) on Nesting Beaches. In: *K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois, M. Donnelly* (*eds.*) *Research and Management Techniques for the Conservation of Sea Turtles*. IUCN/SSC Marine Turtle Specialist Group Publication No. 4

Spalding. M.D., Ravilious. C., Green. E.P. (2001) World atlas of coral reefs. Prepared at UNEPWCMC. University of California Press, Berkeley.

White, M. (2011) Cook Islands Turtle Project: 2010 Annual Report (Available from crwban681@yahoo.co.uk)

White, M. (2012) Cook Islands Turtle Project: 2011 Annual Report (Available from crwban681@yahoo.co.uk)

Woodrom-Rudrud, R., J. Walsh Kroeker, H. Young Leslie and S. Finney. (2007) Sea turtles wars: Culture, war and sea turtles in the Republic of the Marshall Islands. *SPC Traditional Marine Resource Management and Knowledge Information Bulletin;* 21: 3-29.

Woodrom-Rudrud, R. (2010). Forbidden Sea Turtles: Traditional laws pertaining to sea turtle consumption in Polynesia (including the Polynesian outliers). *Conservation and Society* 8(1): 84-97.

Appendices

Table 1 results of the beach assessment

Record	Date	Beach name	Beach type	Index beach	Latitude	Longitude	Substrata	Access	Tracks	Attempts	Nests	Possible nest	Notes
MKB001	05/06/12	Patito	C	No	20.09.008	157.21.601	Rocky	Reef	0	0	0	0	High water to makatea
MKB002	05/06/12	Anaio	C	No	20.09.132	157.21.625	Sand	Reef	0	0	0	0	High water to makatea
MKB003	05/06/12	Teauri	C	No	20.09.231	157.21.646	Kilikili	Reef	0	0	0	0	High water to makatea
MKB004	05/06/12	Taeta	C	No	20.09.334	157.21.647	Kilikili	Reef	0	0	0	0	High water to makatea, 3 small coves
MKB005	05/06/12	Noname 1	C	No	20.09.490	155.21.628	Sand	Reef	0	0	0	0	2 channels, water run-off land (frequently washed)
MKB006	05/06/12	Noname 2	C	No	20.09.522	157.21.628	Kilikili	Reef	0	0	0	0	High water to makatea
MKB007	05/06/12	Anaputa	C	No	20.09.668	157.21.629	Kilikili/rocky	Reef	0	0	0	0	High water to makatea
MKB008	05/06/12	Nuka	B	No	20.09.817	157.21.609	Sand	Reef	0	0	0	0	15 metres wide/5 metres of sand suitable for nesting/steep incline/makatea bordered
MKB009	05/06/12	Noname 3	B*	No	20.09.851	157.21.606	Sand	Reef	0	0	0	0	3 metres wide/high water to makatea in most of cove/small part possible for nesting although unlikely due to: drainage run-off/shading and waves funnelled in
MKB010	05/06/12	Noname 4	C	No	20.09.959	157.21.602	Kilikili	Reef	0	0	0	0	High water to makatea/gully
MKB011	05/06/12	Noname 5	C	No	20.10.050	157.21.581	Rocky	Reef	0	0	0	0	High water to makatea
MKB012	05/06/12	Pooki	B*	No	20.10.084	157.21.577	Kilikili	Reef	0	0	0	0	10 metres wide/nestable spots where sand depth allows/often shallow with rock underneath
MKB013	05/06/12	Noname 6	C	No	20.10.180	157.21.559	Sand	Reef	0	0	0	0	High water to makatea/gully
MKB014	05/06/12	Noname 7	B	No	20.10.414	157.21.470	Sand	Reef	0	0	0	0	7m wide gully
MKB015	05/06/12	Tukumi	C	No	20.10.459	157.21.453	Rocky	Reef	0	0	0	0	High water to makatea/hardly any sand
MKB016	05/06/12	Noname 8	B	No	20.10.829	157.21.206	Sand / stones	Reef	0	0	0	0	20 metres wide/sand extracted at back of beach

Record	Date	Beach name	Beach type	Index beach	Latitude	Longitude	Substrata	Access	Tracks	Attempts	Nests	Possible nest	Notes
MKB017	05/06/12	Te Oneroa	B	No	20.10.932	157.21.093	Sand	Reef	0	0	0	0	130 metres total/main beach and several small coves good for nesting/some rocks obscuring beach access/mixed forest behind main beach/coves with makatea surround
MKB018	05/06/12	Takoto	B	No	20.10.963	157.21.053	Sand	Reef	0	0	0	0	60 metres total/3 small coves/rocky beach access - passable in places/makatea surround
MKB019	05/06/12	Pole leg house	B	No	20.11.030	157.21.966	Sand	Reef	0	0	0	0	25 metres/sand suitable for nesting accessed through 3 metre wide channel
MKB020	05/06/12	Utu	C	No	20.11.075	157.20.905	Rocky	Reef	0	0	0	0	3 small bays
MKB021	05/06/12	Noname 9	C	No	20.11.118	157.20.828	Rocky	Reef	0	0	0	0	3 small bays/gullies - last of which had more sand and 4 metres wide
MKB022	05/06/12	Noname 10	C	No	20.11.196	157.20.673	Kilikili	Reef	0	0	0	0	7 metre wide bay / gully
MKB023	05/06/12	Poutukava	A	No	20.11.257	157.20.555	Sand	Reef	0	2	1	0	3 small coves/2 attempts then nest in first (30 metres from water) - accessed through 6 metre wide rocky mid-beach area/second cove (Type C) 6 metre wide, sandy, no access to higher beach/third cove (Type C) rocky, no access to higher beach
MKB024	05/06/12	Ana Okae	B	No	20.11.309	157.20.313	Sand	Reef	0	0	0	0	30 metres wide/makatea bordered
MKB025	05/06/12	Anaraura	A	Yes	20.11.149	157.20.025	Sand	Reef	0	6	3	3	170 metres wide/western side (30 metres) has high water to makatea/opening into two small coves (20 metres wide each) easterly of which had 1 attempt into nest (confirmed) +1 anecdotally reported but not found/main part of beach 100 metres wide with 2 nests (confirmed), 3 x possible nests, 3 x AEC, 2 x BP

Record	Date	Beach name	Beach type	Index beach	Latitude	Longitude	Substrata	Access	Tracks	Attempts	Nests	Possible nest	Notes
MKB026	06/06/12	Anaraura bay 1	B	Yes	20.11.112	157.19.978	Sand	Reef	0	0	0	0	80 metres wide/low bush/pandanas at rear/Evidence of sand extraction
MKB027	06/06/12	Memorial	B	Yes	20.11.049	157.19.865	Sand	Reef	0	0	0	0	25 metres wide cove/channel 2 metre wide mid beach leading to sand suitable for nesting
MKB028	06/06/12	Anaiti Bay 1 (south cove)	B	Yes	20.10.966	157.19.752	Sand	Reef	0	0	0	0	20 Metres wide/3 nests (anecdotal) not found - all signs washed away/2 metres sand suitable for nesting (above high water)
MKB029	06/06/12	Anaiti Bay 2 Terua Okea	A	Yes	20.10.871	157.19.646	Sand	Reef	0	2	1	0	30 metres wide cove/2 x AEC then nest/ 15 metre sand suitable for nesting (above high water)
MKB030	06/06/12	Anaiti Bay 3 (north cove)	A	Yes	20.10.814	157.19.580	Sand	Reef	0	2	2	0	60 metres wide/half of which is suitable for nesting/2 x nests (Confirmed) , 2 x AEC
MKB031	07/06/12	Te Pari Aanga	B	No	20.10.344	157.19.377	Sand	Reef	0	0	0	0	100 metres wide/7 - 10 metres sand suitable for nesting (above high water)
MKB032	07/06/12	Aanga	B	No	20.10.059	157.19.329	Sand	Reef	0	0	0	0	100 metres wide/5 - 10 metres of sand suitable for nesting (above high water)
MKB033	07/06/12	Noname 11	B	No	20.09.926	157.19.319	Sand	Reef	0	0	0	0	100 metres wide/half of beach has 2 - 3 metres sand suitable for nesting (above high water)/the other half 5 - 10 metres of suitable sand(above high water)
MKB034	07/06/12	Te Unu	B	No	20.09.730	157.19.303	Sand	Reef	0	0	0	0	30 metres wide
MKB035	07/06/12	Arap Aea (boat ramp)	B	No	20.09.291	157.19.338	Sand	Reef	0	0	0	0	40 metres wide/5 metres of sand suitable for nesting (above high water)
MKB036	07/06/12	Ana Takapua	B	No	20.09.291	157.19.373	Sand	Reef	0	0	0	0	50 metres wide
MKB037	07/06/12	Oneunga	B	No	20.09.555	157.19.734	Sand	Reef	0	0	0	0	30 metres wide/5 metres + of sand suitable for nesting (above high water)
MKB038	08/06/12	Uriuriata	B	No	20.08.426	157.20.084	Sand	Reef	0	0	0	0	10 metres wide

B* Most of beach is Type C with small areas suitable for nesting (nesting is unlikely)

Table 2 Turtle activity records

Record number	Date	Beach	Latitude	Longitude	Track visible	Total number of attempts*	Successful nest	Nest code	Beach position	Notes
1	05/06/2012	Poutakava	20.11.273	157.20.559	No	2	Yes	MKH01	Back	2 x BP** then nest
2	06/06/2012	Anaraura	20.11.156	157.20.045	No	1	Yes	MKH02	Back	1 x BP into nest
3	06/06/2012	Anaraura	20.11.142	157.20.033	No	1	No	N/A	Mid	1 x BP
4	06/06/2012	Anaraura	20.11.142	157.20.033	No	1	No	N/A	Mid	1 x BP
5	06/06/2012	Anaraura	20.11.143	157.20.035	No	0	Pos	MKN01	Mid	Possible nest EC*** not found
6	06/06/2012	Anaraura	20.11.142	157.20.040	No	0	Pos	MKN02	Mid	Possible nest EC not found
7	06/06/2012	Anaraura	20.11.128	157.20.036	No	0	Yes	MKH03	Back	
8	06/06/2012	Anaraura	20.11.127	157.20.033	No	1	No	N/A	Back	1 x AEC****
9	06/06/2012	Anaraura	20.11.127	157.20.030	No	1	No	N/A	Back	1 x AEC
10	06/06/2012	Anaraura	20.11.128	157.20.025	No	0	Yes	MKH04	Back	
11	06/06/2012	Anaraura	20.11.129	157.20.030	No	1	No	N/A	Mid	1 x AEC
12	06/06/2012	Anaraura	20.11.125	157.20.022	No	0	Pos	MKN03	Back	Possible nest EC not found
13	06/06/2012	Anaiti Bay 2 (Terua Okea)	20.10.870	157.19.644	No	2	Yes	MKH05	Back	2 x AEC then nest
14	06/06/2012	Anaiti Bay 3	20.10.816	157.19.584	No	0	Yes	MKH06	Back	EC not found, four hatched shell found near surface
15	06/06/2012	Anaiti Bay 3	20.10.816	157.19.581	No	1	No	N/A	Mid	1 x AEC
16	06/06/2012	Anaiti Bay 3	20.10.815	157.19.582	No	1	No	N/A	Back	1 x AEC
17	06/06/2012	Anaiti Bay 3	20.10.816	157.19.577	No	0	Yes	MKH07	Mid	

* Total number of attempts excluding successful nesting attempts
** Body pit (BP) initial stage of nesting attempt
*** Egg chamber
**** Abandoned Egg Chamber (AEC)

Table 3 Data from nest excavations

Nest code	Beach	Distance to top egg (cm)	Distance to bottom egg (cm)	Number of hatched shells	Unfertilised eggs	Eyespot embryo	Early stage embryo	Middle stage embryo	Late stage embryo	Total number of dead embryos	Dead pipped hatchling
MKH02	Anaraura	35	55.0	74	5	0	0	0	1	1	0
MKH05	Anaiti Bay 2 (Terua Okea)	41	58.0	86	0	0	0	0	0	0	0
MKH07	Anaiti Bay 3	54	67.0	88	2	0	0	0	0	0	8
MKH03	Anaraura	38	54.0	92	9	0	3	0	8	11	0
MKH04	Anaraura	33	45.0	70	2	1	0	0	0	1	0
MKH01	Poutukava	52	68.0	122	5	0	0	0	2	2	1

Nest code	Live pipped hatchling	Total unsuccessful eggs	Dead hatchling in nest	Live hatchling in nest	Dead hatchling in top 10cm	Live hatchling in top 10cm	Clutch size	Hatching success (%)
MKH02	0	6	0	0	0	0	80	92.5
MKH05	0	0	0	0	0	0	86	100.0
MKH07	0	10	0	0	0	0	98	89.8
MKH03	0	20	0	0	0	0	112	82.1
MKH04	0	3	0	0	1	0	73	95.9
MKH01	0	8	0	0	0	0	130	93.8

Figure 1 nesting green turtle

Figure 2 rescued green turtle

Figure 3 Te Oneroa

Figure 4 largest bay of Takoto

Figure 5 largest bay of Anaraura (two nests, three possible nests, three abandoned egg chambers and two body pits)

Figure 6 Anaiti Bay 1

Figure 7 Anaiti Bay 2 (two attempts then a nest)

Figure 8 Anaiti Bay 3 (two confirmed nests and two abandoned egg chambers)

Figure 9 Te Pari Aanga

Figure 10 Aanga

Figure 11 Noname 11

Figure 12 Te Unu

Figure 13 Arap Aea

Figure 14 Ana Takapua