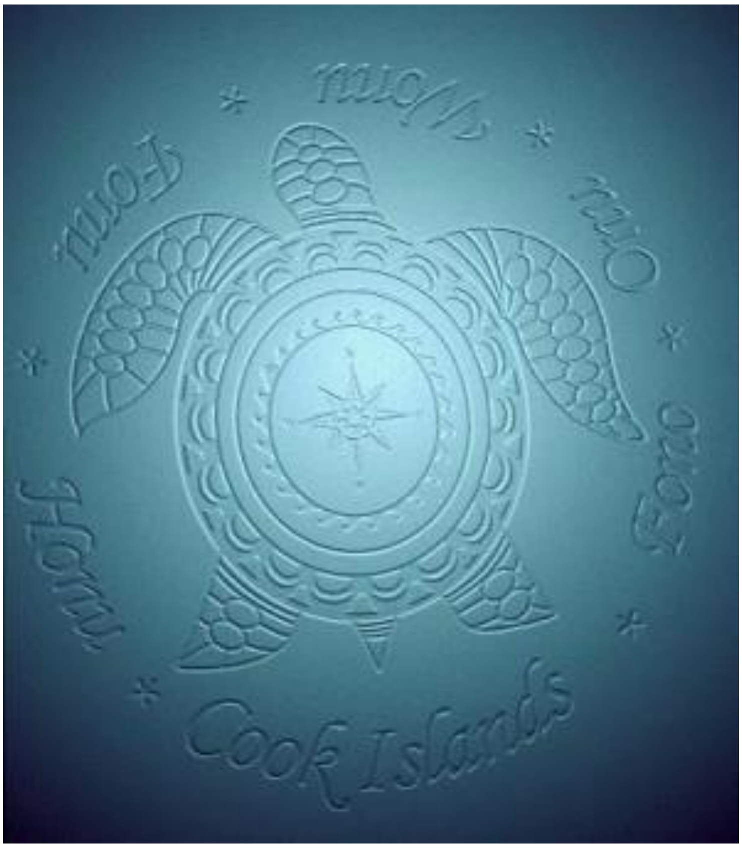
Sea Turtles in the Cook Islands

Volume One: 2009-2012



Honu o te Kûki Airani

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This study was conducted under Cook Islands research permit #07/09e; authorised by the National Research Committee

Hawksbill turtle seen regularly at 'Edna's Anchor'; a popular dive-site at Avarua, Rarotonga

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Just as this manuscript was in its final review, a very dear friend **~ Lui Bell ~** unexpectedly collapsed and never regained consciousness. Lui was a wonderful man, always kind and very approachable. He fulfilled his role as Marine Species Adviser for the Secretariat of the Pacific Regional Environment Programme with great passion; he has many achievements to his credit: whales, dolphins, Marine Species Action Plans, and turtles to name but a few. Lui was great ~ he worked well at all levels of society: from the simple fishermen to the heads of international organisations. Bravo Lui!

Our thoughts are with his family, friends and colleagues ~ especially the larger SPREP family ~ as we come to terms with Lui's passing. Reading the many comments that were posted on the tribute page www.sprep.org it is clear that we all felt the same about Lui: he was a good friend and very helpful. I'll leave others to tell Lui's life-story; but we will not let his shining example go to waste.

Curiously, I did not feel sad when Cathy Siota told me the news, as ALL of my memories with you, Lui, are happy ones. Your very sudden and unexpected passing reminded me just how tenuous and fragile our existence on Earth is: one moment we are here, going about our daily business … and then we are not! So my friend, as you make this most unknown journey, I wish you *'Safe Voyaging'* and you are forever in our hearts. *Meitaki Poria e Kia Manuia,* Michael

And from the research team at ***Honu Cook Islands***: "Lui most of us hadn't met you, but we also send our heart-felt thoughts and good wishes to your family and friends. May you find Eternal Peace. Farewell from those of us who Love Oceania. *Meitaki Korereka e Kia Manuia, Bye*."

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Abbreviations

CCL: Curved carapace length
CCW: Curved carapace width
CITES: Convention on international trade in endangered species of wildlife and flora (Washington 1973)
CMS: Convention on the conservation of migratory species of wild animals (Bonn 1979) *Honu: Honu Cook Islands*
MMR: Ministry of Marine Resources
MTSG: Marine Turtle Specialist Group
NES: National Environment Service *Tu'anga Taporoporo*
NOAA: National Oceanic and Atmospheric Administration
NPOA: National Plan Of Action
RFMO: Regional Fisheries Management Organisation
SPREP: Secretariat for the Pacific Regional Environment Programme
SWOT: State of the World's Sea Turtles (Conservation International)
TREDS: Turtle Research and Monitoring Database.
USP: University of the South Pacific

P Think before you print.
An electronic document.

AUTHOR'S NOTE: CURRENT SEA TURTLE RESEARCH IN THE COOK ISLANDS

Dr Michael White (Marine Zoologist) commenced research in the Cook Islands in 2009 with the intention of undertaking a long-term assessment of sea turtles throughout the archipelago; very few scientific studies had been conducted on sea turtles nationally; and none in recent years.

This scientific research is authorised by the Cook Islands National Research Committee **(Permit No. 07/09e; and superseded by No. 17/12)** and the author works closely with the Government of the Cook Islands. The principal departments concerned with this research are: Office of the Prime Minister (OPM), Foundation for National Research, Ministry of Marine Resources (MMR), National Environment Service (NES), Ministry of Education; Ministry of Foreign Affairs and Immigration; and the Focal Points for the relevant Conventions to which the Cook Islands is party to (e.g. CMS and CITES). Government oversight of the research programme was provided by Pamela Maru (MMR), acting on behalf of the National Research Committee. The author is the Principal Investigator for sea turtles in the Cook Islands and provides data directly to MMR and the National Biodiversity Assessment (NBSAP 2002).

Dr White's research group is known as ***'Honu Cook Islands'*** and includes associated government scientists (Ministry of Marine Resources and National Environment Service), Cook Islanders including Island Councils; and we also provide research opportunities for post-graduate researchers from selected universities. We have very high regard for Traditional Knowledge and Practices, and endeavour to explain the underlying scientific principles to the various Wisdom Keepers. One important aim is to identify and facilitate islanders who wish to study at tertiary-level, so that the long-term and sustainable use of natural resources is guided by well-informed Cook Islanders themselves. *Honu* aims to establish a functional locally-managed sea turtle monitoring-team on each atoll in the archipelago[1].

Honu Cook Islands operates a policy of utilising best practices (e.g. Eckert *et a*l. 1999), and it is guided through professional association with scientific colleagues, including the IUCN Species Survival Commission – Marine Turtle Specialist Group. The author undertakes all research following the guidance of endangered species legislation. In cases where national legislation does not yet exist, or does not refer directly to marine turtles, other relevant international legislation is used instead. Data concerning sea turtles in the Cook Islands are very scarce, so the precautionary principle has been adopted based upon our knowledge of sea turtles globally; in other words sea turtles in the Cook Islands are assumed to be endangered (Broderick *et al.* 2006), even if there are few current data to support or refute this

When researching in the Outer Islands the author works closely with the Island Councils, local government, and the schools: advising, guiding, teaching and training any interested community members. The absence of turtle studies generally, means that there is not a consistent organisation in place that can care for or understand these endangered animals;

[1]This has proved very successful in Vanuatu: the Vanua-Tai are local monitors (G. Petro *pers. com.*)

and this varies from atoll to atoll. The Ministry of Marine Resources is responsible to the Crown for administering the Marine Resources Act (1989), but one of its main functions is to raise national income by exploiting resources from the sea. Pamela Maru was the *de facto* turtle official nationally, but she has now moved to take up a regional post. Another MMR biologist (G.Langdon@mmr.gov.ck) and two Fisheries Officers have taken some responsibility for sea turtles. The National Environment Service *Tu'anga Taporoporo* provides the Focal Points for the various international Conventions, and is responsible for Biodiversity; however, it often has limited resources and personnel. Furthermore, the Environment Act (2003) only applies to Rarotonga, Aitutaki and Atiu in the Southern Group (two others - Takutea and Mitiaro - implemented it by regulation in 2008); each of the Northern Group atolls and other Southern islands is governed locally.

The best and easiest method of managing resources sustainably in the Outer Islands is for the Island Councils to administer *Rahui* (Ra'ui): the traditional opening or closing of each particular natural resource for harvesting. Sea turtles have not usually been included, but it seems likely to be the optimum method for these animals too; and discussions are well advanced with several of the Councils (White *pers. com.* 2012). It would be difficult for an external authority to enforce legislation in these remote atolls, not least because of extremely limited inter-island transportation; therefore, the most appropriate and practical means of conserving sea turtles and protecting their important habitats seems to be by the common consent of the islanders, working within a system of *Rahui* administered by each Island Council. Bylaws are enacted locally on each island; the Cook Islands Parliament develops and implements national legislation; assented to by the Queen's Representative (QR). Traditional Leadership (*Te Kotou Nui* - House of Ariki) forms an important part of the Cook Islands Legislature; and even during the colonial period (pre-1965) it was, and still is, very present amongst the People.

The author works with whoever is most interested on each island, and helps to develop a locally-relevant monitoring system. On Rakahanga, for instance, the School Principal and the Island Policeman are actively protecting turtle nests (Tuhe Piho *pers. com.* 2011); on Palmerston Atoll it is the Fisheries Officer (Bill Marsters *pers. com.*); and on Mauke it is the Environment Officer who has taken responsibility for turtles (Basilio Kaokao *pers. com.*). *Honu Cook Islands* teaches the data-collection methods laid out in the present document during its *'Turtle Rangers'* programme[2] for local monitoring teams, so that the key results from each atoll will be broadly comparable.

http://www.honucookislands.com

[2]The *Turtle Rangers* programme was conceived by Retire Puapii and Dr Michael White during the Lifeskills Expo held at Ruamanu School, Manihiki, in September 2011.

This research programme has been funded by:

1) Dr Michael White: ***Honu Cook Islands***

Details: NZ$ 50,000
Purpose: Operating costs and travel

2) SWOT: (State of the World's Sea Turtles)

Award $US 1,000
Purpose: Initial nesting assessment (track-counts) at Tongareva Atoll in 2010

3) Rufford Small Grants Foundation:

Grant # RSG 10964-1 Dr Michael White
Award £6,000 (NZ$ 11,257)
Purpose: Palmerston Expedition in April 2012

4) British Chelonia Group:

Award £800 (NZ$ 1,370)
Purpose: Rakahanga Expedition in July-August 2012

5) Ministry of Marine Resources, Rarotonga:

Award (i) NZ$ 1,200
Purpose: Rakahanga Expedition in July-August 2012
Award (ii) NZ$ 1,000
Purpose: Printing posters of the Palmerston Expedition

6) National Oceanic and Atmospheric Administration:

NOAA Award # NA12NMF4540263 Dr Michael White
Award $US 30,000
Purpose: Nesting census and genetic-sampling of an unstudied marine turtle population at Tongareva Atoll, Northern Cook Islands [initiated in September 2012]

Thank you all for helping to make this research so successful.

Monitoring the Distribution, Population Structure and Status of Sea Turtles in the Cook Islands

Introduction

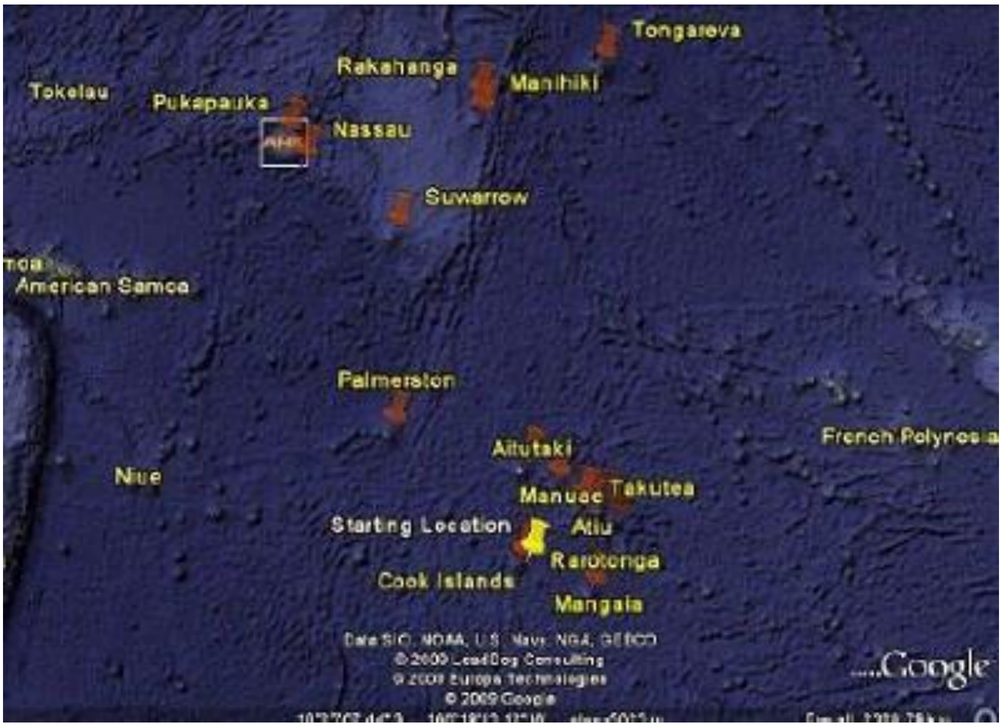
Sea turtles are an ancient group of marine reptiles that have been on Planet Earth for at least 110 million years (Hirayama 1998; and see FitzSimmons *et al*. 1995). Sea turtles are long-lived animals, with delayed maturity (Scott *et al.* 2012), that may be migratory during all life-stages (e.g. Limpus *et al.* 1992). Apart from adult females, which emerge onto beaches for egg-laying, and the subsequent hatchlings that crawl from nests to the sea, the entire life cycle of sea turtles can be completed in the marine environment. Most populations are endangered or threatened to some degree (King 1982); usually due to the impact of various human activities on the turtles and their habitats.

The Pacific Region covers about one-third of the planet's surface: six of the seven extant sea turtle species are known from the region [spp. *Chelonia mydas*; *Eretmochelys imbricata*; *Lepidochelys olivacea*; *Caretta caretta*; *Natator depressus*; *Dermochelys coriacea*; a seventh species *Lepidochelys kempii* has not been reported from the region]. The status of sea turtles in the Pacific Islands region remains unclear or poorly reported (Marquez 1990; SPREP 1980, 2007, NMFS 2010 SWOT 2011).

Sea turtles are known traditionally throughout Oceania and they have played an important role in the culture of the Polynesian peoples of the South Pacific, frequently appearing in art, weavings, songs and dances, and tattoos; they have also been an important and often highly regarded source of food (see Allen 2007 and Woodrom Rudrud 2010 for reviews). Scientific information concerning sea turtles in the South Pacific Islands is, however, fairly limited; this seems mainly due to a lack of resources, including scientific expertise, and, above all, infrequent transportation between these remote atolls (White *pers. com.*).

The Cook Islands

The Cook Islands is an independent nation (1965) that has the Queen of England as its Head of State, and is in a Free Association with New Zealand. There are fifteen atolls or islands separated into a Northern and a Southern Group, with a total land area of about 241 km2 spread over some two million km2 of ocean (09°S to 23°S; 156°W to 167°W). Transport to many of the Outer Islands is infrequent and expensive, particularly so for the Northern Group (Nassau, Pukapuka, Rakahanga, Suwarrow and Tongareva; with only Manihiki being better-served because of its black pearl industry). Most of the land (95%) is traditionally-owned and has typically been passed down through extended families since the original migrants arrived twenty-seven generations ago (see Land Tenure 1987). The Crown has the power to take land; with the courts deciding if compensation is due to the Owners. The Crown also has jurisdiction over the marine environment seawards from the Mean High Water mark. However, traditional and customary ownership of land includes the ocean, which is similar to the *'Sea Country'* of the Indigenous Australians, and is likely to be a cause for dispute between Traditional and Parliamentary government.



Overview of the Cook Islands Archipelago. (Image from GoogleEarth.com.)

Geological notes for the Cook Islands (from Spalding *et al*. 2001):

i) Northern Group atolls, apart from Tongareva, are on the Manihiki Plateau; these atolls probably formed when the plateau was a shallow volcanic feature and then the reefs grew as the plateau subsided.
ii) Tema Reef is a sub-surface platform reef between Pukapuka and Nassau.
iii) Tongareva Atoll is on a seamount rising from the deep ocean (i.e. an isolated feature). Flying Venus Reef is on the same seamount, but separated from Tongareva by a deep channel (>500 m deep).
iv) The Northern Cook Islands form two parallel chains, running NW to SE, that continue as the Austral Islands in French Polynesia.
v) Winslow Reef – Southern Cooks – is a shallow platform reef that does not show above the surface; it is about 150 km NE of Rarotonga.
vi) Takutea is an uninhabited platform island; and an important bird sanctuary.[3]
vii) Manuae and Palmerston are true atolls.
viii) Aitutaki is a near-atoll, with one large and two small volcanic islands in the lagoon.
ix) Atiu, Mangaia, Mauke and Mitiaro are *makatea* (i.e. fossilised coral reef – a volcanic centre with a carbonate rim of reef origin).
x) Rarotonga is a volcanic island (height 652 m) with fringing reefs.

[3]Originally gazetted in 1903; re-established in 1950 under *Aronga Mana* (Cook Islands Biodiversity 2002).

Sea turtles in the Cook Islands

The following review represents the state of knowledge for sea turtles in the Cook Islands (White *pers. com*. 2012). Scientific records for turtles in the Cook Islands are sparse and fall into two main categories: i) information from surveys that were made some decades ago (e.g. Hirth 1971, 1997; Balazs 1976, 1995; Witzell 1983; Marquez 1990; Pritchard 1995a); ii) recent reviews that have had to use data from the 1960's and 1970's (e.g. Dethmers *et al*. 2006; Maison *et al*. 2010; NMFS 2010; Wallace *et al*. 2010; Woodrom Rudrud 2010; SWOT 2011); in addition there was one poster (McCormack 1995) and a very general pamphlet on sea turtles (WWF undated). Prior to the present study the most recent marine turtle research had been a 24-day nesting survey at Cook's Islet, Palmerston Atoll, in November 2000; when eleven nesting *Chelonia mydas* were tagged (Cetacean Research Centre 2000; Trevor 2009; Siota 2010). A management report (Teariki-Taoiau Rongo 2006) prepared for the Traditional Land-owners of Manuae, an uninhabited atoll in the Southern Cook Islands, noted a few *C. mydas* nests from both *motu* (cays). The absence of a systematic survey in the Cook Islands means that it is very difficult to determine how the present populations of sea turtles compare with their past distribution and abundance; and also there is no clear indication of when or where nesting actually occurs.

Present Understanding (2012)

Four sea turtle species: **green** *Chelonia mydas* (Linnaeus 1758); **hawksbill** *Eretmochelys imbricata* (Linnaeus 1766); **leatherback** *Dermochelys coriacea* (Vandelli 1761); and **loggerhead** *Caretta caretta* (Linnaeus 1758) are now confirmed as using Cook Islands territorial waters; the first two species throughout the year (White *pers. obs*.). *D. coriacea* is at present only known from the offshore industrialised fisheries (Pam Maru *pers. com.* 2010); and *C. caretta* has been reported from Palmerston Atoll; although it is not known to nest (Bill Marsters *pers. com.* 2010).

Egg-laying by *Chelonia mydas* can now be confirmed for the following atolls: Aitutaki, Manihiki, Manuae, Nassau, Palmerston, Pukapuka, Rakahanga, Suwarrow and Tongareva (White *pers. com.*). Nesting emergences were reported from Mauke, Southern Cooks, in February 2012 (June and Andrew Hosking *pers. com.*; Cathy Siota *pers. com.* 2012) [4].
Hawksbill turtles *E. imbricata* have **not** been found nesting in the Cook Islands recently, and most of the individuals encountered in the archipelago so far appear to be juveniles (White *pers. com.*). Meylan and Donnelly (1999) found no data from the Cook Islands during their global review to justify listing *E. imbricata* as being critically endangered. Hawksbills are also the turtle species that has suffered the greatest exploitation by humans for almost four millennia (Parsons 1972). Hawksbill turtles have been heavily exploited in the Pacific Islands Region, for meat, eggs and tortoiseshell (see Groombridge & Luxmore 1989); and it is likely that nesting populations are declining, depleted or only remnants (NMFS & USFWS 1998). This species is rapidly approaching extinction in the region (NMFS & USFWS 1998), with many, if not most, nesting populations having declined by more than 80% throughout its global range in the last 105 years: i.e. three generations of

[4] Emergences occurred in several small coves from ***Anaiti* to *Pohutukava*** ~ about 2 km. Track-widths varied from 0.9 m to 1.3 m and there were some daytime emergences (June Hosking *pers. com.*).

hawksbills (Meylan & Donnelly 1999). Lack of long-term census data for hawksbills (see Limpus & Miller 2008) means that there are no trends for the status and stability of populations in the South Pacific Region.

Egg-laying period

Little has been written about when sea turtle nesting occurs in the Cook Islands (White *pers. com.*) and so the exact period for egg-laying in the archipelago, and neighbouring Tonga and Samoa, is unclear. There are some reported nesting observations from Fiji, Tonga and the Samoan islands (see Witzell 1982; Marquez 1990; Hirth 1997; Craig *et al*. 2004; Batibasaga *et al*. 2006; Tagarino *et al*. 2008; Maison *et al*. 2010; NMFS 2010; Woodrom Rudrud 2010; SWOT 2011), however, even these are sparse or perhaps from surveys undertaken several years ago (e.g. Balazs 1975, 1977, 1995; Pritchard 1995a). Balazs (1983) has also reported the traditional usage of turtles at Tokelau.

Seasonal nesting in the Cook Islands probably occurs at some period between September and April; but there may be differences in nesting-activity between northern and southern group islands, as well as between species. The author suggests three possible scenarios: that the egg-laying periods for green and hawksbill turtles are co-incidental, overlapping, or separate. Nesting might also occur year-round at certain locations; *Mangarongaro* [5] for instance (White *pers. com.* 2011). Balazs (1975) gathered anecdotal evidence from Canton, Phoenix Islands (Kiribati) that reported green turtles nesting sporadically in all months, with peak-nesting in October and November (and see Balazs 1995); Enderbury was similar. Dobbs *et al.* (1999) reported year-round nesting by hawksbills on Milman Island, Australia. Jennifer Cruce (*pers. com*. 2010) reported that green turtles were nesting year-round at Yap (Federated States of Micronesia); also see Maison *et al*. 2010) [6].

A lack of data: Implications for Regional Management

As very little is really known of the distribution and population status of sea turtles in the Cook Islands (White, *this report*) and some of the other Polynesian nations (e.g. Marquez 1990; Meylan & Donnelly 1999; SPREP 2007; NMFS 2010; and see the data citations in SWOT 2011), it is difficult to assess the actual risk of extinction or vulnerability of these animals regionally.

Regional Management Units (RMUs): with an aim of better managing sea turtle stocks, 58 RMU-polygons have been identified globally, which include different areas of the Pacific Region (Wallace *et al*. 2010).

[5] A motu at Tongareva Atoll.

[6] Islands north of the Equator would normally have their nesting period during the Boreal summer; and so those data may not be of much help for calculating the egg-laying season in the Southern Hemisphere.

Nesting Aggregations (NAs): Dethmers *et al*. (2006) offer another approach for regional management that is based on nesting-stock data: these Nesting Aggregations typically link areas within 500 km of each other; and these may also be genetically distinct [7]. The following NAs are of direct relevance to us in the Cook Islands:

i) Western Polynesia: Pukapuka has been included with Samoa and American Samoa;
ii) Northern Cook Islands: Manihiki, Nassau, Rakahanga, Suwarrow and Tongareva;
iii) Southern Cook Islands: Aitutaki, Atiu, Mangaia, Manuae, Mauke, Mitiaro, Palmerston, Rarotonga and Takutea.
(See **endnote** for details of these and other adjacent NAs).

For places where few sea turtle data exist a conservative approach has been adopted when defining the NAs; these geographical locations are categorised in the lowest group: *1-25 nesting females per annum* (based on 4.5 nests per female per annum; Van Buskirk & Crowder 1994). The Cook Islands are data-deficient (DD) and have thus been placed into this lowest nesting-category: i.e. no more than 25 green turtles *Chelonia mydas* would nest annually, in each of the Northern and the Southern Cooks Nesting Aggregations (NMFS 2010). There appear to be no Cook Islands data for nesting hawksbill turtles *Eretmochelys imbricata* (Witzell 1983; Marquez 1990; Balazs 1995; Meylan & Donnelly 1999).

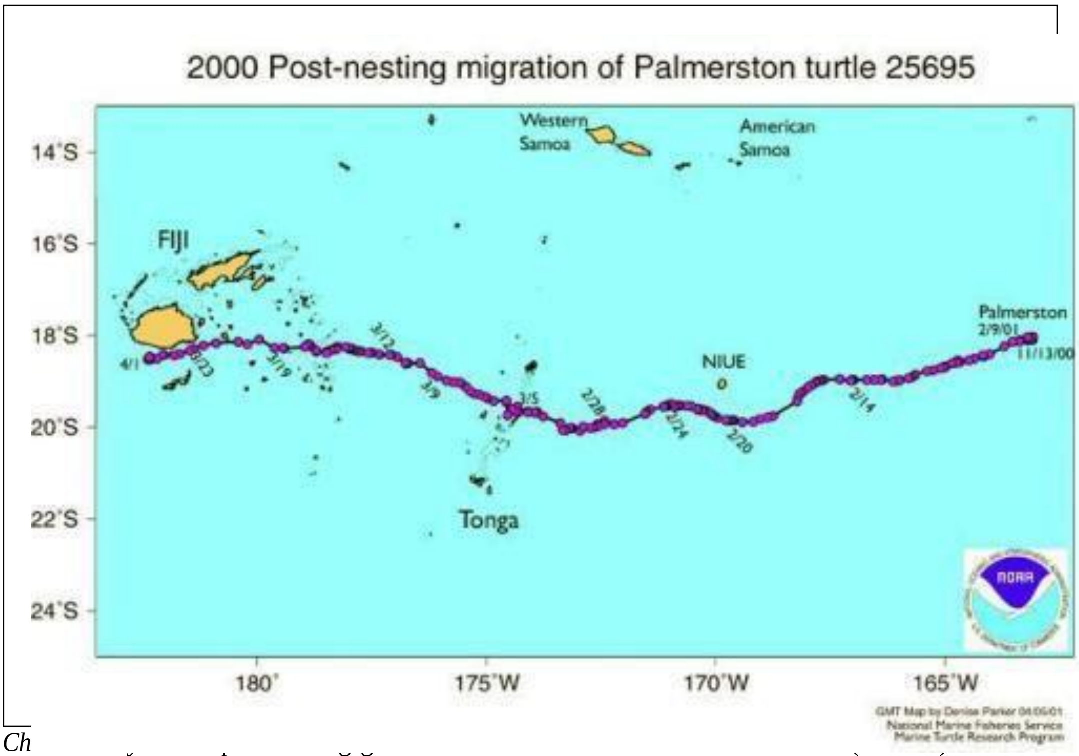
THE TRUE LEVEL OF SEA TURTLE NESTING NATIONALLY IS HIGHER THAN THIS
(White *pers. com.* 2012)

[7] Genetic data are absent for most documented nesting sites in Oceania; about 171 locations have been grouped into 24 NAs (Dethmers *et al*. 2006; NMFS 2010).

General movements of sea turtles through the Cook Islands

Before the present study began there were very few published data concerning sea turtles in the Cook Islands (Balazs 1977, 1995; Pritchard 1995a; McCormack 1995; Centre for Cetacean Research Centre 2000; Maison *et al*. 2010; NMFS 2010; Woodrom Rudrud 2010; WWF undated) and only three records for turtles using the marine environment:

> The following are noted as being the only known records for turtles entering or leaving the Cook Islands EEZ[8]: i) a green turtle tagged at Scilly Atoll, French Polynesia, was captured in the Cook Islands (Balazs *et al*. 1995); ii) a green turtle tagged at Rangiroa, French Polynesia, was recaptured in the Solomon Islands, so may have traversed Cook Islands waters (SPREP 1993); iii) a green turtle was satellite-tagged (tag # 25695, November 2000) while nesting at Palmerston Atoll, Cook Islands, and migrated westwards to the south of Fiji (Balazs *pers. com.*).



Ch ... ton Atoll (November 2000) migrated westwards to Fiji, arriving in April 2001 (Balazs, NOAA).

Sea turtle with satellite transmitter attached. Photo: www.sprep.org

[8] Cook Islands territorial waters cover over two million square kilometres of the South Pacific Ocean.

Do sea turtles actually live in the Cook Islands?

An earlier hypothesis which suggested that '*green turtles do not usually reside in Cook Islands sea areas, but instead live at Fiji or Vanuatu; perhaps making nesting migrations to the Cook Islands*' (McCormack 1995; & WWF undated) - based on the known close association of green turtles and seagrass meadows, which are largely absent in the eastern Pacific (see Hirth 1997) - was not supported by the present author; who has shown that both green and hawksbill turtles are present in Cook Islands waters throughout the year (White, *this report*). McCormack (*pers. com.* 2011) suggested that the presence of *Chelonia mydas* in the Cook Islands during the Austral winter may have been a consequence of head-started [9] turtles that had been released from Palmerston, and other atolls, since the 1950's (Ron Powell, unpublished data); rather than a naturally-occurring population (see also Balazs 1977).

So what evidence is available either way?

It is known that marine turtles are capable of making extended oceanic migrations (e.g. SPC 1979b; Mortimer & Carr 1987; Uchida & Teruya 1988; Lohman 1992; Papi *et al*. 1995; Hirth 1997; Lohman *et al*. 1997; Sakamoto *et al*. 1997; Hughes *et al*. 1998; Luschi *et al*. 1998, 2003; Miller *et al*. 1998; Cheng 2000; Nichols *et al*. 2000; Polovina *et al*. 2000, 2004; Godley *et al*. 2002; Lohman & Lohman 2003; Craig *et al*. 2004; Boyle *et al*. 2009); **satellite-telemetry** (an electronic transmitter is attached to the carapace of a turtle and its subsequent locations are uplinked to Earth-orbiting satellites) has enabled some of these journeys to be better understood.

Satellite tracking from Samoa

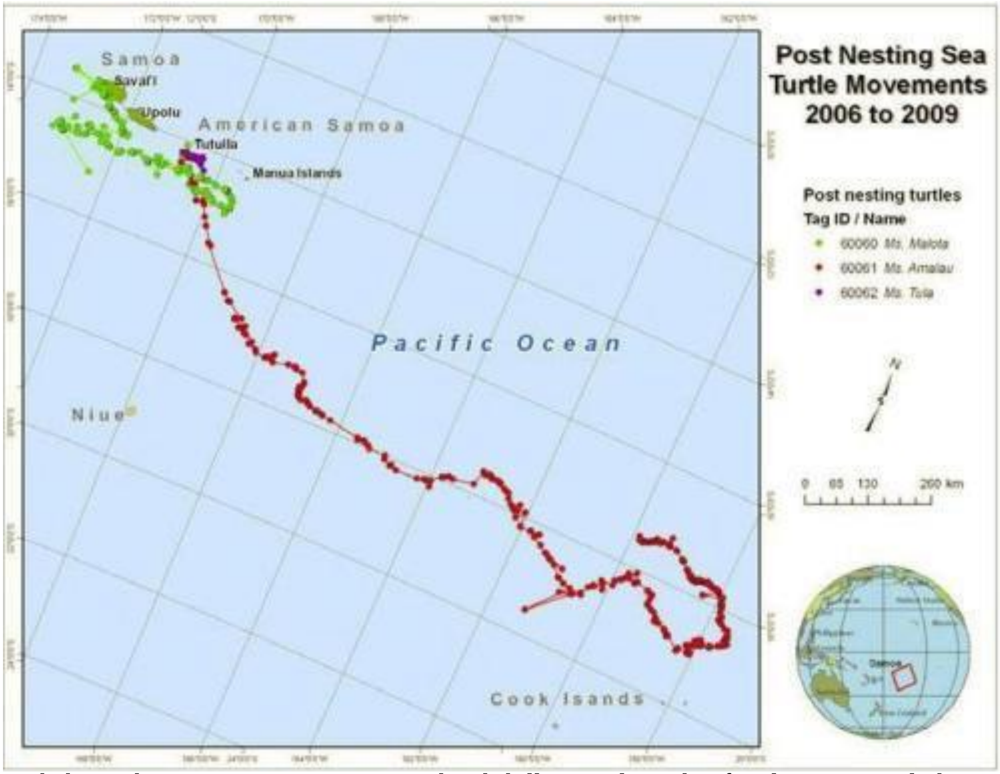
In the South Pacific Craig *et al*. (2004) released seven green turtles that had nested on Rose Atoll (east of the Samoan islands): each had been fitted with a UHF transmitter (an eighth transmitter malfunctioned) during the period 1993-1995. Six of those seven turtles migrated westwards into Fijian waters; the seventh went eastwards to *Raiatea*, French Polynesia: on average those turtles covered about 1600 km, swimming at 1.8 km/hr, with journeys taking around 40 days (Craig *et al*. 2004). Those authors (Craig *et al*. 2004) suggested that green turtles could spend as much as 90% of their adult life in Fijian waters, based on: i) their telemetry evidence; ii) several assumptions (that turtles take 4-5 years to replenish their body-fat reserves following nesting; that reproductive migrations take several months to complete; and that nesting migrations are made quadrennially); iii) a series of flipper-tag returns.

Satellite tracking from American Samoa

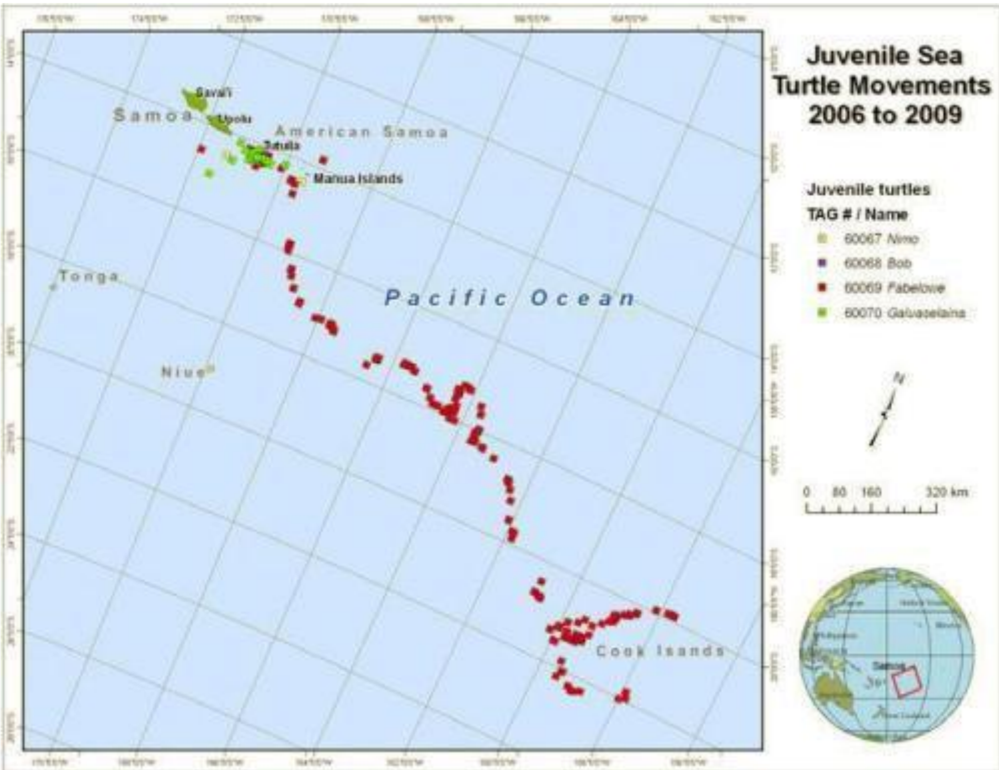
Further information was recently provided by **Alden Tagarino** (Department of Marine & Wildlife Resources, PagoPago, American Samoa): hawksbill nesting occurs in American Samoa (Balazs 2009), especially on *Tutuila Island*. Of two post-nesting hawksbills fitted

[9] Turtle hatchlings are kept in captivity for months or years and allowed to grow to a larger size before being released. This may reduce the impact of predation on neonate turtles as they enter the ocean.

with satellite tags on *Tutuila*, one migrated several hundred kilometres to Samoa, and the other migrated >1000 km to the Cook Islands (Tagarino *et al*. 2008). Also a juvenile hawksbill migrated into Cook Islands waters, thus confirming that these animals are a shared resource (See maps below).



Eretmochelys imbricata. Top: Post-nesting hawksbill passed north of Palmerston and then to Aitutaki. Below: Juvenile hawksbill was near to Palmerston and may have foraged at Rarotonga, Atiu, Takutea, Mitiaro and possibly Mauke



Author's comment on hawksbill turtles: Some hawksbills are thought not to make long migrations (e.g. Witzell 1982; Grant *et al.* 1997), so the tracked journeys of turtles from *Tutuila* (Tagarino *et al*. 2008) are of interest; and, similarly, post-nesting hawksbills on the Great Barrier Reef, Australia, migrated >2,000 km (Miller *et al*. 1998). This contrasts with tracked post-nesting hawksbills in the Hawaiian Archipelago, which migrated <100 km (Parker *et al*. 2009); perhaps because Hawai'i is more isolated than archipelagos in the western and south Pacific where multiple atolls and islands are within a few hundred km of each other.

Satellite tracking from French Polynesia

A telemetric study was undertaken at *Tetiaroa*, French Polynesia: between late-October 2010 and early-March 2011 five green turtles were fitted with UHF satellite transmitters.

The following turtle data[10] were provided by Dr Cécile Gaspar & Dr George Balazs:

i) **Tini**: (88066) CCL (curved carapace length) 44.5 cm; released Opunohu Bay, Moorea 28th October 2010; transmitted for 81 days and headed eastwards to southwestern side of Tahiti; no further transmissions were received after 17th January 2011.

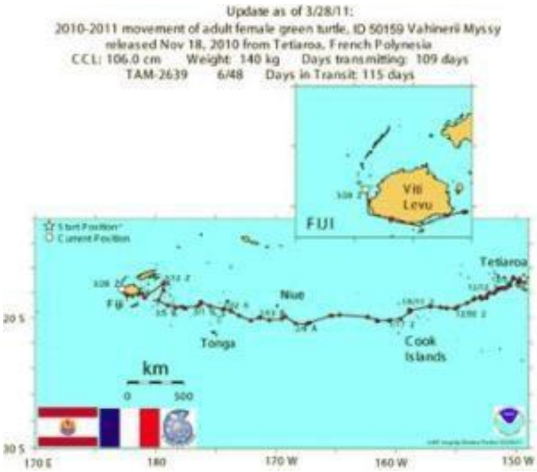
ii) **Vahinerii Myssy** (flipper-tags: 974 & 975) CCL 106 cm; released 18th November 2010 at Tetiaroa; travelled 3500 km in 115 days to Fiji (Viti Levu, south & west sides). **[MW note: appears to have traversed Southern Cook Island waters in early January 2011 (exiting around 17th January); passing south of Niue in early February 2011].**

iii) **Vaea** (flipper-tags: 966 & 967) CCL 104 cm; released 15th December 2010 at Tetiaroa. Remained around the atoll for 54 days and then no further transmissions; she had moved east.

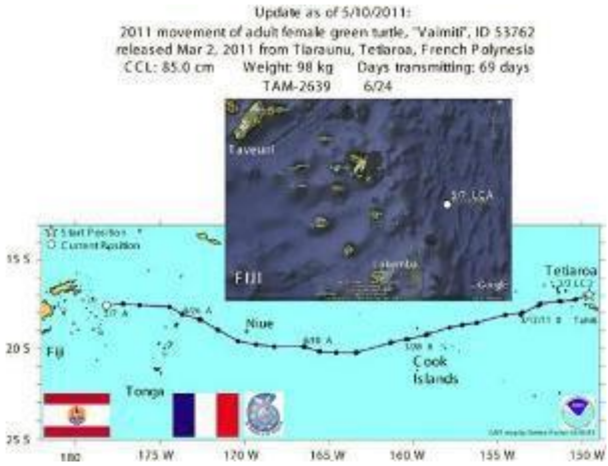
iv) **Maruia** (flipper-tags: 973 & 969) CCL 97 cm; released 14th February 2011 at Tetiaroa. She travelled directly towards Niue, covering 1500 km in 42 days; and then onwards to Fiji. **[MW note: appears to have transited the Southern Cooks in early March 2011; passing north of Niue and was between *Ha'apai* & *Vavau* islands (Tonga) on 10th April 2011; arriving eastern Fiji 21st April 2011].**

v) **Vaimiti** (flipper tags: 896 & 110) CCL 95 cm; released 2nd March 2011 at Tetiaroa.
[MW note: She appears to have transited the Southern Cooks during the second half of March 2011 and then headed for Niue; arriving east of Fiji in early-July].

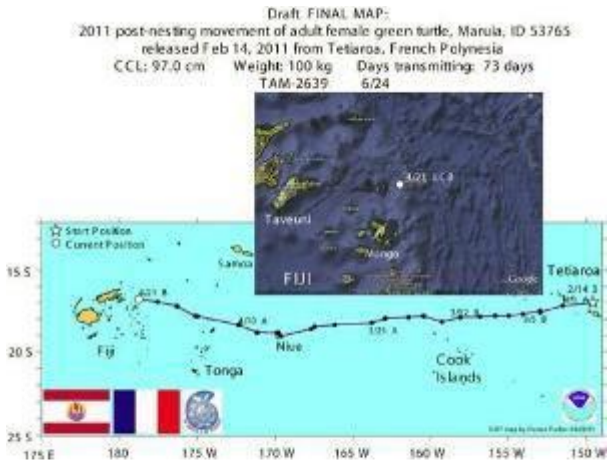
[10] The trackings are a collaboration of *Te Mana o te Moana* (Moorea, French Polynesia), Directorate of Environment (French Polynesia), and PIFSC Marine Turtle Research Programme (Hawai'i).



Final NOAA tracking map for *Vahinerii Myssy* (ID # 50159); date 28/03/2011



NOAA tracking map for *Vaimiti* (ID # 53762); date 05/10/2011



NOAA tracking map for *Maruia* (ID # 53765); date 05/10/2011

Author's commentary on the *Tetiaroa* study:

i) Three of these five turtles (60%) tracked from French Polynesia have migrated through Cook Islands waters. Interestingly they all traversed through the Southern Group (close to 20° S latitude) somewhere north of Rarotonga. The tracking-maps are a little deceptive because even if the turtles pass, say, to the south of Aitutaki – it is a 100-km gap southeast to Manuae ~ basically open ocean. Likewise if the route is north of Aitutaki but south of Palmerston, or between Palmerston and Suwarrow: it is mostly open ocean.

ii) The main questions raised for the present author by the *Tetiaroa* study, which would similarly apply to turtles in the Cook Islands, are: i) How many of the turtles nesting at *Tetiaroa* migrate; ii) How many migrate westwards; iii) How many migrate elsewhere; iv) How many return to French Polynesia (or to the Cook Islands) and at what intervals; v) How many stay locally? (see Balazs *et al.* 1995 Grant *et al.* 1997; Randall 1998).

iii) A known problem of satellite-telemetry is the battery-life (how long transmitters will function for) – this has improved in recent years as micro-technology has become more efficient and widespread. The present author noticed that many telemetric studies are of short duration, just a few months; this could be a result of programming other parameters into a transmitter (e.g. dive-depth, water-temperature or swimming-speed), which greatly reduces its operational life (perhaps to 300 days). In contrast the present author recently concluded a telemetry study on three marine turtles in Albania, Mediterranean Sea: the longest of which transmitted for 763 days (www.medasset.org) (White *et al.* 2010). Battery-life can thus be extended considerably if only locational data are required in the experimental design[11].

iv) To properly answer the questions raised above it would be necessary to track a return migration: e.g. a journey from the Cook Islands to some other place and its return; or to tag a turtle on a feeding ground in, say, Fiji[12] or Vanuatu and see where it ends up This may well require a device that could transmit for five years or more (White *pers. com.*).

v) *Honu Cook Islands* will collaborate with regional authorities (e.g. SPREP) and other Pacific Island nations and marine researchers: deploying satellite-transmitters onto turtles encountered at remote atolls to improve our understanding of their migratory routes and habitat use in the Pacific Ocean (see Tucker 2010). A *Honu* research goal is to investigate the distribution and behaviour of hawksbills in the Cook Islands: do they also make long migrations or just remain locally?

***

[11] A suitable transmitter is the SPOT 5 (www.wildlifecomputers.com); this may function for 700-800 days if only providing locational data.

[12] There has been a recent telemetry programme for green turtles at *Yadua*, Fiji.

Summary (Oct. 2012) for sea turtles passing through Cook Islands sea areas:

Flipper-tag returns:

i) *Chelonia mydas*: a green turtle tagged at Scilly Atoll, French Polynesia, was captured in the Cook Islands (Balazs 1995).

ii) *Chelonia mydas*: a green turtle tagged at *Rangiroa*, French Polynesia, was recaptured in the Solomon Islands, and so may have traversed Cook Islands waters (SPREP 1993).

iii) Siota (2011) noted that two *C. mydas* tagged at Scilly Atoll were found at Palmerston Atoll (Tag # P841, applied 21st June 1993, recaptured 14th October 1994; tag # S757, applied 1st October 1993, recaptured 11th September 1995). **Note:** this may include the Balazs 1995 tag (i).

Satellite-tracking:

i) *Chelonia mydas*: a green turtle was tagged (ID 25695) while nesting (November 2000) at Palmerston Atoll, Cook Islands, and migrated westwards to the south of Fiji (NOAA).

ii) *Chelonia mydas*: a green turtle was tagged (ID 50159) at *Tetiaroa*, French Polynesia (released 18th November 2010) and migrated to the west of Fiji (NOAA).

iii) *Chelonia mydas*: a green turtle was tagged (ID 53765) at *Tetiaroa*, French Polynesia (released 14th February 2011) and migrated to the east of Fiji (NOAA).

iv) *Chelonia mydas*: a green turtle was tagged (ID 53762) at *Tetiaroa*, French Polynesia (released 2nd March 2011) and migrated to the east of Fiji (NOAA).

v) *Eretmochelys imbricata*: a hawksbill turtle was tagged (ID 60061) while nesting at *Tutuila*, American Samoa, and migrated southeastwards towards Aitutaki, Cook Islands (Tagarino *et al.* 2008).

vi) *Eretmochelys imbricata*: a juvenile hawksbill turtle was tagged (ID 60069) at *Tutuila*, American Samoa, and migrated southeastwards towards Aitutaki and the eastern atolls, Cook Islands (Tagarino *et al.* 2008).

Summary for green turtles in Oceania (from NMFS 2010):

The total number of green turtles nesting annually in Oceania is 17,399-37,525 females. The region is divided into 24 NAs, but the Australian NAs: i) Northern GBR (Great Barrier Reef) ii) Southern GBR make up approximately 90% of the total. Over half of all nesting in Oceania occurs at a single island: **Raine Island** in the Northern GBR. Trend data are not available for all of the 24 NAs. However, trend data are available for certain nesting sites within the Ogasawara Island, Northern GBR, Southern GBR, and Hawai'I NAs, where long-term monitoring projects have been collecting data for sufficient time to determine a significant trend. Trend information provided for other NAs is based on well documented anecdotal evidence from local residents, and not long-term nesting beach monitoring datasets. Nesting trends appear to be stable at Raine Island (Northern GBR), and at Heron Island (Southern GBR), and are increasing at Chichi-jima in the Ogasawara Island NA (Chaloupka *et al*. 2007).

However, stable and increasing nesting trends at these sites do not necessarily correlate with a stable or increasing trend overall for Oceania (NMFS 2010) because of low nesting-success, hatchling-production, and recruitment at Raine Island, where the majority of nesting for the entire region occurs (Limpus *et al*. 2003, Hamann *et al*. 2006).

In addition, NAs with small numbers of nesting females may be of greater importance than their proportional numbers indicate (Bjorndal & Bolten 2008). Loss of individuals from smaller, more vulnerable Pacific island rookeries is likely to have a greater impact on that particular nesting assemblage than removal of individuals from a large rookery. Over half of the 24 NAs in Oceania have 100 or fewer documented nesting females annually. Many of these NAs are geographically isolated and **likely to harbour unique genetic diversity.** Small nesting assemblages of green turtles are unlikely to re-colonise their historic nesting areas once they have been extirpated (Avise & Bowen 1994; Schroth *et al.* 1996)[13].

[13] Schroth *et al.* (1996) found that genetic separation existed between different nesting beaches in Greece, Cyprus and Turkey (demonstrated by analysis of nuclear and mitochondrial DNA). This was likely to be due to nesting site fidelity by females and a low male-mediated gene-flow, insufficient to prevent genetic substructuring of even adjacent beaches. Their conclusion was that loss of nesting sites would lead to the loss of specific genotypes. [From White 2007].

Research Techniques

Turtle Research Overview

This research programme has now become an ongoing study, which is producing reliable baseline-data and also developing suitable conservation, co-management, or management options for the Cook Islands Government and People. Each island is treated in a similar way, with the main difference being whether it is inhabited or not; a strong social component is included for populated places. The author's initial approach is to visit each atoll, depending upon when transport is available, so that first-hand knowledge can be gained of: i) the geography; ii) the contempory abundance and distribution of sea turtles; iii) the species and life-stages that are present; iv) the availability of suitable nesting habitats; v) the availability of foraging resources; vi) the level of traditional take (meat and eggs); vii) any other threats or impacts; viii) any traditional management practices, such as *Rahui* (*Ra'ui*)[14]. One aim is to identify important nesting sites (*index beaches*) that will be used in future surveys, so that sea turtle population-trends can be determined in subsequent years: these do not exist. Further aims are to: develop marine education; raise awareness of global problems and their local impacts; and explore the most suitable conservation measures for each atoll.

Research activities can be divided into three phases: i) an initial fact-finding survey; ii) an assessment of habitats and the distribution and abundance of sea turtle species; iii) an ongoing research programme; which over time will be community-led.

The author has now visited all Northern Group atolls at least once:

Manihiki (2010-2012)
Nassau (2009 & 2010)
Pukapuka (2010)
Rakahanga (2010 & 2012)
Suwarrow (2009)
Tongareva (2010-2012)

And the following islands in the Southern Group:

Aitutaki (2010)
Palmerston Atoll (2009, 2010 & 2012)
Rarotonga (2009-2012)

The *makatea* islands have not yet been visited.

[14] Collection of various species or using certain locations is prohibited for a period of time. The *tapu* is imposed by the Island Council and adhered to by common consent. The rahui is lifted as needed.

Methodology for nesting beach surveys

Determining the suitability of coastal habitats for sea turtle nesting

Assessments were made of the suitability of each island to support sea turtle nesting. Surveys of habitats included their substrata types, proximity to the high water mark, ease of access from the ocean or lagoon and vegetation cover. Beaches were walked during daylight hours searching for tracks and any signs of nesting activity, such as body-pits or digging attempts. Habitat maps were prepared to show the nesting suitability of beaches.

1) Classification of beaches

Beaches were allocated into three main types:

i) Type A – suitable nesting habitat: good quality sand or gravel with sufficient depth for nest construction and an adequate nestable area above the high water mark. Evidence included egg-laying females, confirmed nests, hatchling tracks or hatched eggshells at the surface.

[A*] indicates that habitat is suitable, but tracks or direct nesting evidence were not found at the time of surveying. Anecdotal information may confirm previous nesting at sites.

ii) Type B – possible nesting habitat: good substratum, but with some aspects that may hinder nesting.
Some examples are: **a)** a flat area that is dry land for much of the time, but is inundated occasionally (e.g. the western side of *Matunga* and *Tehara* at Tongareva); **b)** areas where access over the reef is difficult (e.g. some sectors of *Moananui* at Tongareva); **c)** areas with thick vegetation that makes access to the nesting zone difficult, but not impossible.

iii) Type C – generally[15] unsuitable for nesting: usually a solid substratum where nest construction is not possible.

Other examples include: **a)** a steeply-sloping, narrow, rubble shore, with either very little, or impenetrable vegetation at the top (e.g. eastern shore of *Pokerekere* and *Patanga* at Tongareva); **b)** areas covered in large boulders; **c)** areas where the sand is water-logged or intertidal (e.g. *Tepuka* at Manihiki and *Oneroa* at Rarotonga); **d)** areas where access from the ocean is very difficult (e.g. Rakahanga's western shore); **e)** areas that are densely-covered with fallen vegetation; **f)** beach areas with little sand depth, overlaying a

[15] The dynamic nature of coastal habitats means that what may happen at Type C locations is that in some years the sand depth increases sufficiently to support nesting, perhaps during cyclone or tsunami activity, but then the natural coastal processes render it unsuitable again (the author has observed this on Aitutaki: at the airport and *Rapota* motu during 2010). A further consideration is that there are many other very suitable and easily-accessible nesting sites nearby, which turtles would be more likely to use.

rocky substratum (e.g. some parts of the nesting-zones on *Moananui* and *Mangarongaro* at Tongareva).

iv) Beach sectors: beaches were divided into sectors of varying lengths, usually based on a major change in nesting suitability (e.g. substratum shifts from sand to boulders); small beaches were single sector (and see Varela-Acevedo *et al.* 2009). Recognisable natural features, such as an unusual tree; or a man-made feature (e.g. a building) can be used to confirm research locations (see Stapleton & Eckert 2008; Varela-Acevedo *et al.* 2009). In April 2012 The Rufford Foundation (www.ruffordsmallgrants.org) provided us with GPS equipment[16]; subsequently, waypoints could be used to delineate sectors and mark extremities of motu or atolls (north, south, east and west); the latitude and longitude were verified using any available printed maps and marine charts; and Google Earth.

v) Seawards access: another consideration for nesting areas was the ease of access from the ocean or lagoon onto a beach. Sea turtles are large and heavy animals that are limited in their ability to move on land: their limbs are adapted for swimming rather than walking and so they have to drag themselves across the reefs and beaches. The presence of *'ava'* (passages through the reef) and the tidal state were also noted, especially at places where near shore rocky barriers were present; this later proved to be important.

vi) Vegetation cover: the presence or absence of plant cover was recorded. Green turtles locally prefer to nest in the forest or under bushes and trees at the back of the beach (the distance to the vegetation line can be measured); nests laid mid-beach were very rare, and it was noted if nesting sites were usually in shadow. Descriptions for plant cover were (**'local name'** ~ common English name, *species name*):

i) Low bush (e.g. **'ngasu'** ~ *Scaevola frutescens*)
ii) Coconut trees (**'niu'** ~ *Cocos nucifera*)
iii) Pandanus (**'hara'** ~ *Pandanus tectorius*)
iv) Ironwood (**'ngangie'** ~ *Pemphis acidula*)
v) Mixed forest (e.g. **'tamanu'** ~ Alexandrian laurel *Calophyllum inophyllum*; **'tausunu'** ~ heliotrope *Tournefortia argentea*; **'hano'** ~ *Guettardia speciosa*, **'noni'** ~ *Morinda citrifolia*; **'tou'** ~ cordia *Cordia subcordata*)
vi) Open area

vii) Threats and impacts: habitat impacts were noted and potential threats considered:

i) Marine debris, especially plastics ~ a ubiquitous problem
ii) Oil, tar, or toxic chemicals; terrestrial run-off into the lagoons
iii) Sand extraction (for building purposes)
iv) Light pollution
v) Roads and houses near by
vi) Building developments (e.g. harbours or tourist resorts)
vii) *El Niño* effects

[16] Global Positioning System: Garmin GPSmap 78 (www.garmin.com).

2) Classification of turtle tracks

Gathering information to show nesting seasonality and peak egg-laying period

a) Age of tracks

Turtle tracks on the beaches were allocated into three categories based on the estimated date that the track was made:

i) **Recent:** made within the last 14 days
ii) **Older:** 3-4 weeks old
iii) **Oldest:** faint, but still recognisable as a turtle track; it was usually possible to locate the nesting site, although this could be difficult when the nest had been laid underneath coconut or pandanus leaves.

Note: With experience it is fairly easy to *'read the story written in the sand'*. Tracks may be eroded by heavy rain; even though rain may be a rare event in the Northern Islands; this would make tracks appear older than they really were.

b) Patterns of movement

Track patterns were examined to determine if turtles used symmetrical or asymmetrical

modes of locomotion (Miller 1997); turtle species tend to move in different ways on land[1 7].

c) Nesting events

An uptrack and its corresponding downtrack were considered as a single event i.e. a turtle crawls up the beach and sometime later returns to the sea. It was not always possible to determine track-pairs, particularly in areas with high-density nesting, so a conservative estimate of nest abundance was used if the evidence was unclear; these present data can be regarded as minimum nest numbers.

Egg-laying events could be clustered (i.e. several nests being laid close to each other) or isolated (i.e. a single nest). One reporting option if necessary is to use density *'bins'* (e.g. <10 nests; or >50 nests). Isolated nests were usually marked with a waypoint (late-2012).

Confirmed nesting was where the various stages associated with the egg-laying process (Miller 1997) had been completed, but with the proviso that final covering of the body-pit might not have restored the beach surface completely (White *pers. obs.*).

The designation **'undetermined nest'** (Limpus 1985) or **'suspected nest'** (Stapleton & Eckert 2009) can be applied when it is uncertain if eggs were actually laid. The author prefers to monitor the nest for emergent hatchlings, about two months after the event, and

[17] Green and leatherback turtles normally use symmetrical movements on land (both fore-limbs are moved simultaneously); the other species move asymmetrically (diagonally-opposite limbs are moved together).

then confirm it as a nest; rather than dig into a suspected nest until eggs are visible, which has two associated risks: i) introducing bacterial and fungal agents into the egg-chamber; which could lead to loss of the clutch; ii) altering the compaction of the sand above the egg-chamber (determined by the female when she in-filled the nest), which would affect gas (O_2 and CO_2) and water exchange between the eggs and surrounding environment, and also the temperature within the egg-chamber: which may alter the embryonic sex ratios (Ackerman 1997; Miller 1997).

An emergence was noted as an **'attempt'** if some signs of nesting activity were apparent (e.g. a body-pit or abandoned egg-chamber), but a nest could not be confirmed.

A track was deemed a **'U-turn'** if a turtle had emerged from the ocean and then returned without making any attempt to nest. [The term *'false crawl'* was not used, as a turtle had actually emerged onto the beach; the preferred term was **non-nesting emergence**].

The relationship between a nest location and the high water mark was noted (Stapleton & Eckert 2008). In many parts of the world this seems to significantly influence the nest success. In the Northern Cook atolls the beaches tend to be steeply-sloping, presumably providing sufficient water drainage through the sediment for successful egg development, and successful nests have been found within 1-2 metres of the high water mark.

NOTE: Although likely to be a very rare occurrence, if a nest has to be moved a standard method of egg relocation will be followed (e.g. Boulon1999; Mortimer 1999; Pfaller *et al.* 2008; Stapleton & Eckert 2008). The most important consideration is that nest relocations should take place soon after the eggs were laid: eggs are in stasis until 10-12 hours after oviposition when the process of development continues (Miller 1997). If an egg's orientation is changed after this time then egg-death will occur (Limpus *et al.* 1979). Nests are most-commonly relocated when a high risk of destruction exists (e.g. eggs laid near the surf-zone (beach-erosion or overwash), or where nest predation is high (e.g. dogs, foxes or jackals); both of these factors are rare or absent in the Cook Islands.

3) Nesting period

Note: The egg-laying period has rarely been reported for the Cook Islands.

i) Date-of-lay: Estimates were made of the likely dates that nests may have been laid; these could be based on any of the following evidence:

- i) Adult females observed on the beach
- ii) Hatchlings (baby turtles) observed on the beach
- iii) Adult tracks on the beach
- iv) Hatchling tracks on the beach
- v) Eggshells found in the nesting areas
- vi) Other sources (including anecdotal information)

ii) Incubation period: The time that would be required for eggs to incubate successfully (i.e. for hatchlings to emerge from a nest) was selected as being of 60-days duration (two months). On nesting-beaches this is usually determined precisely by noting the date that a nest was laid, then monitoring it until the first hatchlings emerge. The incubation period is determined by the temperature within the nest: higher temperatures mean that eggs can hatch more quickly (perhaps in 45 days); cooler temperatures can extend incubation to 80 days or more (e.g. Marquez 1990; Miller 1997, White 2007).

If any hatchlings were observed during the surveys the date-of-lay would be estimated by subtracting the assumed incubation period (60 days) from the date that the observations were made. If egg-shells were discovered in the nesting zone (i.e. these had been moved from the egg-chamber to the beach surface as emerging hatchlings dug their way upwards through the sand-column[1][8]) a further factor then had to be taken into consideration, which was: *'how long had the egg-shells been on the surface'?* Shells were examined closely to determine how flexible or brittle (desiccated) the fragments were[1][9]. If for example a shell had perhaps been on the beach surface for three weeks, this is added to the incubation period to estimate the date-of lay (i.e. 21 days since hatching, plus 60 days incubation, would suggest a date-of-lay as 81 days earlier). If hatchling tracks were seen they were treated as described above: the likely age of tracks plus the incubation period would give an estimated nesting date.

[1][8] It may take hatchlings 3-7 days to dig from the nest to the beach surface.

[19] Sea turtle eggshells are flexible like parchment, rather than being hard like birds eggs.

4) Determining nest success

Selected nests were excavated after hatching and their contents inventoried to determine the level of egg success (Miller 1999; Cruz & Frazier 2000). The decision to examine a nest or not depended largely upon the time available to do the work; the process is quite time-consuming. On a short expedition or once-only survey other research tasks may have priority. The ideal target was to assess 50% of the hatched nests; at some sites all nests were examined.

The following method was used to quantify nest success:

i) Count the total number of eggs
ii) Count the number of hatched eggs (empty shells)
iii) Count the number of undeveloped, misshapen, or small eggs
iv) Count hatchlings dead-in-nest, and pipped eggs (i.e. turtle emerging from the shell)
v) Calculate hatching % **(hatched eggs/total eggs laid × 100)**
vi) Calculate overall nest success **(hatched eggs minus any mortalities)**

Determining reasons for non-development or egg failure

Unhatched eggs were opened and the following stages of egg development were used:

i) Unfertilised
ii) Eye-spot present
iii) Early-stage embryo (yolk-sac is larger than the embryo)
iv) Mid-stage embryo (yolk-sac is a similar size to the embryo)
v) Late-stage embryo (embryo is larger than the yolk-sac)
vi) Pipped mortality (the hatchling died while trying to exit the egg)

At sites where adjacent nests had low success rates, possible environmental impacts were considered (e.g. inundation; or high temperatures that had solidified the egg-yolks).

Nest depth

During the excavation process the distance from the beach surface to the top-most eggshell was measured (cm). Then hatched eggshells and any unhatched eggs were lifted out, and the distance to the bottom of the nest was measured. The difference between the two measurements is the egg-chamber diameter (cm).

AUTHOR'S NOTE:

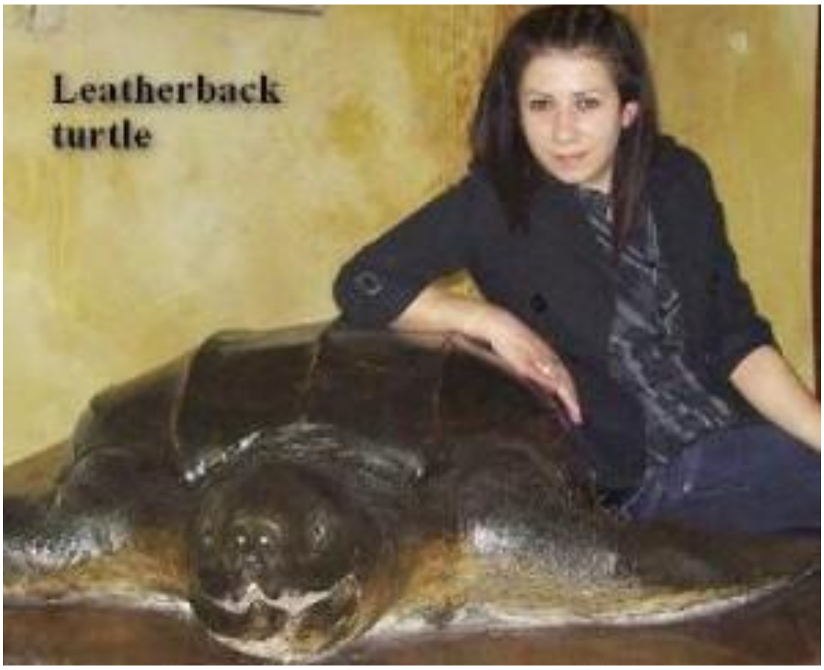
Many photographs can be found below under '**Research Findings'.**

Four sea turtle species are shown here for comparison

Hard-shelled species (Cheloniidae)

Top left: *Eretmochelys imbricata* ~ juvenile hawksbill (these are rare); **top right:** *Caretta caretta* ~ sub-adult loggerhead (these have been reported from Palmerston Atoll); **Bottom:** *Chelonia mydas* ~ juvenile green (the most common species in the Cook Islands). The head shapes and scale patterns are completely different in each species; carapace scutes are described below.

Soft-shelled species (Dermochelyidae)



Top: *Dermochelys coriacea* ~ sub-adult leatherback (University of Tirana, Albania) ~ the dorsal ridges improve hydrodynamic efficiency; note also the two *'cusps'* at the front of the upper beak. **Below:** juvenile leatherback (Universita di Napoli, Italy). This species can weigh 1000 kg & reach nearly 3 m in length. In the Cook Islands these are encountered occasionally in the offshore fishery but egg-laying cannot be discounted as they are oceanic migrants - nesting on any suitable atolls.

Sea turtle morphometrics

The following techniques were used on encountered or captured turtles:

a) identify species (scute and head-scale counts); life-stage and sex
b) measure CCL and CCW (Curved Carapace Length and Width)
c) tag the turtle (numbered metal tags are inserted into the front flippers)
d) collect small skin biopsy for DNA analysis
e) record photo-recognition characteristics
f) assess general health status of turtle; note any tag-scars (i.e. missing tags)
g) note existing tag numbers and tagging-project details
h) note presence & details of any telemetric equipment (e.g. transmitters)

i) Species identification: the carapace scutes were counted (nuchal, vertebrals, costals left/right, marginals left/right) and any anomalies noted. Dorsal head-scales were counted from two regions: pre-frontal and fronto-parietal (see below). Standard taxonomic keys are used to confirm the species (e.g. Witzell 1983; Marquez 1990; Pritchard & Mortimer 1999; Wyneken 2001).

ii) CCL (Curved Carapace Length): The centre-line distance over the carapace (shell *'tua'*) was measured from where the skin at the back of the neck joins the anterior scutes (keratinous plates) to the posterior margin (green and loggerhead turtles); for hawksbill turtles the measurement terminated at the anterior end of the 'V-shaped notch' between the rearmost marginal scutes (Eckert *et al*. 1999). Epibiota (e.g. barnacles), if present, can be removed before measuring the carapace (see below).

iii) CCW (Curved Carapace Width): The widest distance over the carapace.

iv) Size-classes: Turtles were allocated into 10-cm size-classes based on their CCL: e.g. 70-cm CCL size-class is from 70.0 cm to 79.9 cm *et seq*. (White 2007).

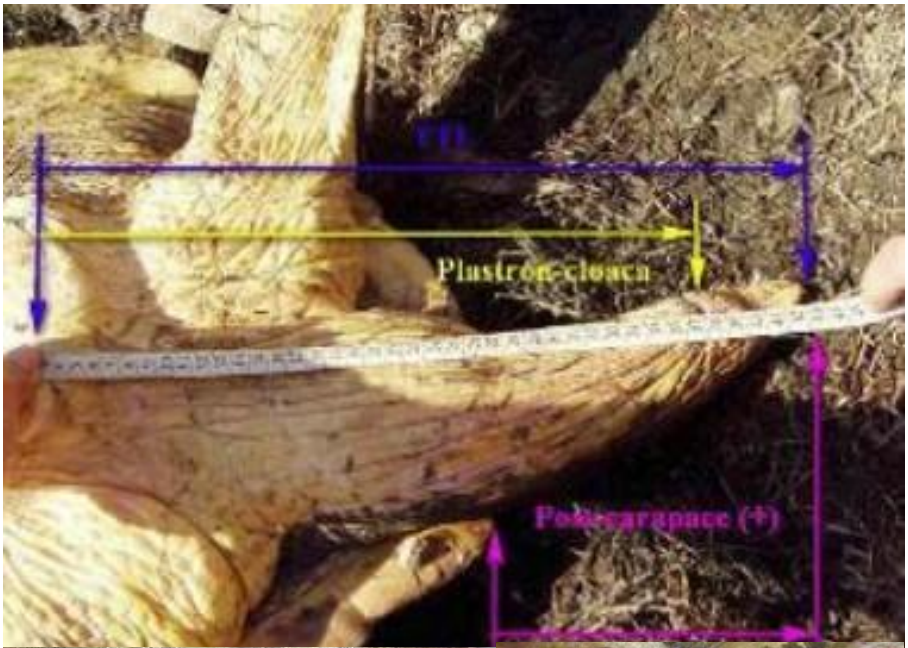
v) Sex: if laparoscopy is unavailable, measurements of the **external tail morphology** can be used instead as an indicator to ascertain the developmental stage of secondary sexual characteristics: i.e. if animals are adult or immature[20]. Three measurements were recorded from the tail ventrally (Casale *et al*. 2005, White *et al*. 2011, *& In Press*):

i) Distance from posterior margin of plastron to midline of cloacal opening **(Plas-clo)**
ii) Total Tail Length **(TTL)**
iii) Distance from tip of tail to posterior margin***** of the carapace **(+/- cara):**

[20] Adult males are easily-identifiable by the muscular tail that extends, perhaps 30-40 cm, beyond the carapace's rear margin. In sub-adult males the tail has begun to develop, widening proximally and extending distally, but may still only protrude a few centimetres beyond the carapace (see White *et al*. 2010 & 2013 *In Press*). Turtles laying eggs on a beach are obviously adult females; whereas smaller short-tailed turtles could be juveniles of either sex, or maturing females.

a) ***The rearmost margin of the carapace (supra-caudal scutes) was taken as the zero datum (0.0).
b) **Post-carapace (>0.0):** in males the more-developed tail extends beyond the carapace margin.
c) **Sub-carapace (≤0.0):** females and smaller juveniles of both sexes tend to have shorter tails.

Measuring the tail:

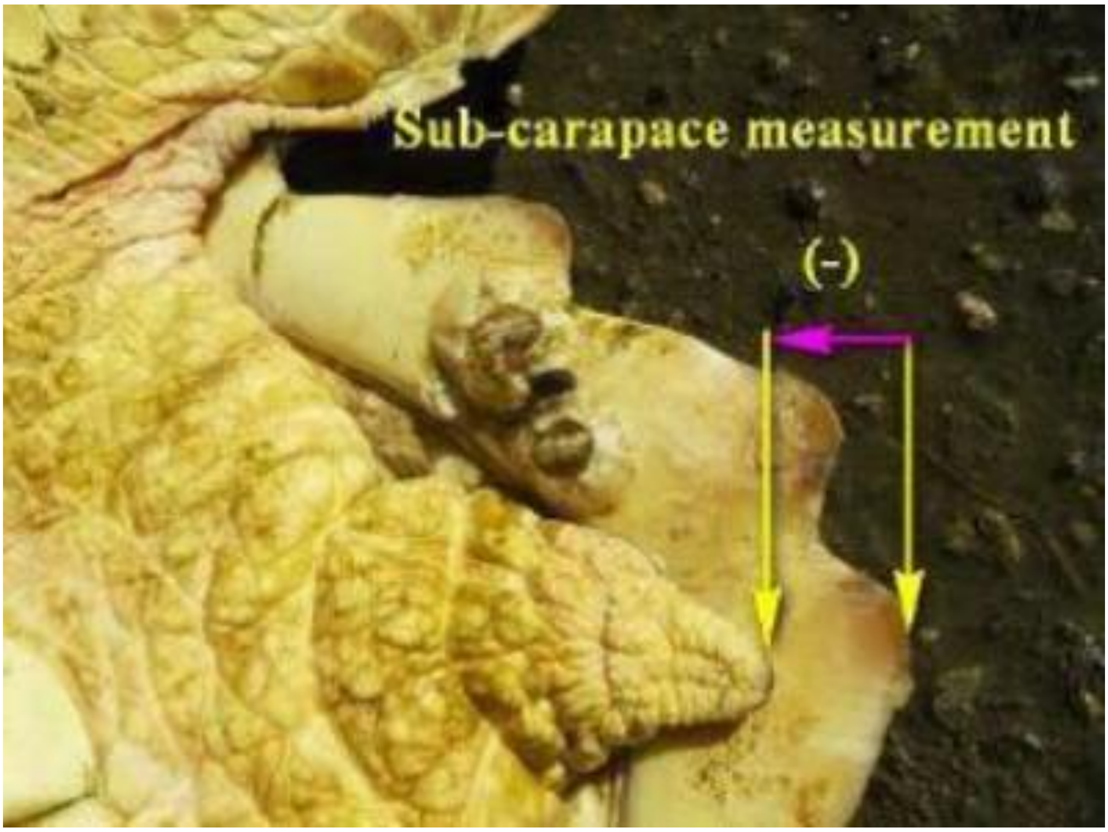


Adult male sea turtles have an elongated tail.

Caudal morphometrics.

Maturing male: shows tail development

Adult female has a short tail (sub-carapace)



Short-tailed turtle: could be a juvenile of either sex.

Measuring the carapace:

CCL is measured between arrows A & B. **Top:** green turtle; **bottom:** hawksbill turtle

Curved Carapace Width (CCW) is the widest measurement over the carapace: we use the outer edges of the marginal scutes. Note the special problem of very small juveniles: they have sharp spikes on their scutes ~ as an anti-predation adaptation

Epibiotic fauna (e.g. barnacles) can be removed carefully with a knife or paint-scraper. Do this before measuring CCL & CCW.

Flipper-tagging

A long-standing approach used to determine distribution patterns is to apply a numbered tag to one or more of a turtle's flippers in order to confirm its identity (Balazs 1999). This technique is widely-used in nesting-beach studies, and also on turtles captured at foraging grounds or during migrations (e.g. Meylan 1982b; Lazar *et al*. 2004); and, more recently, by observers monitoring fishery bycatch (see Eckert *et al*. 1999). In order to gain any useful information the animal has to re-encountered at some point in the future, and its tag-data reported. Mark-release-recapture studies show the dates and locations for where individual animals were released and subsequently re-encountered, but not where they lived between-times (White 2007). In fact, tag-return data typically account for just 1-3% of the total tagged population (e.g. Hughes 1974a, 1974b; Margaritoulis (1988c);Argano 1992; Baldwin *et al*. 2003; Bell *et al*. 2005; White *et al*. 2011) (**See endnote ii**).

Flipper-tagging undertaken on the remote Cook Island atolls is likely to encounter at least four problems:

i) Turtles have to be captured or encountered on a beach to apply the tags; and then again to read the numbers at a later date.
ii) An awareness campaign has to be implemented so that islanders know how to report tag numbers; even if they have eaten the turtle.
iii) Certain types of flipper-tags may increase the risk of a turtle becoming entangled in fishing gear (Suggett & Houghton 1998).
iv) Transportation to an atoll to conduct research may be very limited.

***Honu's* mitigation measures are to:**

i) Systematically tag nesting turtles and any live captures, particularly when undertaking fieldwork on the remote atolls: this method is our best option immediately.
ii) A nationwide sea turtle information programme is being implemented in conjunction with MMR: it will be possible to report tag numbers to their website (www.mmr.gov.ck).
iii) Use tags that minimise incidental entanglement. We have implemented this by using *Stockbrand's* titanium tags, which lock into a 'closed-U shape'[21].
iv) Plan joint-expeditions to remote sites with other professional researchers (e.g. birds, cetaceans, corals, alien-species surveys, or predator-control): a charter-vessel will be used for the survey period, thus reducing each organisation's costs.

[21] Tags and tagging equipment were provided by SPRE

Small Kentucky tag; larger Stockbrand's tag   Inserting a Stockbrand's titanium tag

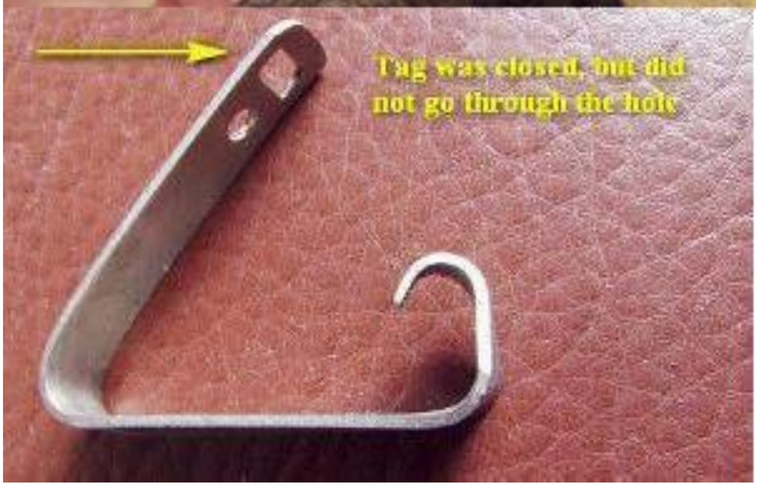
Honu uses conventional metal flipper-tags (Balazs 1999) that were provided by SPREP (www.sprep.org) as part of its regional turtle management programme. Two sizes of tag are used: the smaller are inconel (Kentucky National Band & Tag Company); and the larger are titanium (Stockbrand's Australia). New tag-series numbers are reported to the Archie Carr Centre for Sea Turtle Research (ACCSTR; http://accstr.ufl.edu), Florida; in order to avoid duplication of tag-numbers by different projects. Transfers of SPREP tags between projects in the Pacific are reported via TREDS (see below). Best practice is followed when applying tags in order to avoid injury and subsequent tag-loss; two tags are applied to individual turtles, one on each anterior flipper (L3/R3 positions; SPREP). The right-hand tag-number is reported preferentially by *Honu* as the 'primary tag' (TREDS database record); but either tag may be used. Tag-numbers are also recorded in an Excel (*xls*) spreadsheet ~ cross-linked to a turtle's morphometric, biographical and any genetic data ~ these data are used by SPREP in their annual TREDS national reports.

Juvenile green turtle at Tongareva Atoll: tagged and ready for release

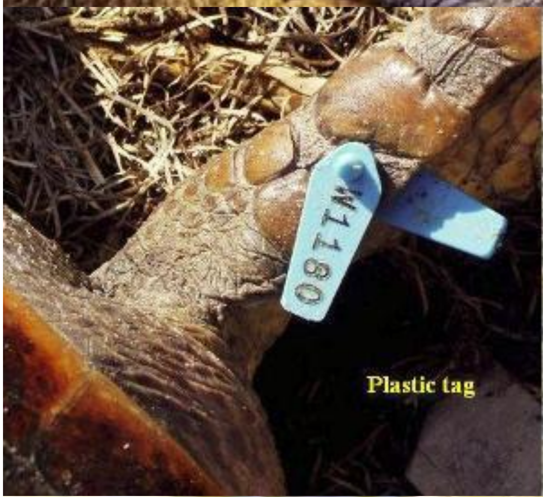
These pictures show good tagging procedures. Researchers should look underneath the flipper as well, before applying the tag: if a scale is in the way then choose another site. Always check that the tag is ‘locked’. The spike passes through a hole and then bends round to secure the tag; the Stockbrand’s titanium tags shown here prevent the point from irritating the animal too. A very good design.

*Occasionally it may be necessary to put a tag into a rear flipper, in which case it goes into the webs ~ avoiding the small bones. Researchers should always use their judgement on a case-by-case basis.

Bad tagging: too near edge; too much of the tag overhangs, so it moves up & down as the turtle swims



Tagger did NOT check that the tag went through the limb & locked; he just squeezed the pliers & that was it! The bent spike was inside the animal.



Roto-tags were widely used, but could snag on line or nets. They are easily removed & replaced with titanium tags, which remain legible indefinitely

Genetic-sampling

Axilliary skin (ventral and proximal to a fore-flipper) is very soft and easy to biopsy; other areas may be sampled instead.

The most recent approach for identifying turtle populations is to collect tissue samples for DNA analysis, so that the haplotypes of sampled turtles can be determined: mitochondrial DNA (mtDNA) is passed directly from mother to her offspring; nuclear DNA (nDNA) is the combined genetic material from both parents. Maternal inheritance (mtDNA – Bowen *et al*. 1994; Abreu-Grobois *et al*. 1996) tends to accentuate genetic differences between populations (Moritz *et al*. 2002). Genetic studies have also revealed other important findings, including: evolutionary descent (FitzSimmons *et al*. 1995); natal homing (Meylan 1982; Meylan *et al*. 1990); population structure (e.g. Bowen *et al*. 1992, 1993; Carreras *et al*. 2006; Pont *et al*. 2006); stock analysis of fishery bycatch (e.g. Bowen *et al*. 1995; Laurent *et al*. 1998; NMFS 2010); multiple-paternity (Harry & Briscoe 1988; Galbraith 1993; Fitzsimmons 1996); distinct nesting aggregations (Schroth *et al*. 1996; Moritz *et al*. 2002; Dethmers *et a*l. 2006); foraging populations (e.g. Lahanas *et al*. 1998; Dutton *et al*. 2008); migrations (e.g. Avise & Bowen 1994; Bowen 1995; Bowen *et al*. 1995; Bass *et al*. 1996; Bolten *et al*. 1998); and relationships between adjacent oceans (e.g. Laurent *et al*. 1993; Tomas *et al*. 2003; Carreras *et al*. 2006; Garofalo *et al.* 2009).

In the Pacific region, especially for the South Pacific islands, there are very few genetic data available for marine turtles (NMFS 2010; SWOT 2011), which makes it difficult to determine the origin of nesting or foraging turtles, and likewise the origin of turtles that are caught in fisheries.iii (**See endnote iii**). Extensive DNA-sampling for green turtles has been undertaken in Australia (e.g. Moritz *et al*. 2002 & references therein) and at Hawai'I (on nesting beaches, especially at French Frigate Shoals, and also foraging-grounds); the Hawaiian archipelago appears to comprise one genetic stock that is distinct from other known Pacific stocks (Dutton *et al* 2008; NMFS 2010; Pilcher 2011). A high priority is to sample nesting female turtles[22], especially *Eretmochelys imbricata*, so as to understand which nations share the same individuals; turtles migrate to different places at different stages in their lives. There are no known DNA data for the Cook Islands.

[22]The priority for analysing tissue samples is lower for turtles at neritic foraging-grounds or oceanic-phase juveniles; these biopsies will be archived and sequenced in due course (Irene Kinan Kelly *pers. com.* 2011).

Protocol for DNA sampling

a) Tag and measure the turtle
b) Wipe target area with a topical antiseptic (e.g. Betadine; alcohol is not to be used)
c) Surgically remove a small section of skin (0.5 cm2) from one of the softer areas using a new scalpel bade and sterile forceps to avoid tissue cross-contamination
d) Place biopsy into a clean plastic vial & label with sample-number[23]
e) Sample is preserved in a suitable medium (e.g. DMSO[24]; 96% ethanol; saturated NaCl)
f) A numbered piece of bond paper or label written in pencil goes inside the vial
g) Vials are securely closed and labelled on the outside with permanent marker (species, date, location, and field ID no.); and then wrapped in parafilm ('food wrap')
h) Scalpel blades are disposed of in a *'sharps container'*
i) Forceps are sterilised between samples (dip into alcohol & hold in a lighter-flame)

j) **Before shipping** double-wrap sample vials in airtight plastic bags (Ziplocs)
k) CITES export/import permits are obtained (Joseph Brider, NES, Rarotonga)

l) DNA-samples **and permits** are sent by courier to the pre-arranged laboratory[25]
m) Samples are analysed using standard laboratory protocols
n) Results are reported to ACCSTR (Dr Alan Bolten); and novel haplotypes to GenBank

Notes:

i) A biopsy tool (0.5 cm diameter) can also be used to sample skin or muscle tissue
ii) Dead animals[26] can also be sampled; if *'fresh'* (dead less than 2 hours) use the heart and liver; if dead more than 2 hours then use skin and muscle
iii) Tissue can be chopped several times to increase preservative penetration
iv) Whole embryos from non-viable eggs can also be preserved
v) Tissue-samples in DMSO can be stored at ambient temperature for at least a year; but avoid extended exposure to heat or sunlight (P. Dutton *pers. com.*)

[23] This is cross-referenced to the animal's flipper tag numbers (*xls* is emailed to the laboratory).

[24] Di-methyl sulphoxide (20 % DMSO and 80% saturated NaCl (salt) solution).

[25] The author uses Canberra University, Australia (Dr Nancy Fitzsimmons), or NOAA California (Dr Peter Dutton). We participate in the Pacific Regional DNA-sampling programme.

[26] Researchers should be familiar with biohazard procedures when sampling dead animals.

Photo-recognition

The hard shell of a cheloniid turtle is formed from a number of interlocking keratinised scutes (plates) in a readily-identifiable pattern; the number and layout of scutes varies slightly between turtle species (e.g. Marquez 1990; Eckert *et al.* 1999; Wyneken 2001). Sea turtles, in common with other reptiles, are covered with scales, which, along with the scutes, may take a unique shape during development (Davenport & Scott 1993). Such patterns and shapes of scutes and scales, particularly those on the face and dorsal surface of the head, may well allow the identity of at least some individuals to be reconfirmed (Wyneken 2001). White (2007) utilised carapace scutes and dorsal head-scales[2][7] to good effect during behavioural studies of loggerheads; other researchers have preferred facial profiles, especially for green turtles (e.g. Bennett *et al*. 2000; Richardson *et al*. 2000; Bennett & Keuper-Bennett 2004; & Schofield *et al*. 2006 for loggerheads), although this means that close-up images have to be obtained.

It is possible to positively identify individual turtles by using a combination of their scute and scale patterns; CCL size-class; identifiable sexual characteristics; and any existing injuries such as amputated limbs, the loss of an eye, or carapacial damage e.g. strike from a boat's propeller (White 2006, 2007; White *et al*. 2011).

Head-scales of *C. mydas*

C. caretta prefrontal scales

Fronto-parietal scale

C. mydas. Facial profiles from the same turtle: scale patterns are different on each side

[2][7] In mathematical terms such patterns are known as 'complex nets' (White 2007).

At present photographs may still have to be sorted and compared visually; consultation with mathematicians (School of Mathematical Sciences, University College Cork, Eire) indicated that scanning hardware and analytical software were as yet incapable of consistently reliable analysis and comparison of these patterns (White 2007). Recently a computerised programme (MIDAS) was developed and is being tested in Australia (Ian Bell *pers. com.* 2010); human facial-recognition software is improving rapidly and also undergoing trials in several major airports (e.g. London-Heathrow; White *pers. obs.*). A pilot study by OBIS-SEAMAP (see below) uses a Web-based prototype photo-ID system, which includes variable search-criteria and produces matching images from its different species catalogues (Halpin *et al*. 2009).

Photo-recognition of individual turtles can be optimised by using the following data:

i) Pre-frontal number. These scales are on the dorsal surface of the head between the beak and the eyes **[PF no. is the count of these scales].**

Note: *C. mydas* usually has 2 PF scales; *E. imbricata* usually 4; *C. caretta* between 4-8.

ii) Fronto-parietal Index. On the dorsal surface of the head behind the eyes is a large central scale (the fronto-parietal). It is a polygon surrounded by other scales, so a small change in the length of any side of the frontoparietal scale causes the shape of adjoining scales to alter, perhaps resulting in a unique pattern (White 2007).
[FP no. is the count of scales that touch the fronto-parietal].

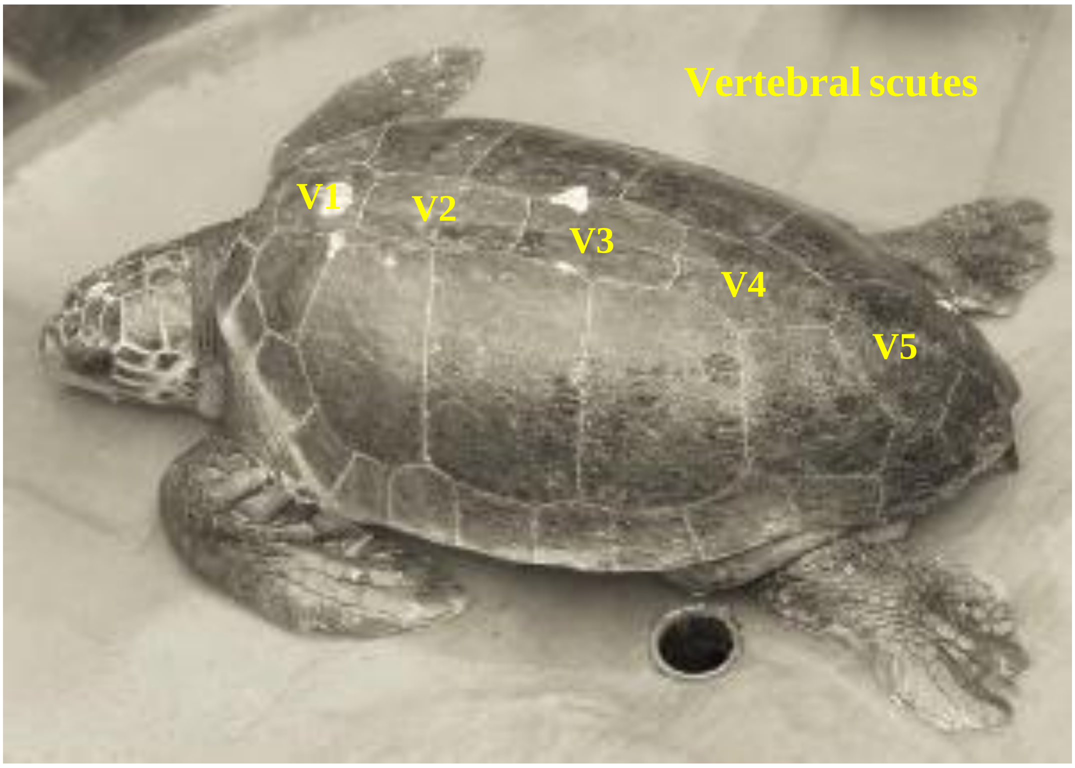
Note: *C. mydas* usually has 7 FP scales; *E. imbricata* usually 7; *C. caretta* between 9-15.

iii) Number of carapace scutes. These are easiest to count in four regions:
a) vertebrals (a central line above the spine)
b) marginals (around the outside)
c) costals (between marginals and vertebrals)
d) nuchal scute (this is the central anterior marginal scute)

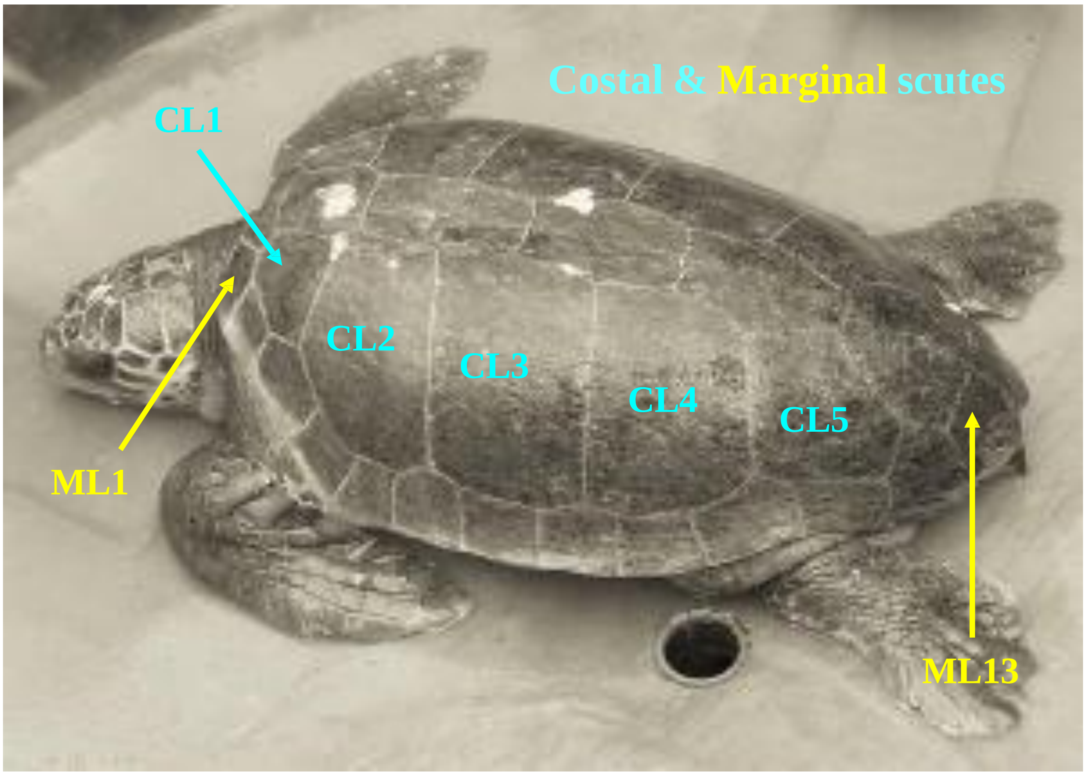
Notes:
Record any deformities and anomalies (e.g. additional scutes, or asymmetry).
Scutes are numbered counting from the front (e.g. vertebrals = V1 to V5)
Costals and marginals are recorded as being left or right of the vertebrals (e.g. CR1 is the anterior costal on the right)

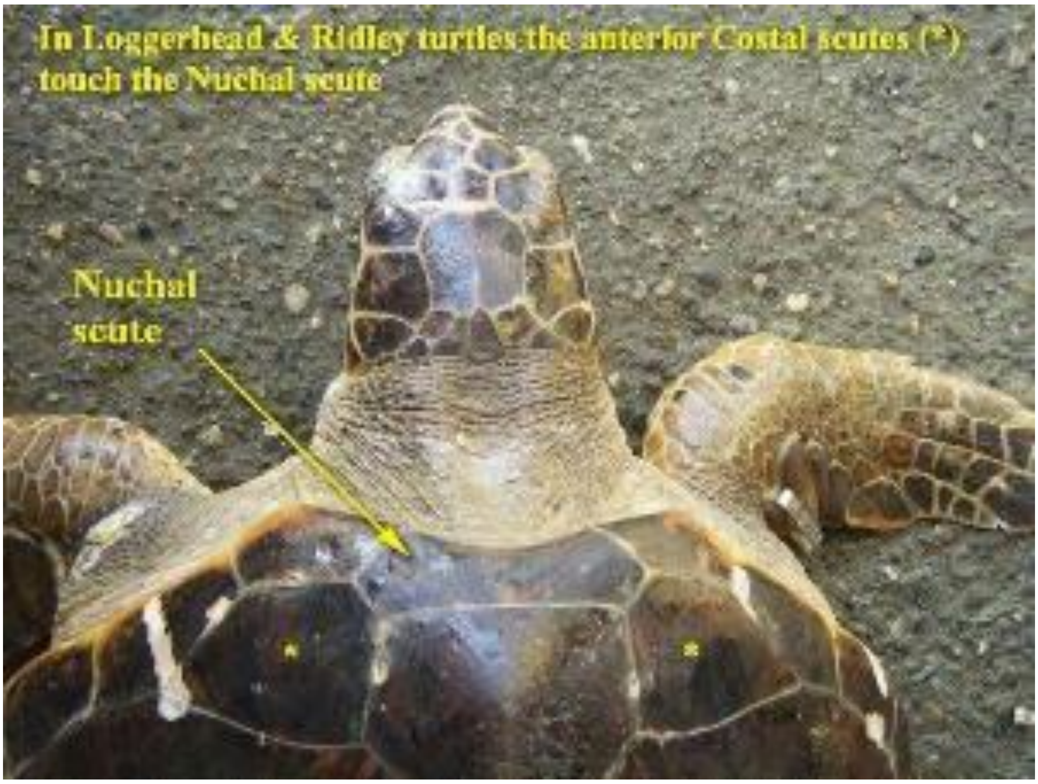
Scutes inhabited by epifauna[28].

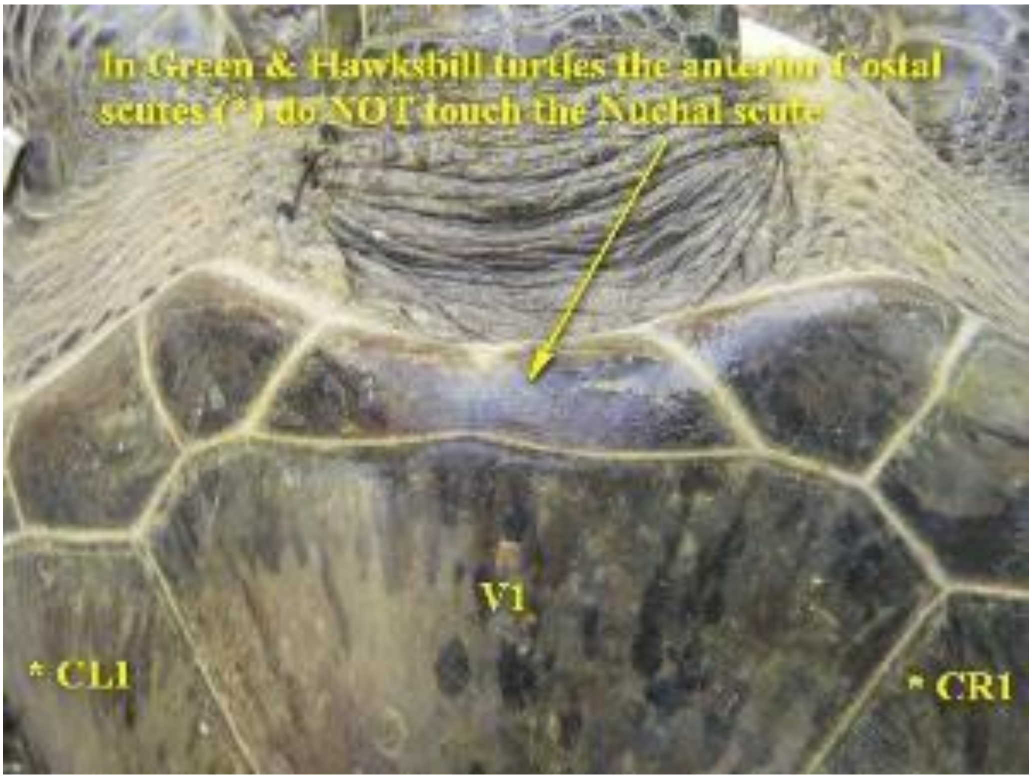
[28] These are more reliable in short-term studies such as foraging or inter-nesting habitats, than over intermigrational periods, because epibiota may change in different sea areas (salinity or temperature).



Scutes are numbered from the front; costals & marginals are also left/right




In Loggerhead & Ridley turtles the anterior Costal scutes (*) touch the Nuchal scute
Nuchal scute
*
*


In Green & Hawksbill turtles the anterior Costal scutes (*) do NOT touch the Nuchal scute
V1
* CL1
* CR1

Asymmetry: the number of costal or marginal scutes differs between left and right sides.

Anomalies: these have high value in distinguishing individual turtles (White 2007). Most turtles, for instance, have a single nuchal scute; exceptionally, this may be divided into two equal or unequal parts. A simple way of reporting anomalies is: *"Turtle 'Y' has 6 vertebral scutes ~ an extra one between V3 & V4"*.[2][9]

Above: ***C. caretta*** **with several anomalous scutes**

C. caretta. 7 costal scutes; left side is normal (5) The 5th vertebral scute is subdivided

[2][9] Kamezaki (1989, 2003) found that a higher incidence of scute anomalies occurred when nest incubation temperatures were lower: hence a longer incubation period.



Three examples of green turtle carapaces: the top two were from Papua Passage, Rarotonga; the lower image has an extra vertebral scute (www.seaturtle.org).

Body colour is not a reliable identifying feature, and may be distorted by seawater quality and light levels, but it can aid the identification of an individual turtle. During a six-year study by White (2007) loggerheads ranged in colour from pale-orange to almost black.

vi) **Physical abnormalities or injuries**: e.g. deformed carapace; amputated limbs; ocular or carapace damage.


Carapace deformed during embryonic development


Deformed during embryonic development

Top: Embryonic deformity; **Centre:** boat impacts; **Bottom:** missing flipper & eye (fisheries)

Top: turtle has a subdivided nuchal scute: these are rare. The turtle also has a 'hump' on a right-hand costal (CR3): taken together these two features make re-identification virtually certain. **Below:** this turtle has an old injury, but it is healing well; the area is still soft to the touch.

vi) **The sex of mature animals.** Tail morphology provides a useful guide to the sex of large animals, but in addition adult males have well-developed flipper claws that they use to hold a female during mating; females may have mating-scars (bite marks) on the back of the neck. Developing males also show tail differentiation.[30]

[30] Turtles are sexually dimorphic.


Loggerhead & Hawksbill turtles have two claws on each flipper


Green turtle has one claw on each flipper

Adult male loggerhead in breeding condition. A particularly interesting feature is that the central area of the plastron becomes ‘de-keratinised’ (softens), which allows the male to fit over the domed carapace of the female ~ he then curves his tail right under the female to copulate. The photo below shows a bite mark on the neck of an adult female, which suggests she had recently mated.

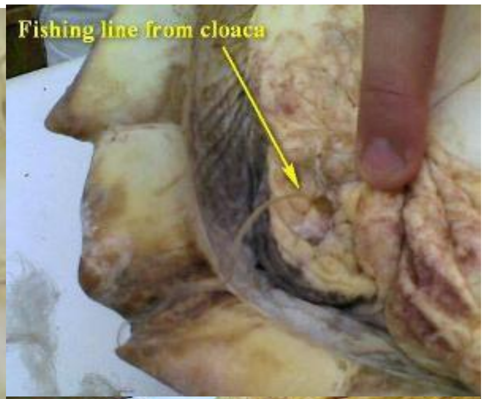
Health assessment. During fieldwork a brief examination was conducted to assess a turtle's general health. Captured animals could be examined more-thoroughly; nesting females were not usually disturbed. **The following negative impacts were noted:**

i) Signs of debilitation (very reduced fat reserves, lethargic, looks unwell)
ii) Carapace damage (recent or old injuries)
iii) Lesions on soft tissue or head
iv) Missing limbs or an eye
v) Heavy parasite loading (e.g. leeches); also commensals such as barnacles
vi) Fibropapillomas
vii) Presence of fishing gear (monofilament line may be visible from mouth or cloaca: indicating that the turtle probably has a hook inside. Limbs may be entangled by line or net; tissue necrosis may be obvious).
viii) Signs of impacts from plastic or other pollutants (oil, tar, bleaching, entanglement)
ix) Presence of tag-scars (i.e. missing flipper-tags)
x) Presence of telemetric equipment (e.g. satellite transmitter or a data-logger)

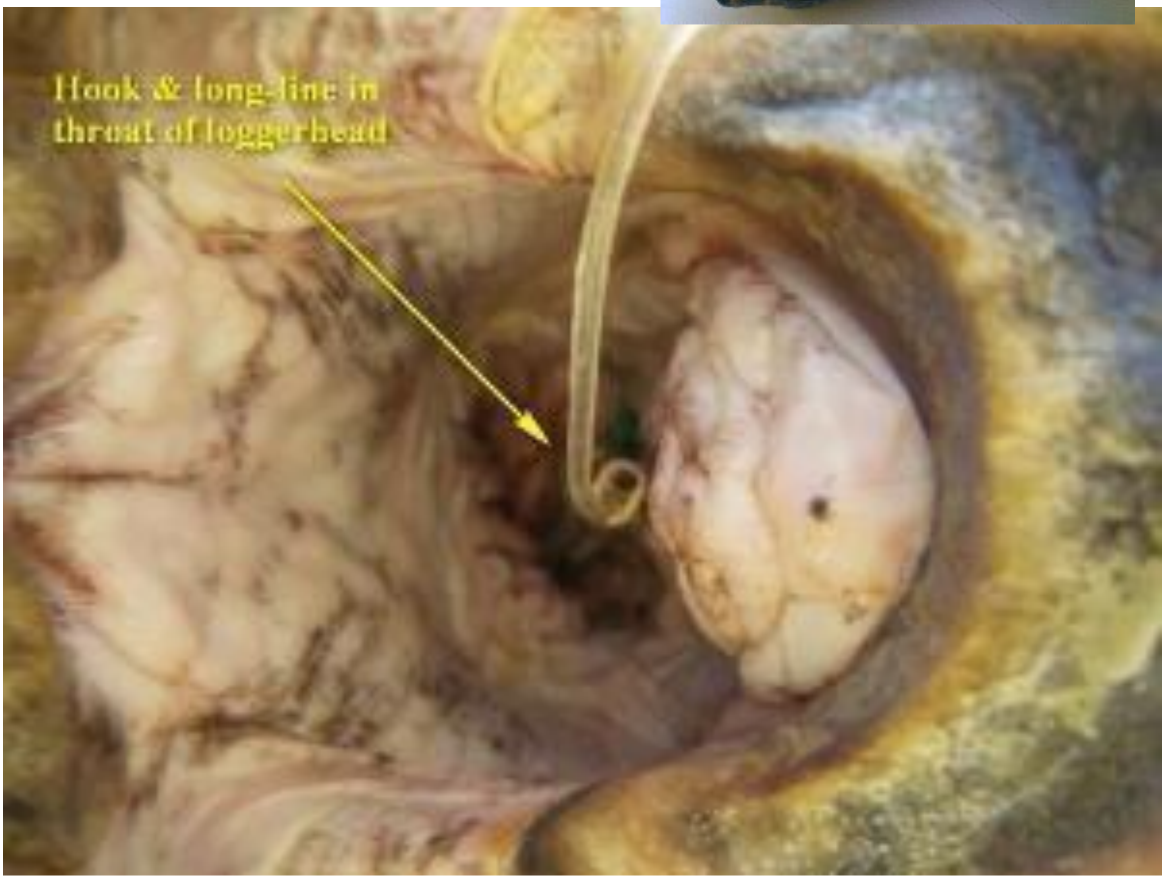
Left: heavy epibiotic load (barnacles) on a loggerhead; **Right:** green turtle with fibropapillomas (a type of tumour) ~ photo: Robson G Santos.

Loggerhead with fishing line from its mouth; it has a hook inside.

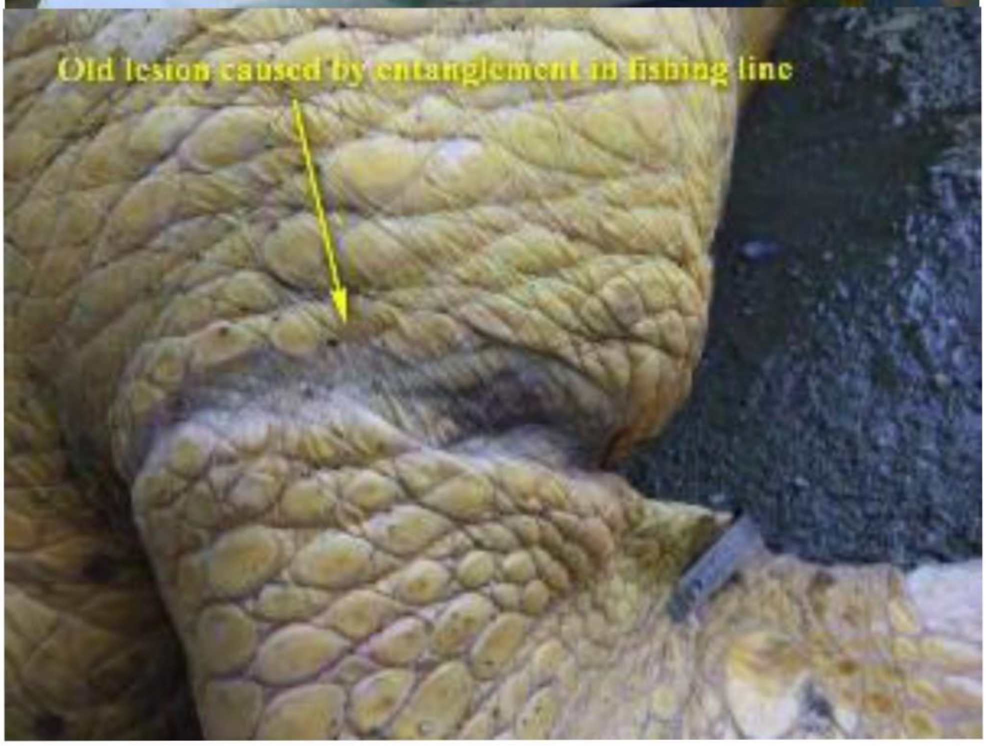

Missing rear flipper


Fishing line from cloaca


Fishing line from mouth


Hook & long-line in
throat of loggerhead

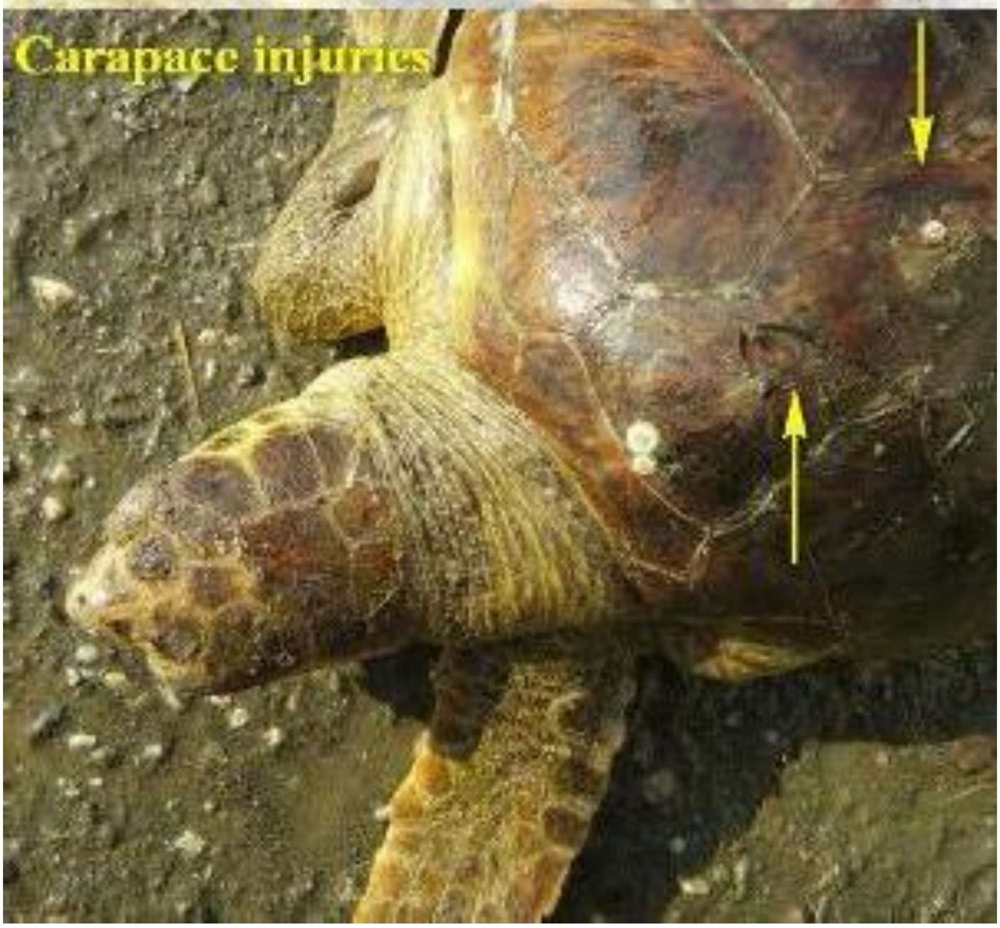

Loggerhead swallowed a hook & was dragging the
line around for weeks

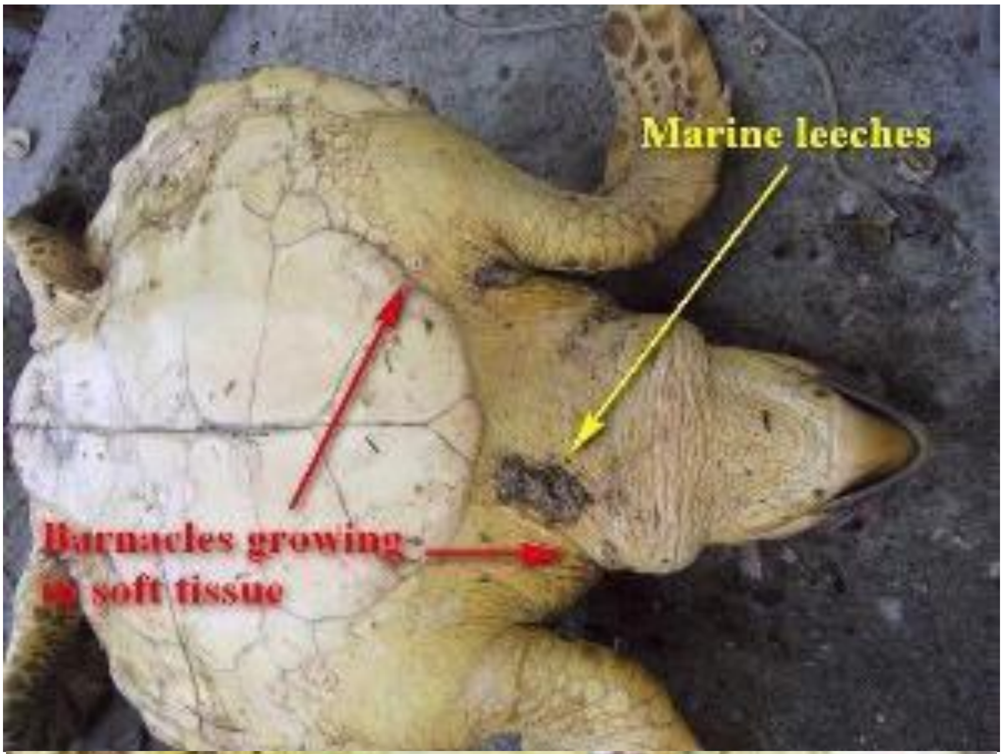

Old lesion caused by entanglement in fishing line


This turtle couldn't breathe because the muscles
had no anchoring point: the bungy cords fixed it

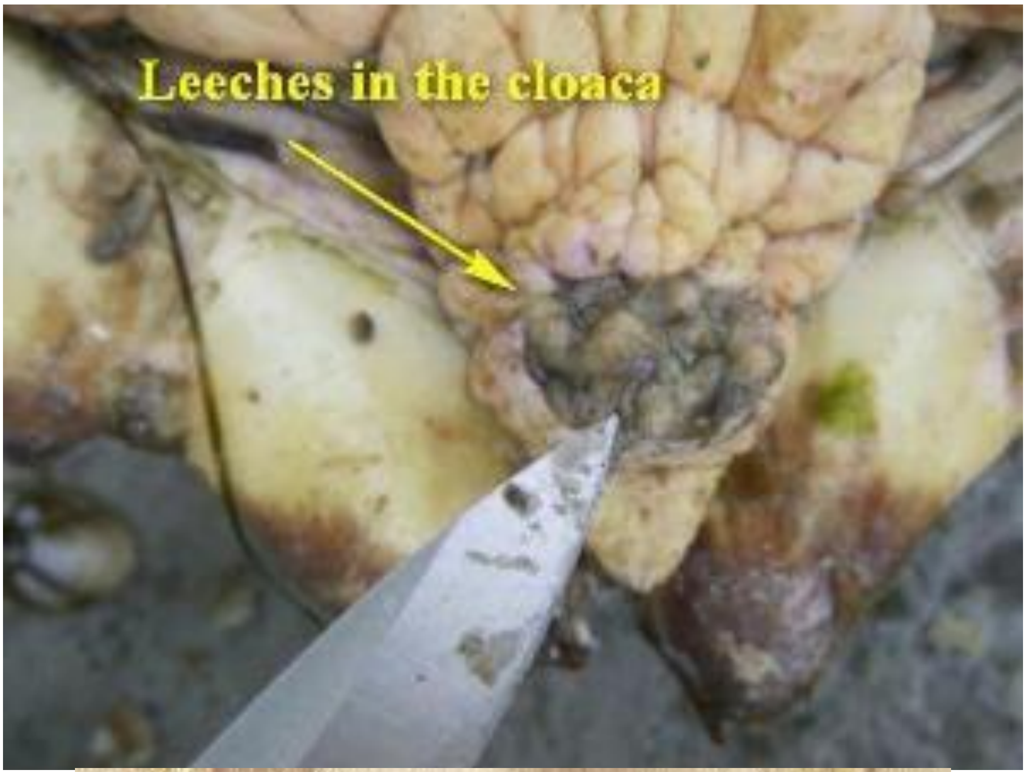

Carapace injury ~
possible boat-strike


Marginal scutes are broken:
probably from a trawl wire


Carapace injuries


Marine leeches
Barnacles growing
soft tissue


Marine leeches ~ parasites


Leeches in the cloaca


Marine leech ~ blood-sucking parasite
mm
10
20
30


Adult male claws
Leech eggs


Tube-worms: 'bio-fouling'


Crab in a 'symbiotic' relationship with a turtle
It uses its claws to stay attached & feeds at random

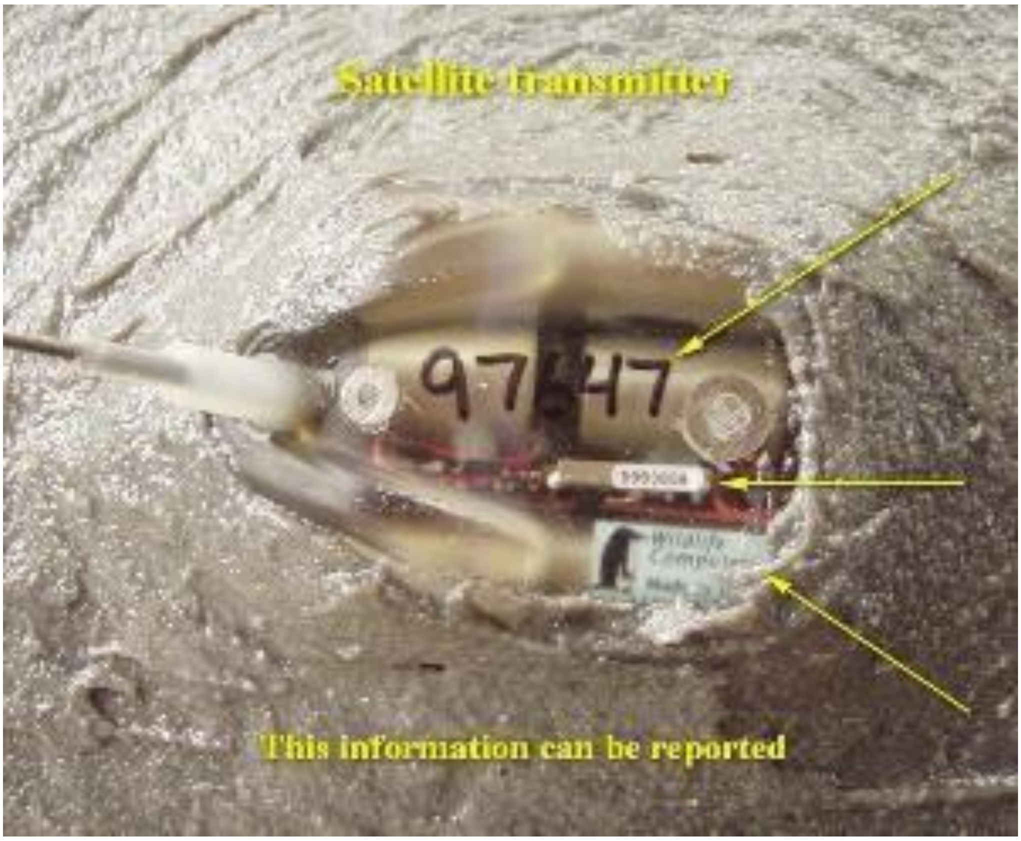

Stalked-barnacles (*Lepas* spp.)

NOT A SEA TURTLE ~ BUT SAYS IT ALL


Cloaca is everted
Kept upside down on concrete ~ all the head
scales were rubbed off; the skull is visible


Missing plastic tag


Metal tag is missing



NOTE: It is important that researchers record what they see, rather than what might be expected for a species. The photographs above show a wide range of possibilities that the author has encountered during field-research; over a few years this has developed into an unusual catalogue.

Researchers also need to be methodical, especially when working at night. A step-by-step approach is ideal: identify the species and life-stage; measure; tag; DNA sample; health assessment. When habitats are being surveyed: the environment will still be there later, the turtle may not be! So double-check the data before the turtle goes. It may never be seen again.

Sea turtles in the marine environment

Overview

Sea turtles spend more than 99% of their lives in the marine environment. Compared with the extensive body of knowledge gathered from nesting beaches globally, there have been far fewer surveys conducted on turtles in the maritime space. White (2007) summarised the main reasons for this as being: sea turtles are migratory at all life-stages; their marine habitats may be very extensive and remote; they are capable of remaining submerged for extended periods; they are frequently solitary animals; research at sea is costly and often challenging; relatively few researchers work at sea.

1) Identify important marine habitats used by sea turtles
a) Identify locations where turtles are seen regularly

i) Scuba diving when air is available
ii) Snorkelling - using free swimming transects in safe areas
iii) Observations from shore
iv) Observations from boats (GPS if possible)
v) Note any effects of weather (e.g. wind direction, sea-state)
vi) Prioritise key habitats for further study

b) Note the species, size-classes and any aggregations of sea turtles

i) Date/time and place of event
ii) Number of animals and species if known
iii) Approximate size (small, medium or large)
iv) Sex if identifiable (e.g. adult male)
v) Presence of tags (reportable data if numbers cannot be read include: which flippers are tagged; tag-type (metal or plastic, including colour); presence of electronic equipment)
vi) Obvious injuries
vii) Interactions with other animals (this included ‘cleaning’)

c) Note preferred depths (depth-gauge, marine chart, or estimated)
d) Describe habitats (e.g. reef, bommies, passages, sand, coral rubble (*kirikiri*) etc.)
e) Note presence of foraging resources[31] (e.g. algae, molluscs etc.)

2) Threats and impacts

i) Note anthropogenic pollution impacts, especially plastics and terrestrial run-off
ii) Record the presence of algal ‘blooms’
iii) Note any discarded fishing gear
iv) Quantify extent of direct take: species; method of capture; frequency; main locations
v) Identify any fishery bycatch (non-target species); note impacted size-classes

[31]A simple key for comparing richness of foraging resources is: **absent, poor, adequate or abundant.**

3) Determine habitat purpose

Behavioural observations***** and size-classes of turtles are used to categorise the purpose of regularly used sites:

i) foraging
ii) resting
iii) mating
iv) developmental
v) access to nesting sites

*****The following behavioural codes were used (White 2007):

Underwater codes:

Su Swimming underwater
Ru Resting underwater
Cu Crawling on the sea floor
Fu Foraging – used when turtle was searching for food
Eu Eating – the food item was described if possible

CL Cleaning (cleaner spp were noted; and location e.g. sea-floor or mid-water)
M Mating

At-surface codes:

Ss Swimming at the surface
Rs Respiration (usually only a single breath is taken; for about 0.5 seconds)
Bs Basking at surface (turtle may appear to be asleep)

This idea of size-classes can be of use underwater: turtles were recorded as being small, medium or large.

The floor-tiles are 25 cm square

Caretta caretta at CRTM Lampedusa, Italy

Mating. Thanks to OneWorld-OneOcean for their photo (via FaceBook).


Very small juvenile loggerhead swimming underwater (Su)

Top: *E. imbricata* swimming underwater; **Below:** *C. mydas* swimming underwater

Top: *C. mydas* resting underwater; **Below:** *C. mydas* self-cleaning – rubbing carapace on coral

Top: *E. imbricata* ~ adult male foraging, but not possible to see the prey; **Below:** *E. imbricate* breathing (Rs) ~ this is the typical posture: head tilted up, body submerged. Thanks to Nan Hauser for the sighting report

4) Site-fidelity

Photo-recognition techniques were used to confirm site-fidelity by individual turtles: this included observations of the same turtle at a particular place or time, and also finding known individuals at different locations. Such information is important when trying to legislate for these endangered species and their habitats (White 2007).

5) Captured turtles

In the event of a turtle being captured (either intentionally as part of in-water research, or incidentally ~ bycatch for instance): morphometric, tagging and DNA-sampling methods described above were followed. **N.B.** Photographs showing turtles on their backs were usually taken when fishermen presented their bycatch; or during brief health assessments.

Abiotic factors

Various environmental aspects may be recorded: a simple approach is preferred as technical equipment, such as anemometers and thermometers may be unavailable:

- **i) Wind-speed and direction:** this can be based on the direction of waves[32]
- **ii) Sea-state and tidal height:** Neap or Spring tides; High or Low water
- **iii) Sea temperature:** if possible measure in °C (ignore if no thermometer)
- **iv) Cloud cover:** measure in % cover: e.g. no cloud = 0%, total cover = 100%
- **v) Phase of the Moon:** New, 1st Quarter; Full; 3rd Quarter

These data are not essential, but they give a greater understanding of sea turtle behaviour; and also can be reported to TREDS (see below).

[32]The Beaufort Scale gives detailed criteria for estimating wind strength from natural observations.

Data dissemination

Honu provides key research findings to the Ministry of Marine Resources, National Environment Service, the Cook Islands Biodiversity Assessment (NBSAP 2002); and to three biogeographic databases: TREDS, SWOT, and OBIS-SEAMAP. An annual report is submitted to the Office of the Prime Minister.

i) **TREDS** (Turtle Research & Monitoring Database, www.sprep.org):

TREDS is a regional database (operated by SPREP at Samoa) that has been developed to be the overarching database system for sea turtle research and monitoring by SPREP member countries (Noumea Convention 1986). TREDS is a joint initiative of the Western Pacific Regional Fishery Management Council; Secretariat of the Pacific Regional Environment Programme; the Secretariat of the Pacific Community; the Queensland Environmental Protection Agency; the US National Marine Fisheries Service-Pacific Islands Fishery Science Centre; and the Marine Research Foundation-Malaysia. Turtle researchers in the Pacific region are encouraged to use this programme; which *Honu* does. The author is the National Co-ordinator for TREDS in the Cook Islands.

ii) **SWOT** (State of the World's Sea Turtles; www.seaturtlestatus.org)

SWOT includes a global database for sea turtles, but it has also expanded into providing small grants for three different areas of focus: i) networking & capacity-building; ii) science; iii) education & outreach. This database is housed at Duke University (Roderic Mast -Editor's Note in SWOT 2011) within OBIS-SEAMAP.

iii) **OBIS-SEAMAP** (http://seamap.env.duke.edu/swot)

Ocean Biogeographic Information System-Spatial Ecological Analysis of Megavertebrate Populations (Halpin *et al*. 2009). This is operated by Duke University (North Carolina) and has become the most comprehensive resource of its kind; and is also likely to become the global clearing-house for data concerning sea turtles.

The author investigated the exact linkages between: OBIS, OBIS-SEAMAP, SWOT and TREDS to understand if data submitted to one organisation were then linked to the other resource-providers (White *pers. com.* 2012). SWOT data are added to OBIS-SEAMAP; but TREDS was not known at Duke University and is now being considered (C. Kot, *pers. com.* 2012).

TWO GENERAL NOTES FOR SEA TURTLES IN THE COOK ISLANDS

Some island-specific names for sea turtles:
Honu: Tongareva and Hawai'i
Fonu: Manihiki and Rakahanga
Fono: Rakahanga
Wonu: Pukapuka
'Onu: Rarotonga and Aitutaki

Known dates for green turtle nesting in the Cook Islands:

Possibly late-September 2010 - Palmerston (Bill Marsters *pers. com.*)
September 2012 – Tongareva (*Hakasusa* & *Te Toto*) this report (White *pers. obs.*)
September to December - Tongareva (*Hakasusa*) – (Shibata 2003, but *spp.* not certain)
Late-September to December 2011 - Rakahanga - this report (Tuhe Piho *pers. com.*)
October 2011 - Tongareva - this report (White *pers. obs.*)
October 2012 – Palmerston (Goldeen Nikau & David Marsters *pers. com.*)
November 2000 - Palmerston (Nan Hauser *pers. com.*)
November 2010 - Suwarrow (Paul Green *pers. com.*)
December 2010 - Aitutaki (2 nests on 5th December; Charley Waters *pers. com.*)
December 2010 - Palmerston - this report (3 nests; White *pers. obs.*)
December 2010 - Nassau - this report (6 nests; White *pers. obs.*)
January 2012 - Tongareva - this report (White *pers. obs.*)
January 2012 - Palmerston - this report (White *pers. com.*)
February 2012 - Palmerston - this report (White *pers. com.*)
February 2012 – Mauke – (June Hosking *pers. com.*)
March 2011 – Tongareva - this report (White *pers. obs.*)
March 2012 - Palmerston - this report (White *pers. com.*)
March-April - 2009 – Suwarrow - (John Samuela *pers. com.*)
April 2012 – Palmerston – this report (1 nest on 20th April; White *pers. com.*)
May 2011 – Tongareva (*Moananui*) – this report (White *pers. obs.*)
July-August 2012 – Tongareva – this report (White *pers.com.*)
Year-round - Tongareva - (*Mangarongaro motu*) - this report (White *pers. obs.*)*****

*****Nesting by green turtles might occur all year-round at *Mangarongaro* and perhaps some other sites at Tongareva. Human presence on the uninhabited motu is very low; these are visited occasionally for fishing, collecting coconuts, or for direct take of turtles and eggs. In the tropics the temperatures required for successful incubation of eggs are likely to be suitable throughout the year; in temperate parts of the world nesting tends to be seasonal: dependent upon sand and seawater temperatures. Green and hawksbill turtles are the most tropical of the extant sea turtle species; seeking out waters warmer than 25°C for nesting (Marquez 1990); the Cook Islands meet this requirement.

Understanding the human dimension in sea turtle conservation

"The biggest planetary challenge that we face is to make people aware of the impacts of our everyday activities: few people ever think about the consequences of how we live; each thing that we do has some effect upon our world and its inhabitants: education is the essential key in raising our awareness." Dr Michael White for 2013

The core philosophy of *Honu Cook Islands* recognises that people are an integral part of each ecosystem. We work with four interwoven threads:

Scientific research
Meaningful education
Conservation
Legislation

~~~~~~People are woven through them all~~~~~~

Scientific research is easy: it's just a matter of going out and patiently doing the work. The hard part is making the results understandable for a wide range of people. This is achieved by using different approaches for the various focus groups. Community talks and slideshows are very popular on remote atolls; playing games and drawing pictures are perfect for infant classes; basic biology and geography work very well with the junior students; senior classes receive an in-depth course that includes biology, ecology, threats and impacts, and some conservation approaches. The most rewarding area of education is at the post-graduate level; these MSc and PhD candidates have committed themselves to higher learning, and they will become our future scientists, teachers and leaders: therefore our responsibility is to teach them well and develop their professional skills and ethical standards.

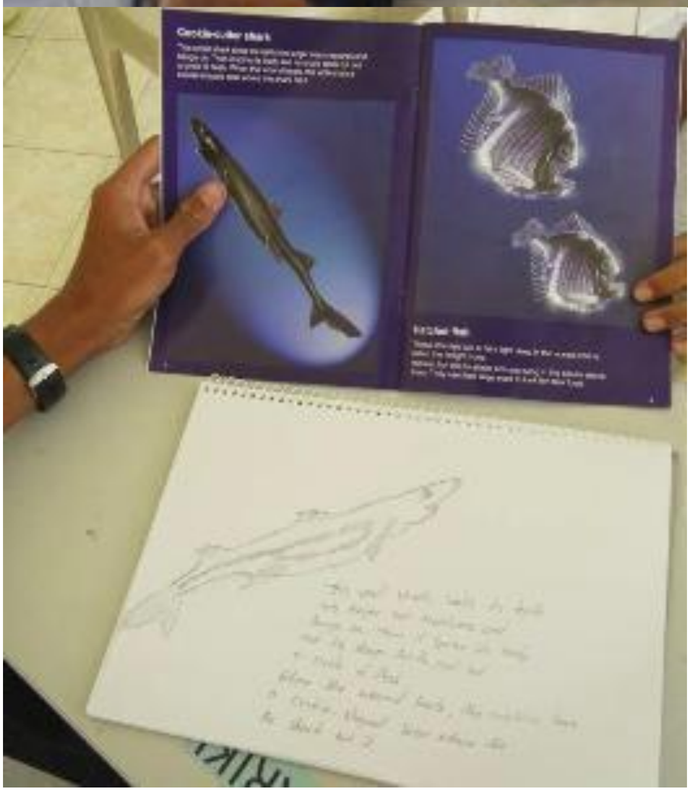
It may be necessary to build capacity at government level too. Governments always have many priorities and the needs of the people and the economy usually take precedence. Special expertise may or may not exist; perhaps because of a lack of higher educational facilities? *Honu* works closely with national and local governments to develop suitable approaches for the conservation or management of endangered species and their habitats: **with sustainability being the underpinning goal.** Legislation may be required, and is usually a protracted process; but of far greater importance is the willingness of islanders to take responsibility for their own natural resources. They have been doing this for centuries on the remote atolls (Pulea 1992).

Education

1) Tongareva Atoll

The author taught a 30-hour course on most aspects of sea turtle biology, ecology, threats and impacts, and conservation possibilities to Senior students from Omoka High School and Tetautua School during June-July 2011. Iconography and the role of sea turtles in the art, tapa, jewellery, tattoos, and stories and dances of Polynesia were also considered. Students were given a written exam during their end-of-term assessments; the results were extremely high – better than most of their other academic subjects. The sea turtle course promoted a wider interest in other scientific disciplines; but there are no science teachers locally. The Ministry of Education is most pleased with this endeavour.

Top: Dr White teaching at Omoka; **Below:** two of the students with their turtle notes



Above: Senior girls used a dance performance to show the effect of sea levels rising by 1 metre

Left: Many of the students are remarkably artistic

2) Northern Group Life Skills Programme (Manihiki 1st - 13th September 2011)

The author was invited to be a tutor on this Life Skills Expo and taught a module on sea turtles twice; initially at *Tukao* and subsequently at *Tauhunu*: six girls and ten boys participated and included students from Tongareva, Pukapuka and Manihiki. This course has triggered a wider interest in science and marine conservation and will be built on over the coming years; the idea to develop a *'Turtle Rangers'* course emerged from this event. The Expo was also an important opportunity to develop networking across the Northern Group; and the author has since been invited to give lectures at other schools and colleges in the Cook Islands.

Life-skills students from Manihiki and Tongareva planning a turtle poster

Left: modern green turtle; **Right:** turtle skull from Cretaceous Period ~ little difference!

Welcoming Feast: *Tukao*, Manihiki: left is Tekemau Ribabaiti (Pukapuka Principal), right Dr White

Life-skills students from Tongareva, Pukapuka and Manihiki, September 2011

'Brain Gym'. An exercise in mental agility taught at Life Skills by Tracy Spiers (Tereora College)

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3) Palmerston 'Lucky School'

A general teaching day was made possible by the School Principal – Yvonne Marsters – this is discussed below under the findings from Palmerston Atoll.

4) Rakahanga School

The author taught the Senior students for two weeks (60 hours) in August 2012. As well as the usual objectives (shown below), the course here focused on how to monitor their local nests; some of which are laid on the school beach. This is discussed below under the findings from Rakahanga Atoll.

The students, teachers and/or principals from seven schools in the Cook Islands have now received some level of sea turtle education and training (Niua, Omoka, Palmerston, Rakahanga, Tauhunu, Tetautua, and Tukao). The author is now establishing an ongoing Lifeskills programme in collaboration with the Ministry of Education (Sharyn Paio & Ian George *pers. com.* 2012)

5) Post-graduate research

During an expedition to Rakahanga the author supervised a post-graduate researcher from the University of York (MSc in Marine Environmental Management). Gemma Galbraith was taught how to conduct fieldwork at a remote location, this built upon her previous knowledge and experience; the main focus was to develop her professional skills. We considered the difficulties of studying sea turtles onshore and in the marine environment, as well as the various threats and impacts that they face. In keeping with the focus of her MSc, Gemma planned and implemented a very useful study with special emphasis on the sociological aspects of natural resource-use on a remote atoll; and also the Islanders' attitude towards conservation and sustainability. The methodology and key results are discussed below under the findings from Rakahanga Atoll.

6) Educational modules

The author taught the following topics to Senior school students and to interested adults. The precise course format depended upon the time available, which in the schools ranged from 6 to 60 hours. Some form of assessment was agreed with Principals: these included formal written exams, poster production, performances of dances, songs or stories; and peer presentations. A suitable marking scheme was developed as required.

Lectures:
Species identification
General life-cycle
Foraging
Development
Migration
Mating
Nesting
Egg-development
Nest environment
Threats and impacts
Research techniques
Data collection
Data presentation
Equipment
Questionnaires
Conservation
Local needs
Traditional Knowledge
Iconography

Practicals:
Morphometrics
Photo-recognition
Tagging demonstration
DNA-sampling
Track-surveys
Nest excavations
Nest inventories
Impact assessment
Beach clean
In-water surveys
Community surveys
Prepare a public talk
Prepare posters
Translate into local languages

Capacity-building and Community Education

Several approaches were used for outreach activities. The first step was to meet with the Island Council and explain the purpose of an expedition or research programme. The author asked for permission to visit all sites on an atoll; and, specifically, if any areas were *tapu* (i.e. forbidden). In all cases their guidance was followed. The next step was to arrange a gathering with the community to explain why researchers had come to their island, who we were, the sort of information we were looking for, and how they could help. Islanders wishing to become involved in the research were interviewed privately, and then training activities were implemented. Traditional Knowledge was sought, and, with the permission of Wisdom-Keepers, was added to the local teaching programme. It is recognised that local fishermen and hunters are highly-knowledgeable regarding their environment and the species present; the older islanders also explained how ecosystem abundance and health compared with days gone past. Such information is usually absent at governmental level.

Island Councils and School Committees were asked for permission allowing us to teach in their schools. The Secretary of Education at Rarotonga has granted the author the right to liaise directly with School Principals; but courtesy e-mails are always exchanged. Any teaching programmes were arranged directly with Principals and their staff.

Research findings were shared with local communities: the preferred mode is to host a *kaikai* (feast), invite everyone, give the presentation and answer any questions; and eat!

Conservation or management needs were discussed directly with the Island Councillors; guidance was offered on sustainable resource-use and how local needs could be met; including direct-take of endangered species. This provided an opportunity to shift hunting away from nesting females, and is discussed below. Global issues such as climate change and sea-level rise were explained; the problem of persistent waste was always discussed. It became clear that complicated policies at national government level were of little interest, people were more concerned with what would happen to them and their island.

Turtle Rangers ™

The '*Turtle Rangers*' ™ course[33] was designed by the author to be a very flexible training programme, which is well suited to the way in which many Pacific Islanders learn: more right-brained than the logical, theoretical models commonly used in western education. Scientific concepts were discussed, but always well-illustrated; student-groups produced posters that showed various aspects of the sea turtle life-cycle, or threats and impacts. The use of flipper-tagging was demonstrated and also how to collect genetic samples. Old carapaces and skulls were used to practice measurement techniques on. If training took place outside of a nesting season ~ the author pretended to be a sea turtle digging a nest, so that students understood the process clearly. We collected data and, as computers are becoming more widespread, entered them into a spreadsheet, explored

[33]*Turtle Rangers* and its associated training programme is a Trade Mark of Dr Michael White

basic statistics and different graph types; and finally exported these results into PowerPoint presentations, which the students presented to their peers. If there were any nests that had hatched, even if from some years ago, we dug them up and inventoried their contents to determine nest success. Practical skills included beach-monitoring, track-counts and nest construction; habitat assessments, and quantifying threats or impacts. We usually cleaned at least one beach. The course was adapted to suit each particular atoll and included any Traditional Knowledge or Practices for that site. Few educational resources exist in local languages, so the author taught students how to design and produce some suitable materials ~ this is proving to be very popular.

The first local researchers are monitoring their nesting beaches; an electronic-support network is in place so that the author can provide advice and guidance whenever needed. The author has also initiated *Cyber-education* at some local schools. A strong benefit of this approach is that by teaching the younger people, the future generations are already influenced. Once funds become available further training will be provided on each atoll.

On the remote atolls it is essential to be accepted by the community, otherwise little of real value will be achieved; and none of it lasting.

Integrating with the Community:
Engage with the Community
Explain what we need to know
Ask if they can help
Listen to their Knowledge and Wisdom
Ask if you may use it in your teaching
Respect their *'Mana'*
Thank the Wisdom-Keepers
Share your findings with the Community
Ask what they need
Help the Island Councils to develop any management plans
Advise on sustainable resource use
Always be honourable
Do everything to enhance and nothing to harm their way of life
Above all enjoy your new life-long friends

Top: Some of Palmerston Island's Councillors at our Welcoming *kaikai*; **Below:** The author's third visit to Palmerston Atoll ~ with friends: Mehau, Caroline & Tamatua.

Top: Welcoming the Cook Islands Christian Church Representative for the Northern Group on his brief visit to Palmerston. **Below:** Welcoming prayers from the Palmerston Community

Government Departments

Neither the Ministry of Marine Resources, nor the National Environment Service has a professional sea turtle specialist. The author's skills, knowledge and expertise have been willingly accepted by both Ministries and these research findings have already been used by the Government in the international and regional arenas; including the Marine Species Action Plan reviews. Consequently, the Cook Islands can now show significant progress in meeting the goals of SPREP Member countries for the sustainable management of island and oceanic ecosystems and biodiversity; another professional researcher ~ Nan Hauser (www.whaleresearch.org) ~ provides similar findings for cetaceans. The National Environment Service has a well-organised and efficient system in place for CITES documentation; *Honu* uses this when exporting genetic samples to the laboratories abroad.

Community Projects

The first projects with local community participation are now underway; each is different but all have the potential to become self-sustaining and community-managed. A blend of practical experience, relevant education, and knowledgeable support should prove to be successful in each case.

Palmerston Atoll has three local researchers working within *Honu Cook Islands*. They are monitoring the various motu for turtle tracks and have already reported the first three nests of our Austral summer (2012). The team has the expertise to excavate post-hatching nests and conduct inventories to determine their success-rates (%). The Island Council, Administration and Government Representative are all interested and willing to help. Our priority is to find a source of funding to cover fuel costs and stipends so that this research is seen as a 'proper' occupation; suitable education will then follow.

Rakahanga Atoll quickly embraced the idea of working with sea turtles. The school is *Honu Cook Islands'* research partner and is counting tracks, protecting nests, and keeping the beaches clean; the students are using this as a *real science* project; the Principal is the driving-force for keeping it going, with guidance from the author. Community-members are interested and the Island Council is supportive.

Tongareva Atoll has the nation's first **Index Beach** monitoring programme in place; and the Island Council is a research partner of *Honu Cook Islands*. Local interest is high and should build steadily; the author also teaches students from both schools on the atoll.

In all three cases people are still likely to eat turtles occasionally; they like them!

Sea Turtle Legislation in the Cook Islands

Maison *et al*. (2010) noted that the Cook Islands Marine Resources Act (1989) [see below] provides for the protection and management of fishery resources, the definition of which includes marine turtles; but they found no specific regulations regarding harvesting of marine turtles; although Pulea (1992) indicated that there is full protection for marine turtle eggs.

The Cook Islands Government decided to formalise the conservation and sustainable use of biodiversity in its National Biodiversity Strategy and Action Plan (NBSAP 2002). Approved by the Cabinet of the Cook Islands Government; 11th April 2002 [CM (02A) 234].

The Cook Islands is a party to the following international legislation that either provides for the protection, conservation and management of marine turtles; or for the protection of biodiversity:

i) Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar 1971); and amendments Paris 1982; Regina 1987
ii) Convention on International Trade in Endangered Species of Wild Fauna and Flora (Washington 1973)[34]
iii) Convention on the Conservation of Nature in the South Pacific (Apia 1976)
iv) Convention on the Conservation of Migratory Species of Wild Animals (Bonn 1979)[35]
v) Convention on the Protection of Natural Resources and Environment in the South Pacific (Noumea 1986)
vi) Convention for the Prohibition of Fishing with Long Driftnets in the South Pacific (1989)
vii) Convention on the Conservation of Biological Diversity (Rio de Janeiro 1992)
viii) Rio Declaration on Environment and Development (1992)
ix) Agreement establishing the South Pacific Regional Environment Programme (1993)
x) Barbados Programme of Action on the Sustainable Development of Small Island Developing States - SIDS (Barbados 1994)
xi) United Nations Convention to Combat Desertification (1998)
xii) Protocol on Biosafety (Cartagena 2000)

The Cook Islands is also party to the following fisheries organisations that are concerned with sea turtle bycatch:

i) Forum Fisheries Authority
ii) Inter-American Tropical Tuna Commission
iii) Western & Central Pacific Fisheries Commission

[34] CITES (1973): lists all sea turtle species in Appendix I.
[35] CMS lists six sea turtle species in Appendix I.

Turtle hunting

At Tongareva, Rakahanga, Manihiki and Palmerston, and probably at other atolls, sea turtles are occasionally killed and eaten, but the true level of direct take remains unclear for the Cook Islands. Commonly, it is the adult female turtles that are captured or killed as they nest on the beaches; some hunters allow the female to complete egg-laying before death (White *pers. com.* 2011)[36]; a smaller, unquantified, number of turtles are taken at sea.

The killing of adult female sea turtles on nesting beaches is a known cause of extirpation of local nesting populations (e.g. Frazier & Salas 1984; Cornelius & Robinson 1986; Lutcavage *et al*. 1997). Pritchard (2011) states that *"consumption, above all else, has been the main factor in the green turtle's global decline"*. Allen (2007) noted that turtle populations may have disappeared locally on remote islands within one or two centuries subsequent to the arrival of human inhabitants. McCoy (1995) reported, importantly, a decline in the number of females nesting annually in areas where there is increased use of motorised-boats; allowing previously difficult-to-access beaches to be targeted more easily.

Limpus *et al* (2003) and Limpus (2009) reported a significant downward trend in the mean size (CCL) of nesting green turtles during long-term-monitoring at Raine Island and Moulter Cay, Australia (1976-2001); this was accompanied by a progressive increase in remigration interval; those authors also note that their findings are consistent with a group <u>in the early stages of decline</u>, as a result of excessive loss of adult females. Harvey *et al*. (2005) also reported a significant decrease in CCLs for nesting green turtles at Coringa-Herald National Nature Reserve (Queensland, Australia), which may be a result of adult turtle mortality, potentially from the Torres Strait/Papua New Guinea region.

The importance of adult female turtles cannot be overstressed (Chaloupka 2004). They have survived long enough to reproduce; achieving maturity may require several decades to complete. They are very fecund animals, and their long life-span means that they may be reproductive for many years; perhaps this could even be a century or more (White *pers. com.* 2011). Yet this is a life-stage that is often targeted for food, being very easy to capture on the beaches (usually the turtles are turned over onto their backs and then killed later).

Discussions with various Pacific Islanders reveal that they believe it is more important to conserve the smaller size-classes, rather than the larger juveniles and adults; whereas the reverse is true (e.g. Crouse *et al*. 1987; Heppell *et al*. 2003). Even in those Pacific Islands where sea turtle legislation does exist, such as Tonga, this is poorly enforced (Havea & MacKay 2009).

[36] Local respondents know that turtles lay more than one nest, and the usual practice on finding a fresh nest is to figure out when the female will return (the old folk can calculate this by looking at the eggs), then kill her during the second nesting event. BUT they may not know that turtles could return for many years i.e. perhaps they believe that turtles lay two nests and that's it!

What legal options exist to protect sea turtles in the Cook Islands?

i) Do nothing. Perhaps sea turtle populations in the Cook Islands are stable or even healthy; however, as we have no population data nationally we cannot say. Furthermore, we are still discovering how each of the islands regards turtles, their conservation; and the full extent of direct take. This approach seems unlikely to support national obligations as a party to international conventions that protect sea turtles.

ii) Enact new legislation pertaining to sea turtles and their habitats. Government and Traditional Leaders would have to decide if the Cook Islands should allow direct take of turtles and eggs; and if so to what extent, also how would it be policed (Pritchard 2011)? Of particular importance would be the species and size-classes that may be taken legally[37]. The special problem of fisheries bycatch should also be considered. Endnote (iv) contains some legislation from other Pacific nations, including some that have traditional hunting rights (Maison *et al*. 2010)[37]. The Cook Islands is party to the SPREP legislation (Noumea 1986; SPREP 1993, 2007), including Marine Species Action Plans (dugongs, sea turtles, whales and dolphins): these provide a good framework for national planning and legislation; the author will continue to assist the Cook Islands Government in implementing these.

iii) Extend existing protective legislation to explicitly include turtles. This may be the most appropriate option, in which case relevant laws should be considered (e.g. *Marine Resources Act 1989*). The customary rights of Cook Islanders to harvest natural resources will also have to be considered (Pulea 1992: see *Cook Islands Act 1915*).

Two Recommendations:

The author recommends that the capture and killing of nesting female turtles on the beaches is prohibited. This is based upon the biological importance of this life-stage: *no reproductive females, no future turtles.* Possible ways to implement this nationally would be via regulation or by-law on behalf of Government; and by the House of Ariki through traditional channels. It is recognised that law enforcement is exceedingly difficult in remote locations (White 2007); therefore any such measure requires common consent in order to become effective; with *rahui*[38] likely to be the most appropriate form of turtle management in the Outer Islands (see the following and their amendments: *Cook Islands Constitution Act 1964; House of Arikis Act 1966; Land tenure in the Atolls 1987; Outer Islands Local Government Act 1987, 1988*).

A counter-argument by supporters of traditional hunting might be to set a quota for the annual allowable take of turtles; however, this is also unenforceable (e.g. Fiji: Laveti & Mackay 2009; Seychelles: Jeanne Mortimer *pers. com.* 2010; Pritchard 2011). **Whether direct take is legal or prohibited: both need to be carefully supervised** (Pritchard 2011).

[37] Hawksbill turtles *Eretmochelys imbricata* are critically-endangered and should be fully protected.

[38] It is understood that the aim of rahui is to ensure a regular food supply; nonetheless it is an effective way to achieve resource sustainability, including the continuance of sea turtles.

A second recommendation is to quantify the level of direct take of turtles nationally. Even if some turtle-kills are not known or reported, a partial dataset will still provide a clearer understanding of the current extent of this impact. Fisheries Officers on each island could record kills in their monthly diaries (FADs)[39]; which presently is only happening at Palmerston Atoll. It could also be undertaken by trained turtle monitors on each island; particularly so as to ensure that any **tagged turtles** are reported accurately (this happens on Vanuatu: the *Vanua-tai* have been monitoring turtles for about 18 years; Petro *pers. com.*).

Traditional Management:

An important aspect of customary marine tenure is the traditional right of islanders to control activities on their traditional fishing grounds and to exclude outsiders (see Hickey & Johannes 2002). A comprehensive review of traditional sea turtle management and use was provided by Woodrom Rudrud (2010). The present author found an interesting example on Pukapuka, where disregarding the *rahui* (*'pule'*) might be dealt with by publicly-shaming the offenders: their public status is diminished, for instance, by not being allowed to eat with the other adults, but having to eat with the children at the end of a *kaikai* (White & Karika *pers. com.*).

There is a noticeable difference between the present day and earlier times in that if turtles are eaten nowadays they are just treated as meat, like steak or chicken thrown onto a barbeque (White *pers. com.* 2009), whereas previously (Bellwood 1978) there was often an element of reverence or sacredness associated with consuming sea turtles; and perhaps only the tribal leaders, or another particular group partook of the flesh (Lamont 1867; Handy 1921; Te Rangi Hiroa 1932; see also Woodrom Rudrud 2010 and references therein).

Traditional Ecological Knowledge (TEK) is now receiving wider attention and is both similar to, and different from Western science (Berkes *et al.* 2000). The most important similarity is that both are based on observations over time; the differences, though, seem numerous, with science focusing on the material, whereas traditions are woven through societies, cultures and religions; however, Agrawal (1995) asked if the dichotomy is real (Berkes *et al.* 2000)?

Because of conflicting paradigms: 'Traditional & sustainable' vs. 'Industrialised & economic' the present author firmly believes that the inclusion of traditional knowledge and management practices (e.g. Johannes 1978, 1989, 2002; Gadgil *et al.* 1993; Vierros *et al.* 2010) integrated with modern scientific concepts is likely to provide a realistic conservation approach for the Cook Islands.

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[39] The Marine Resources Act 1989 is the main legislation that mentions sea turtles in the Cook Islands.

Author's Commentary on the Marine Resources Act (1989)

Several authors have referred to Pulea's 1992 review of Cook Islands Environmental Law (e.g. Maison *et al.* 2010; Woodrom Rudrud 2010) in which she said that the Marine Resources Act (1989) mentions sea turtles in general terms; however, this is actually as a fishery stock (White *pers. com.* 2012). The text box below notes that Act's most relevant sections, but there are conflicts and it appears that the fundamental differences between Parliamentary legislation and customary use, particularly that the latter includes sea and lagoon areas as extensions of land tenure, have not been resolved.

The Marine Resources Act (1989) makes extensive provision for fisheries management and development. A fishery can only be designated by the Minister for Marine Resources on the recommendation of the Secretary, after taking into account the scientific, economic, environmental and other relevant considerations regarding the importance of the fishery to the national interest, and if the fishery requires management and development measures for effective conservation and optimum utilisation (s 3(1)).

Fishery is defined in section 2 to mean:
One or more stocks of fish or any fishing operation based on such stocks which can be treated as a unit for purposes of conservation and management, taking into account geographical, scientific, technical, recreational, economic and other relevant characteristics.

'Fish' is defined to include:
A*ny aquatic plant or animal, whether piscine or not; and includes any oyster or other mollusc, crustacean, coral sponge, holothurian (beche-de-mer), or other echinoderm, turtle and marine mammal, and includes their eggs, spawn, spat and juveniles (s 2).*

7.4 Fisheries Plan

Plans for designated fisheries in the fishery waters i.e. waters of the territorial sea. the Exclusive Economic Zone (EEZ) and other internal waters must:
- identify each fishery, its characteristics and the present state of its exploitation;
- take into account any relevant traditional fishing methods or principles (s 3(2)).

Fisheries plans and reviews require Cabinet approval before implementation (s 3(5)). Where the preparation of fisheries plans and reviews affect lagoon fisheries over which Island Councils have jurisdiction, the Act requires the Ministry to consult with them and the local Fisheries Committee in the island concerned. Where no local committee has been appointed, any local fishermen likely to be affected must be consulted (s 3(4)).

7.5 Fisheries Management

The Island Councils have the power to manage fishery resources by declaring closed and open seasons for the whole or part of the designated fisheries. During the closed seasons no one is permitted to fish for the species or in areas specified in the declaration. During the open season, fishing for any species in the areas specified in the declaration is permitted (s 6).

The Marine Resources Act (2005) No. 7/2005 dated 29th July 2005, broadly follows the same definitions as the 1989 Act: i.e. that turtles are 'fish'; however it goes on to add:

"Marine organism" means any plant or animal, living or non-living, including fish, which spends most of its life cycle in the ocean;

"Non-target species" includes both fish and non-fish species;

Section 3. Objective, Function and Authority - (1) The principal objective of this Act and the Ministry of Marine Resources is to provide for the sustainable use of the living and non-living marine resources for the benefit of the people of the Cook Islands.

(2) The Ministry of Marine Resources has the principal function of, and authority for the conservation, management, development of the living and non-living resources in the fishery waters in accordance with this Act and the Ministry of Marine Resources Act 1984.

Section 4. Principles and Measures

- (ii) the precautionary approach should be applied;
- (iii) impacts of fishing on non-target species and the marine environment should be minimised;

And also:

i) the maintenance of traditional forms of sustainable fisheries management;

ii) protection of the interests of artisanal fishers, subsistence fishers and local island communities, including ensuring their participation in the management of fisheries and of aquaculture; and;

iii) broad participation by Cook Islanders in activities related to the sustainable use of marine resources.

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Another Cook Islands Act includes the first measures for bycatch reduction:

MARINE RESOURCES (LONG LINE FISHERY) REGULATIONS 2008, 2008/2
By Order in Executive Council (Queen's Representative) dated 27th August 2008.

PART 4 - ECOSYSTEM CONSIDERATIONS
13. Protection of Non-Target Species - **(1) Seabird Mortality** - Fishers will be required to adopt mitigation measures as required by the NPOA for seabirds, as well as any other conservation and management measures required by RFMO's, such as using tori lines. Fishers must also record any encounters with seabirds (live or dead) and report this to MMR.

(2) Turtle Mortality- Fishers will have to adopt the use of circle hooks in all fishing activities, as well as follow the 'Releasing hooked turtles' guidelines on how to care for and release live hooked marine turtles. Any further requirements by RFMO conservation and management measures, as well as under the marine turtle NPOA, will also have to be adopted. Marine turtle encounters (live or dead) must be recorded and reported to MMR.

(3) Shark finning - Will be banned by requiring retention of all parts of any retained shark catches excepting head, guts, and skins, to the point of first landing. This will be monitored by ensuring that the total weight of fins shall equate to no more than 5% of the total weight of shark carcasses retained. This ratio may be changed accordingly to scientific review.

(4) Other non-Target species - Fishers will be required to avoid the capture, and release unharmed, to the extent practicable, non-target species that are not to be retained.

PART 6 - MISCELLANEOUS

21. General Obligations of the Secretary - (1) The Secretary shall establish a system for the collection and compilation, storage and exchange of data and other fishery related information on the tuna and large pelagic fishery. This information shall include position reports, catch and effort log sheets, observer and other scientific data. The Secretary shall determine the characteristics and procedures of such a system in accordance with international and regional standards and the objectives of the Act and this Fishery Plan.

(2)Observer Programme - The Secretary shall establish an observer programme for the purpose of achieving a level of observer coverage in the tuna and large pelagic fishery that the Secretary is satisfied is appropriate to meet the objectives of the Act and this Fishery Plan, and which is consistent with any applicable regional and international standards and obligations. This may include participation in regional programmes, where appropriate.

(3)Monitoring, control and surveillance (MCS) - The Secretary may establish an MCS programme that assists in meeting the conservation and management objectives of this Fishery Plan and all relevant international and regional obligations. Such a programme may include -

a) vessel monitoring systems*****;
b) the provision of observers and the conditions under which they operate;
c) a vessel inspection regime;
d) a port and catch inspection regime;
e) the prohibition or regulation of transhipment at sea or in port;
f) aerial and sea surveillance;
g) participation in co-operative regional arrangements.

*****The Cook Islands requires that all foreign vessels fishing within the EEZ be fitted with the vessel monitoring system (VMS). Fishing licences are renewed annually, so the onus is on the ship owners to comply with regulations, in order to continue fishing (White *pers. com.* 2012).

Author's Commentary on the Environment Act (2003)

The final comments in this legislative section concern the Environment Act (2003) and some excerpts are shown below. In scope the Act is broad, but in application limited. As with many other countries jurisdiction falls between two government departments: in this case the National Environment Service and the Ministry of Marine Resources.

Section 4. Application of this Act - (1) On its coming into force, this Act applies throughout the Cook Islands - including the territorial sea and exclusive economic zone [*Territorial Sea and Exclusive Economic Zone Act 1977*] - except as otherwise provided by subsection (2).

(2) This Act shall apply to the islands of Rarotonga, Atiu and Aitutaki but shall not apply to any other Outer Island unless otherwise specified by the Queen's Representative by Order in Executive Council.

(3) No Order in Executive Council may be made under subsection (2) specifying that this Act applies to an Outer Island unless -

a) all of the members of Parliament for the island concerned submit a written request to the Minister for such an order to be made; and
b) the Director certifies in writing to the Minister that the Island State Government has consulted all sectors of the community on the island concerned (including members of Parliament and the Aronga Mana of that island, and the Ui Ariki of that island, if distinct from the Aronga Mana) before requesting the order.

The Act defines various terms including:

"Animal" means any species, alive or dead, of the animal kingdom (other than human beings), and includes the following:

a) marine animals;
b) terrestrial animals;
c) migratory animals that occasionally visit the Cook Islands or Cook Islands waters;
d) any part of an animal's life cycle, such as eggs or parts of eggs;
e) any part of animals or animal products such as skin, feathers, horn, shell or other part of an animal;

"Environment" -

a) Means the ecosystems and the equality of those ecosystems as well as the physical, biological, cultural, spiritual, social and historic processes and resources in those ecosystems; and
b) Includes -
    i) land, water, air, animals, plants and other features of human habitat; and
    ii) those natural, physical, cultural, demographic, and social qualities and characteristics of an area that contribute to people's appreciation of its pleasantness, aesthetic coherence, and cultural and recreational attributes;

"Foreshore" means: (a) in relation to Rarotonga -

i) all that area between the mean high water mark and a line connecting those points landward and measured at right angles to a distance 30 metres from the mean high water mark or to the edge of the vegetation, whichever shall be the greater distance; and

ii) every estuary, stream or river together with the bed of any stream or river and includes that area extending landward and measured at right angles from the mean high water mark in that estuary to a distance 5 metres landward from the edge of the vegetation; and

b) in relation to any Outer Island to which this Act applies -

i) any area specified to be foreshore by the Island Environment Authority for the island concerned and approved for this purpose by the Queen's Representative by Order in

Executive Council;

ii) in the absence of any such order for an island, any area prescribed by regulations to be foreshore for the island, after consultation with the Island Environment Authority for the island concerned;

Another section requires that regard be paid to:
37 (5d) environmentally sound traditional resource management practices and standards.

And that endangered species can be listed and are not to be taken:
55 Protection of Species The service may, with the approval of the Island Environment Authority for an island, from time to time by notice in the Gazette designate specified animals and plants on the island as protected species.

***

Subsequently, in 2008, two Southern Group islands: *Takutea* and *Mitiaro*, developed regulations within the provisions of this Act; the key points are shown below. **These, therefore, represent the first legislation that directly protects sea turtles in the Cook Islands; once again traditional use is allowed (White *pers. com*. 2012).**

COOK ISLANDS: ENVIRONMENT (ATIU AND TAKUTEA) REGULATIONS 2008.
By Order in Executive Council (Queen's Representative) dated 8th July 2008.

Section 4. Designation of Takutea as Community Conserved Area - (1) The island of Takutea***** is hereby declared a community conserved area under the management and control of the Trustees of Takutea.

*****["Takutea" means the island of Takutea and includes the waters within 12 nautical miles of Takutea. The island belongs to the people of Atiu and was originally gazetted as a bird reserve in 1903; and then re-established under Aronga Mana. "Takutea Trustees" means the Trustees and their successors in whom the Island of Takutea was vested pursuant to Freehold Order of the High Court made on the 13th of February 1950 (M.B. 1/382)]. It is uninhabited (White 2012).

Section 12. Protection of Marine Turtles - (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.
(2) Where any person intends to possess, kill, harm, remove or damage a turtle in accordance with traditional practice such person shall apply in advance to the Island Environment Authority in a form prescribed by regulation.
(3) Where any person intends to conduct an activity referred to in subclause (1) (a) - (d) under the auspices of marine turtle conservation and protection management, it shall be the onus of such person to prove that those activities are for conservation and protection management purposes and shall not be detrimental to the survival of that species, such person shall apply in advance to the Islands Environment Authority in a form prescribed by regulation.

***

COOK ISLANDS: ENVIRONMENT (MITIARO) REGULATIONS 2008 (2008/5).
By Order in Executive Council (Queen's Representative) dated 7th October 2008.

Section 11. Protection of turtles - (1) No person shall:-
a) possess, disturb, kill, harm, remove or damage any living wild turtle or eggs;
b) disturb any nest or remove any eggs from nest;
c) disturb any living wild turtle in any reef area or on land; and
d) export from Mitiaro any turtle, eggs or parts thereof whether living or dead.
(2) Where any person intends to kill, harm or possess a turtle in accordance with traditional practice such person shall apply in advance to the Island Environment Authority in a form prescribed by regulation.

AUTHOR'S NOTE: Woodrom Rudrud (2010), in her literature review, reports nesting activity (by *C. mydas*, *E. imbricata* or unidentified species) from all islands except Mitiaro; therefore it is unclear if there are actually any turtles on Mitiaro or not (White *pers. com.* 2012).

RESEARCH FINDINGS FROM THE ATOLLS AND ISLANDS

Aitutaki [18° South; 159° West]

Background

On 6th February 2010 the author went to Aitutaki for a month to assess the distribution of sea turtles and current status of nesting on that island[40]. Unfortunately, in the early hours of 10th February **'Cyclone Pat'** devastated the island; and so the research was put on hold for two weeks while the author assisted in the big clean-up. Later, several terrestrial and in-water habitat surveys were achieved; but a planned trip to Manuae Atoll was cancelled because of the cyclone.

The study site

Aitutaki is a near-atoll of volcanic origin; there is a small mountain *Maungapu* (123 m) and two motu with underlying volcanic rocks (*Rapota* and *Moturakau*); the other motu are coralline and some have sandy beaches. There is an accreting sandbank *'Honeymoon Island'* that did not exist two decades ago. Aitutaki is the second most-visited destination in the Cook Islands and consequently there are several resorts; usually on the best beaches. The lagoon is particularly beautiful and can have good underwater visibility; the southernmost area (between the southwestern and southeastern motus) is sandy with patch reefs. There are a number of locally-operated lagoon cruises offering day-trips.

Cyclone Pat (10th February 2010)

This was a very severe event, with wind-speeds estimated to have reached 240 kph; sea surge was either absent or minimal. Once it was daylight we drove around the island to assess the damage. The first priority was to make the island safe for the people again ~ the major problems included: fallen trees and electricity poles that also blocked many of the roads; loss of power; limited drinking-water supplies; and structural damage to the majority of buildings: approximately 90% of buildings sustained some degree of damage; 63 houses were completely demolished. A number of islanders were in a state of shock; fortunately, nobody was killed and only a very small number of minor injuries were reported. At *Popoara* dozens of trees had collapsed; outside the villas there was a mass of impenetrable trees and debris; likewise at the front of the Boatshed Restaurant. Most of the *hara* trees (pandanus) were broken and many of the coconut trees damaged. The United Nations sent a disaster-assessment team (from Auckland); initial restoration work continued for the next ten days.

[40] Flights were kindly provided by Air Rarotonga and accommodation by Popoara Ocean Breeze Villas & Boat-Shed Restaurant.

Terrestrial surveys

Limited research began on 21st February; the author borrowed a small *vaka* (kayak) to get around the lagoon, visiting several motu: *Aitutaki, Akitua, Angarei, Ee, Maina, Mangere, Motukitiu, Moturakau, Papau, Rapota* and *Tapuaetai* (aka *'One-footprint' motu*)[41]. No tracks were found and there were many small plant-roots woven through the sand on each motu, which would interfere with nest-construction. The eastern motu are low-lying with mostly hard substrata (Type C); access from the lagoon may be possible, but vegetation often reached the waterline. There are some good sandy beaches: e.g. the western shores of *Akaiami, Tekopua* and the northern side of *Tapuaetai*. Tracks were observed in July or August 2009 on the beach next to *Tapuaetai* Post-Office (Te King's crew-member *pers. com.*). *Motukitiu* is unlikely to support nesting (Type C): it is very flat with shallow sand depth; beaches are narrow; access is over very shallow, intertidal, hard substrata; it is also densely-forested, as well as being an important seabird nesting site.

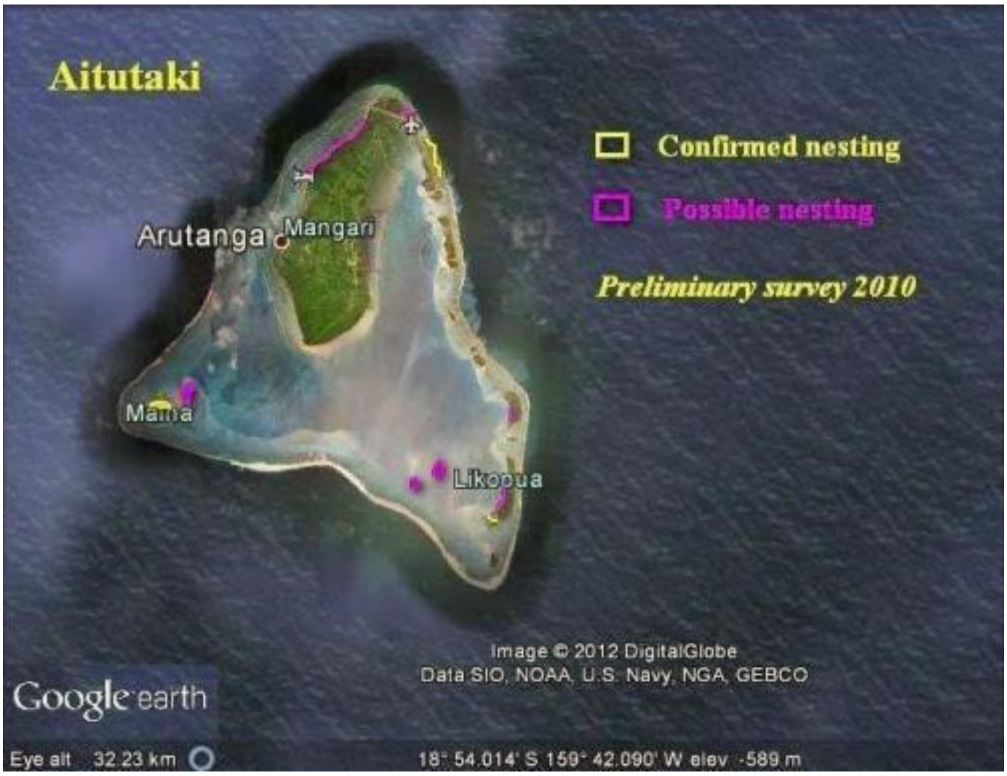
Rapota and *Moturakau* both have an underlying volcanic rock substratum, although there are small beaches and pockets of sand. The author considers that in some years the depth of sand would be sufficient to support egg-laying; as it seems likely that wind and waves will deposit or remove the sand layer, creating a dynamic habitat rather than a static one. Access into the forest may be difficult, as there is dense vegetation, including fallen trees, adjacent to some of the beaches; but there were also wider, more open, nestable zones.

In the southwestern part of the atoll - *Maina* probably supports nesting (access is possible from all directions, the motu is slightly raised, providing about 2-metres of sand depth in its interior; vegetation was mostly pandanus, but these had collapsed in the storm and so the true picture remains unclear. *Honeymoon Island* may be nestable in years to come; the sand is of excellent quality, but at present still has a high water-content.

The main island of Aitutaki consists of two peninsulas: the eastern side has a rocky coastline, but with pockets of sand, occasionally these do support nesting. The northern section has good quality sand of sufficient depth to support nesting (Type A*). The northwestern section has most of the resorts and so nesting probably does not occur, even though some beaches are suitable. There is little suitable habitat round the main town of Arutanga (e.g. by the rugby field the sea comes right up to the grass); continuing to the southwest, beaches are either absent or anoxic, with trees down to the water's edge. The lagoon-side beaches between these peninsulas are poorly-suited for nesting, especially on the Vaipae side. To the southwest of the airport there are several small resorts; some have sandy beaches. These are used by the lagoon cruises to embark passengers, there are small catamarans available for hire; these resorts also have beach-side bars that continue late into the night: so music and lights would probably deter any nesting.

T**wo nests** were laid on the eastern peninsula (05/12/2010), adjacent to the southern-end of the runway (18° 50572 South; 159° 45399 West); vegetation at the back of the beach had been disturbed and the tracks were fresh (C. Waters *pers. com.*).

[41]Bishop's Cruises and Te King Cruises took the author and vaka to the southern lagoon areas; *Meitaki*.



Conclusion

The most likely sites for egg-laying at Aitutaki are the southwestern and southeastern motu: ***Maina, Tapuaetai,*** and possibly ***Rapota*** and ***Moturakau***. This knowledge is not detrimental to the tourism industry. Most guests only visit these southern motu for a few hours as part of an organised cruise (e.g. Bishop's Cruises and Te King Cruises); so the author's recommendation is that this mode (using knowledgeable islanders as guides) should continue (rather than having small motorboats available for privatehire); this will leave the beaches undisturbed and available for turtles to emerge at night and lay their eggs; as well as providing for day-time tourist activities.

Marine Surveys

On 22nd February the author surveyed the sea areas between Aitutaki's two peninsulas as far south as *Tautu Landing* by canoe. The first turtle was encountered midway between *Vaepeka* and *Akitua*; it was a large *Chelonia mydas* and remained on the surface for nine seconds, taking two breaths. Sub-surface visibility was poor (<1 metre), but that habitat is isolated coral bommies and bare sand; depth is less than 20 metres.

Between 24th 27th February, whilst kayaking in all sea areas between *Angarei-Vaepeka-Tautu-Papau*, another 18 *Chelonia mydas* were observed: 10 of them on 26th February.
Surveys typically lasted for 7-10 hours.

Green turtles were also found resting on the sandy floor in the southernmost part of the lagoon (depth <5 m.).

Conclusion

Given the limitations of this survey and the fact that the environment had been drastically altered by the cyclone, the fairest thing is to say that **Aitutaki does support limited nesting at least in some years:** other than three juveniles, all the encountered green turtles were of reproductive size. The island should be resurveyed at a later date.

No hawksbills were seen.

Threat mitigation and an educational opportunity

'*Rumours of Escape*' (a resort) asked the author to investigate whether its beach might be suitable for turtle nesting. The sand was compacted, but generally free from stones and roots. It would be possible, although difficult, to excavate an egg-chamber here. The most important contribution from this resort is that its light-pollution is minimal. The villas, which face the beach, have '*mood lighting*': mostly concealed, of low intensity, and downwards-facing. This means that the beach is mostly in darkness. The lagoon here is wide and clean with isolated coral bommies; there is good potential for this underwater area to be used during the inter-nesting period[42]. **'*Rumours*' provides a good model for minimising seawards light-pollution, which could be utilised by other coastal resorts and developments; and may be an environmentally-friendly marketing attribute.**

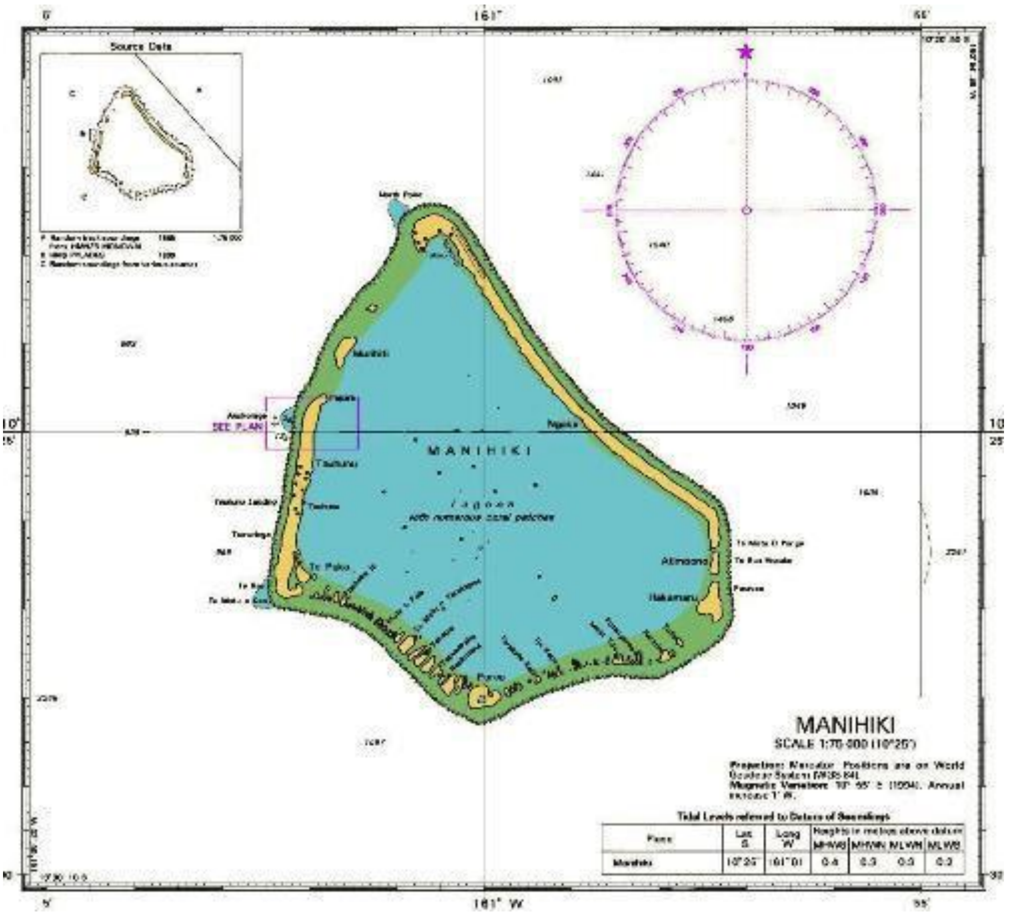
[42] Female turtles usually lay successive nests at intervals of 2-3 weeks; during this time they often remain near to their nesting beach; individual animals do not nest in every year: an interval of 2-3 years is normal.

Top left: Aitutaki (Photo: Ewan Smith, Air Rarotonga); top right: view from *Maungapu* **Centre left:** paddling to *Papau* motu; **right:** good nesting beach at *Tapuaetai* Bottom: the morning after *'Cyclone Pat'*

Manihiki [10° 25 South; 160° West]

Manihiki Atoll consists of two long and narrow motu (*Tauhunu* and *Ngake*) and about 100 smaller motu; mostly along the southern fringe of the atoll; some motu within the lagoon are used for pearl-farming. There is an airport at *Tukao* village on *Ngake*; the larger village is *Tauhunu*, on the motu of that name. This atoll is the best-served for transport in the entire Northern Group, because of its black pearl industry. The author visited *Tauhunu* briefly in late-December 2010 and collected some anecdotal evidence concerning turtles, but it was not possible to survey at that time.

In September 2011 the author went to Manihiki for a fortnight, as part of a Life-skills programme organised by the Ministry of Education: the first week was spent at *Tukao*, the second at *Tauhunu*. When not teaching the author investigated a few motu to determine the likelihood of nesting occurring at those sites. Nothing was found, but an islander said that there had been two green turtle nests on *Atimoono* motu in 2009; and he'd hand-reared about 300 hatchlings for several weeks (Lukan *pers. com.* 2011). The author looked at the approximate locations for those nests and, perhaps unusually, these females would have emerged from the lagoon-side of the motu, rather than the ocean.



Manihiki Atoll (chart from NZ945)

The Findings

Ngake: the reefward (eastern) side of this motu is mostly medium-sized coral boulders with a thick barrier of vegetation adjoining it; there were few points of access into the forest. The airport runway is at the northeastern part, running parallel to the ocean (photo below); and much of the excavated earth has been piled into a barrier along the seawards edge. The reef drop-off is close to the shore, perhaps 15-20 m in most places; there are a few deeper pools on the reef-top, but it is mostly very sharp coral with poor access to the shoreline. At a couple of sites, about half-way down the length of the motu, there are some flatter areas bordering the forest; close examination showed that these have a coral substratum and were submerged or overwashed during high water. There obviously had been at least one emergence by a green turtle, as its skull was found among the rocks; although a dead animal could have just been washed ashore by the waves. Apart from the inhabited areas at *Tukao* (northernmost part of the motu) most of this motu is densely forested with no apparent tracks; access was difficult from south of the runway.

Some years ago *Ngake* was used for gathering copra, and the various sections were open or closed under *rahui*; access was always by boat from the lagoon. The author scanned its entire western side during a boat-trip to the southeastern motu: in most places the forest came right to the water's edge and the vegetation was usually dense with no access to the interior; a few very small sandy beaches would be submerged by rising tides, or at least would be too water-logged for egg-development. Therefore nesting will be **infrequent** on this motu; which is by far the largest on Manihiki Atoll (LINZ 272/8/10; 1986).

Western side of Ngake: vegetation mostly extends to the waterline; not a good nesting habitat.

Atimoono: this small motu is south of *Ngake* and joined to it by a small channel and inter-tidal zone; this was the general area where the two *C. mydas* nests in 2009 were laid (Lukan *pers. com.* 2011). The majority of this inter-tidal area is sandy with a few small bushes, and it is open towards the eastern side where the windward reef is situated. On a rising tide this area is mostly submerged; there is a similar situation at the northeastern section of *Atimoono* itself: the substratum was hard-packed sand or mud with occasional thorny bushes and trees.

Atimoono: inter-tidal zone and thorny vegetation; the reef is visible in both photos

There were several pits and excavations (n = 7) under these bushes, which could conceivably have been made by sea turtles, otherwise feral pigs, but no tracks were seen and it is unclear if such a habitat could even support egg-development, as it seems likely to be underwater at times. Access over the reef by turtles might be possible in some places, although the coast consists mostly of very sharp rock. The remainder of this motu is densely-forested; there are some small tracks giving access. The lagoon-side beaches on the motu's western and southern shores are sandy, but have forest right to the water's edge; there are a few places where emergences are possible, but these are narrow and water-logged. Nesting may occur in some years. but is unlikely to be substantial.

***Atimoono*: left:** scrapes beneath bushes may have been made by turtles or pigs; **right:** some inland areas of the motu are submerged at high water

Above: left: lagoon access at A*timoono & Hakamaru* is poor; **right:** likewise from the windward reef

Hakamaru: this motu is immediately south of *Atimoono* and is also densely-forested. There are a couple of sandy areas, but the conclusions are the same as for the previous section. No further motu in the southeastern sector of the atoll were assessed at this time.

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Tauhunu: the northernmost part of this motu is rocky and inter-tidal and unsuitable for nesting (Type C); there are a few houses and also the island's power-station. Some parts of the reef-side (western) coast could support nesting, but no evidence was found during this survey. The eastern shore is rocky or has constructed walls, wharfs and tiny harbours next to most houses; boat-use is very common. The school, hospital, cyclone-shelter and Marine Resources Centre are also on the eastern shore. The main village extends across the central section of the motu and has small roads to both coasts; with the main offshore landing-place being on its western side. Main roads have streetlights and electrical power is available 24 hours per day. See below for the southern section of this motu (Threats and Impacts).

***Tauhunu*: top left:** looking north to *Murihiti*; **right:** lagoon is to the east

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Te Puka: this is a small densely-forested peninsula that originates on the southeastern side of Tauhunu and partially encloses a muddy inter-tidal lagoon; at low water this can be treacherous to walk across (quicksand). Pigs walk round the edge of this lagoon and cross onto the nearest motu.

Top: inter-tidal zones are treacherous at low water; **Below:** pig tracks on motu

The southern part of the atoll has many small motu; several of them were assessed:

Rangahoe; Motu o Koteka; Hohake Rahi & Hohake Iti: this group of small motu could support nesting on their eastern shores, but it really depends upon the water content in the sand; at times these beaches were submerged. The motu are forested, often densely, but there are spaces underneath some of the bushes that a turtle could crawl through; it would not be an easy nesting site though. Pig tracks were everywhere on *Rangahoe*, the nearest motu to *Te Puka*, but they were absent on the more eastern islets.

Top: typical motu in the south of Manihiki Atoll; **Below:** bushes right to the sea, but some areas are sandy.

Motu o Poia; Tima; Te Pa; Paheke Iti; Paheke Rahi; Te Motu o Tarakapoe; Motu Roa; Tehapai; Motu Vahine; Tupuaekaha; Raukotaha; Te Ruerue Rahi; Te Ruerue Iti; Punganui Rahi; Punganui Iti: the first five of these are very small motu, but all of them are forested and seem to be important nesting sites for seabirds (White *pers. obs.* 2011). The motu are rocky on the reefward sides and there are often fist-sized boulders.

Top: southern shore by reef; Below: seabird nestling.

The small channels between pairs of motu were usually sandy; the channel north of *Motu Roa* has a hard substratum and was deeper than most of the others. Generally these motu have some sandy patches, other areas are *kirikiri*; and usually the vegetation is dense and often reaches close to the water's edge; there is access from the water onto these motu in a few places. At some sites the lagoon flows between the trees and there is no beach at all.

Top: channel between two motu; **Below:** another channel at low water

Top: no access through vegetation; **Below:** hard substratum and overwashed beaches.

On the lagoon side there were two sandbars overwashed by waves from the lagoon that formed pools and channels (depth 1-2 m); bars extended from *Tima* to *Paheke Rahi*; and *Paheke Rahi* to *Te Motu o Tarakapoe*; and they were exposed at low water.

Top: sandy spit runs off to the right; **Below:** spit can be seen in middle distance.

Note: the author was attacked by a blacktip reef shark (*Carcharhinus melanopterus*) whilst crossing the sandbar just north of *Tima* (mid-morning, 10th September 2011). The shark (about 1.20 m long) ignored all attempts to scare it off (splashing, shouting, running towards it) as it seemed determined to make an attack. Unfortunately the author was left with no other choice but to leap out of the water at the last moment and stamp very hard upon the shark's back; it quickly swam away and did not return.

The most likely sites for nesting here, and these may vary from year-to-year, are: the southeastern side of *Tima*; the eastern tips of *Paheke Iti* and *Paheke Rahi*; the northeastern part of *Te Motu o Tarakapoe*; and the northern part of *Tehapai*. The other motu were not surveyed at this time. There was **no evidence of nesting**, or excavation, or any tracks.

Several motu have areas where nesting may occur; much depends upon the water content in the sand or *kirikiri*. This may change from year to year.

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Threats and Impacts

It is possible that turtles are eaten occasionally, but the occurrence is likely to be very low: the atoll's inhabitants have thought a lot about their environment; and both of the Island Councils are very active and work well together; *rahui* is implemented as required for the various natural resources (e.g. clams '*pasua*'). The biggest threat for sea turtles is the extensive sand-mining on what is probably the atoll's best potential nesting beach *Tumuringa* (western side of Tauhunu, southwards from 'Tauhunu Landing'); sand and gravel is removed along much of its length in order to meet the atoll's extensive building needs. This particular beach is wide (perhaps 50 m in places), there is an incline so that sand is well-drained; and access from the reef-side lagoon is good; presumably nesting occurred here in the past. A small road running along the western edge of the forest, parallel to the beach, facilitates sand-extraction; the southernmost section of the beach (*Te Rae*, leading to *Te Motu o Koa*) changes from sand to medium-sized boulders on a steep, rocky slope that is unsuitable for nesting (Type C).

Also at *Te Motu o Koa* and leading around northeasterly to *Te Puka* pigs were observed running in the forest, these may be either feral or escaped domesticated animals; as there are several pig-pens in this area. Pigs were reported to occasionally attack and eat nesting female turtles (Jean-Marie Williams *pers. com.*). The author observed that pig tracks proceeded across the intertidal zone (a semi-enclosed lagoon) at low water onto the small motu at *Te Puka*; and also on to the two westernmost motu at *Rangahoe*; but the pigs did not seem to venture further east than this (similar observations were noted during a Cook Islands bird survey; Ian Karika *pers. com.* September 2011).

Conclusions for Manihiki Atoll

Sea turtle nesting at Manihiki is unlikely to be substantial: the motus are generally unsuitable for egg-laying or embryonic development. Not all motu were visited, but many of them are very small (between 30-100 m long), with the sides nearest to the reef being very sharp, coralline rock; the vegetation is dense and often reaches the waterline, and although there were some sandy areas these were mostly water-logged. As noted earlier, the dynamic nature of coastal habitats would support nesting in some years; and the recommendation for this atoll is to conduct regular surveys on the motu to note the extent and frequency of nesting activity.

The Island Council could decide to implement some level of protection for Tauhunu's southwestern beach; perhaps defining a closed-period for sand-extraction, so that turtles could also utilise the beach: two difficulties with this approach are that at present we have no knowledge of when the egg-laying period is; and that the present beach structure may no longer be suitable for egg-development; although it may be in time. A second option is to select another site for sand extraction.

The Manihiki Islanders, including the Mayor, Island Councils, Churches, Fishery Officers and both school Principals (*Tauhunu* and *Tukao*) are keen to become involved with the author's sea turtle research and conservation: students from both schools will participate in the *Turtle Rangers* programme.

Important note: If nesting is seasonal rather than year-round these surveys may have been too early in the year i.e. before egg-laying had begun. Ian Karika (*pers. com.*) found no evidence of turtle nesting during his bird survey two weeks later either. **So this means that nesting either does not occur or that it starts some time after September.**

***

An educational opportunity

In November 2012 the staff from Manihiki Marine Resource Centre discovered that some small juvenile green turtles were being kept in a floating cage; the *C. mydas* were about one-year old and were being hand-reared: in order *to be large enough to avoid predation when released into the ocean*. They were well-fed, but the cage was in a hot and turbid part of the lagoon, so not an ideal habitat. Georgia Langdon (MMR Pearl Biologist) wrote to the author for guidance, and provided several photographs showing the problems. The main concern was that all of the yearlings had been fighting, and all exhibited eaten rear flippers. At this stage of development the turtles would probably be solitary and feeding opportunistically in the open ocean. The owner agreed to release the turtles and the event was co-ordinated by MMR staff.

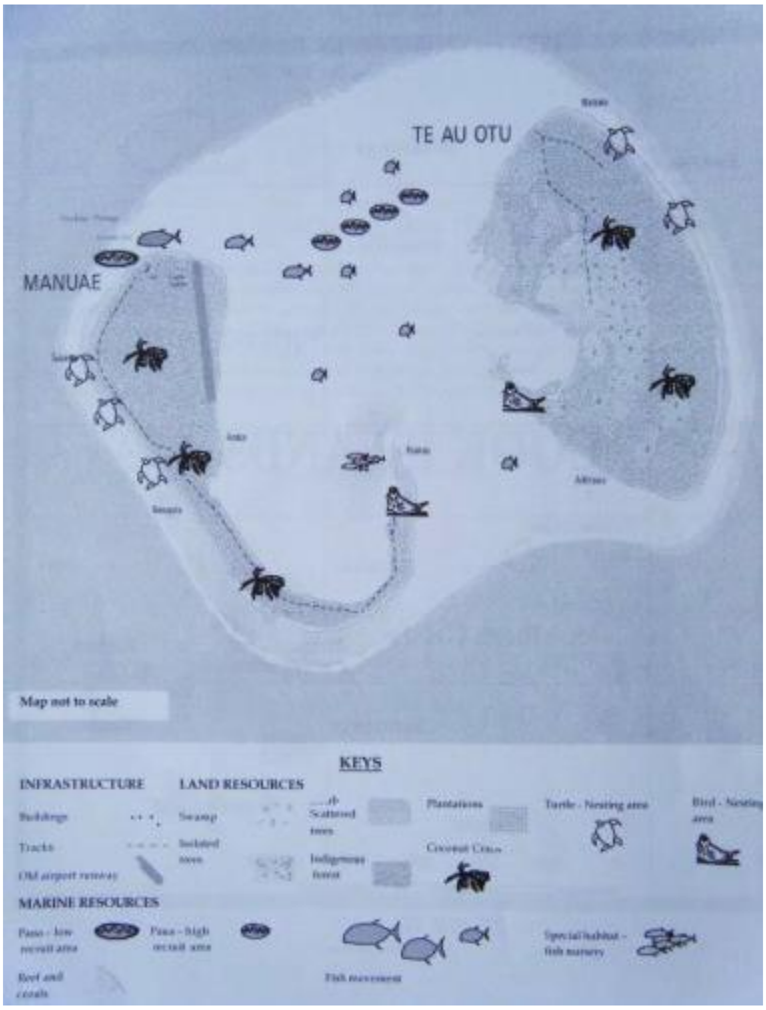
Photos courtesy of Georgia Langdon 2012


adidas
VISA

"Safe Voyaging fonu kai"

Manuae Atoll [19° 15 South; 158° 57 West]

As the expedition to Manuae had to be cancelled because of *Cyclone Pat*, the following information, which is not widely known, may be helpful: **Twelve nests** were found on the western beaches of *Manuae motu* by the Baxter brothers (cited in Teariki-Taoiau Rongo 2006: Manuae Draft Management Report[43]); the same document suggests that nesting occurs on the seawards side of the other motu *Te Au O Tu* (Mark and John Baxter *pers. com.*). Only *C. mydas* is believed to nest, and was the only species observed in the lagoon and on the reefs. **<u>Hawksbill turtles have not been seen at the atoll for several years</u>** (Clive Baxter *pers. com.*).

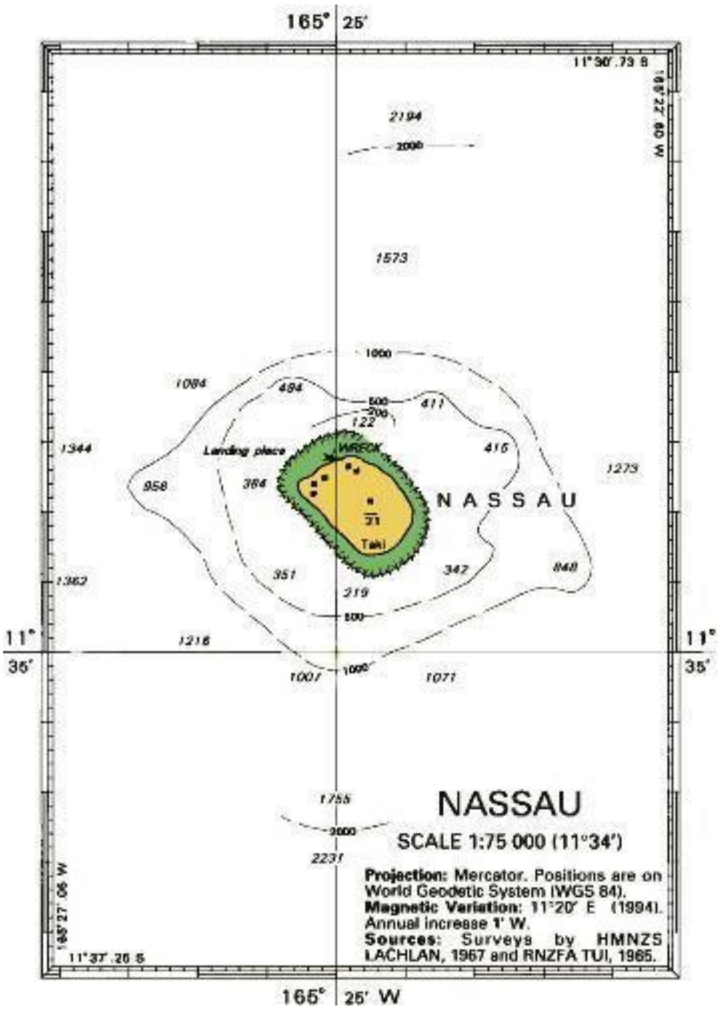


Manuae Atoll - from Rongo 2006

[43]Manuae is traditionally owned by several landowners on Aitutaki.

Nassau [11° 34 South; 165° 25 West]

Nassau is very remote; the nearest atoll is Pukapuka and the people are Pukapukan by descent. Transportation is extremely rare. The author visited Nassau twice, both times from a passing ship that unloaded cargo. During the most recent stop-over in December 2010: there was enough time to survey the entire coastline; about five kilometres all told.



Nassau (chart from NZ945)

Nassau does not have a lagoon, but instead the reef joins directly onto the land. A small passage has recently been blasted out of the reef that allows access for small boats; prior to this visitors had to step onto the reef-top and the boats pulled over the top of the corals. A small mooring jetty has been included in the construction work.

Tractor over the top of the reef at Nassau

Nassau boat passage 2010

Nassau Atoll, Northern Cook Islands, looking East. Photo: Ewan Smith, Air Rarotonga

Research findings

A rapid assessment survey was made of the entire coastline, searching for turtle nests and tracks: <u>six nests were found</u>. The north and northeastern coastlines consist mainly of coral fragments (*kirikiri*) and turtle nesting does occur, especially near to an old shipwreck in the forest: **three nests** were laid in *kirikiri* under *ngasu* at the back of the beach. On the eastern side of the atoll **two nests** were laid in sand: one mid-beach, the other in *ngasu* at the back of the beach (one track was very wide, but probably not *Dermochelys coriacea*). The southern side is mostly sand with patches of *kirikiri*: there was **one confirmed nest** and an older one[44]. The western coast is steeply-sloping and the beaches are narrow but with some sand (Type B); **no nesting was observed** and emergence from the ocean would be difficult. The northwestern corner is unsuitable (Type C)

Nassau: *C. mydas* emergence over *kirikiri* Coarse nesting medium (scale bar = 1 cm)

C. mydas: 3 nests were laid in this area *C. mydas* nest: mid-beach – Nassau Atoll

[44] In 2009 some of the children had pet hatchlings that came from this southern beach.

Nassau. Map from LINZ (272/8/9) adapted to show the suitability of coastal habitats for nesting: yellow is suitable; pink is possible, brown is unsuitable.

Threats and Impacts

Turtles may still be eaten occasionally, but this is unquantified. Sand-extraction occurs on the eastern beach (and possibly southern) for building needs, but this is not excessive and is likely to be sustainable; many people live in *kikau* houses (i.e. traditional woven walls and palm leaf thatch); the roads are unpaved and very clean.

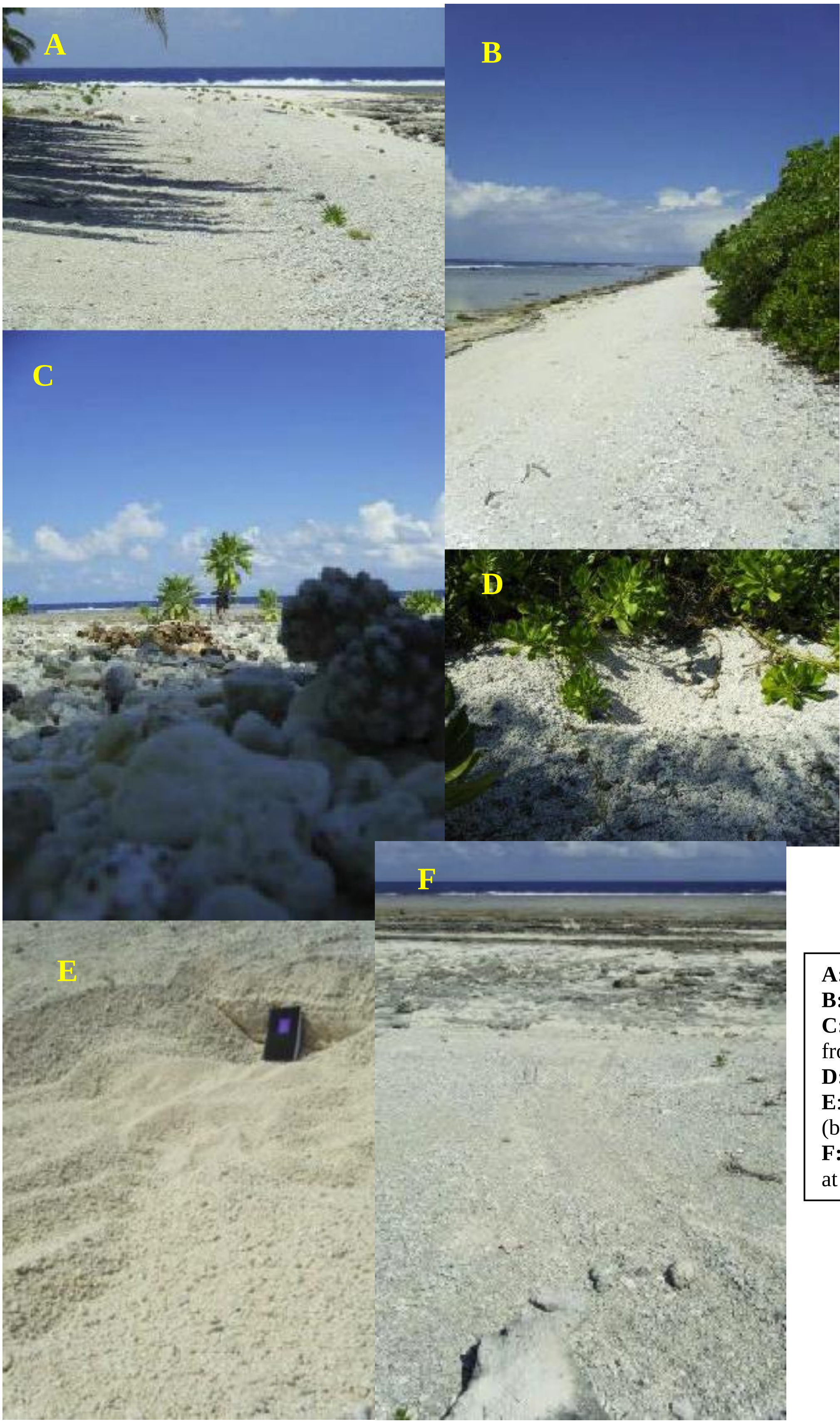
Typical house on Nassau

The atoll is always kept really clean

Author's Notes: This is one of the islands where nesting is most likely to occur around high water, because any emerging females would have to crawl a long way over the top of the reef to reach the beach: the author suggests **a nesting 'window' of HW ± three hours.**

These nests are all assumed to be *Chelonia mydas* and likely to be successful. Nothing is known for the other turtle species and the nesting period also remains unknown.

Nassau: almost low water on the northwestern reef



A: Nesting
B: No nesting
C: Hatchling's eyeview from nest
D: *C. mydas* nest
E: Very big track (book is A5)
F: Emergences are at High water

Palmerston Atoll [18° 03 South; 163° 12 West]

Background

The most recent survey of sea turtle nesting-activity in the Cook Islands was undertaken by Nan Hauser's team whilst monitoring and filming cetaceans at Palmerston Atoll in 2000 (www.whaleresearch.org). During their 24-day survey (November 2000) they found eleven emergences by *C. mydas* on Cook's Islet. The researchers suggested that similar numbers may have occurred on other motu; although it is unclear if they surveyed all of the other motu (Centre for Cetacean Research 2000).

Prior to that, the only other surveys had been conducted by George Balazs (Balazs 1995) and Peter Pritchard (Pritchard 1995a) within their Pacific-wide assessments of sea turtles during the 1960s-1970s. Ever since those days, Palmerston Atoll has been cited as being the most-important sea turtle nesting site in the Cook Islands, based on data from around 1970; this is still true for the most-recent publications (Maison *et al.* 2010; NMFS 2010; Wallace *et al.* 2010; Woodrom Rudrud 2010).

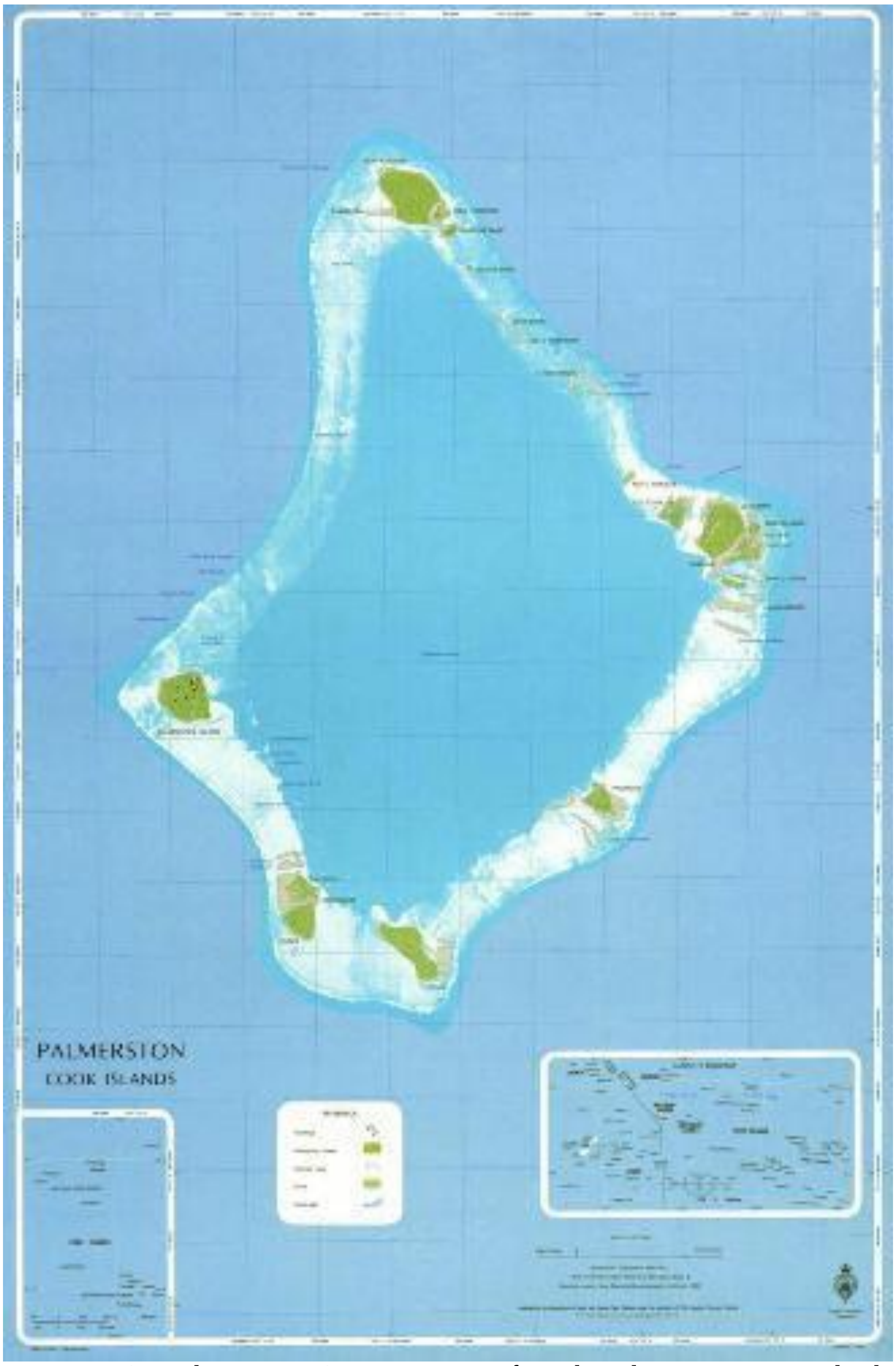
The present author visited Palmerston Atoll three times: i) a diving expedition in 2009; ii) a stopover on *S/V Kwai* that included a beach survey of 'Palmerston Island' (3 nests) and gathering anecdotal information (2010); iii) the Rufford Trust Expedition in April 2012.

Anecdotal information: In 2009 the author was informed by the Fisheries Officer (Bill Marsters *pers. com.*) that there could be as many as **200** *C. mydas* nests laid annually at Palmerston Atoll, although this is completely unquantified; all nesting emergences are by green turtles dispersed across the atoll's different motu; loggerheads and hawksbills, although present, do not nest; the latter are presumed to be juveniles. Victoria Matakere (*pers. com.*) reported that a nest was laid outside her front door in January 2009.

The Study Site

Palmerston Atoll is a true atoll (Spalding *et al.* 2001) with one inhabited village that is also called Palmerston. The population is unusual, perhaps unique, in that it derived from an Englishman, William Marsters, and his three Polynesian wives from Tongareva. Resident population is usually about 60; but there is a larger diaspora spread worldwide. The atoll has six larger motu and 17 minor ones, including some sandbanks; the author had only surveyed the inhabited one.

Palmerston Island (*aka* Home Island) is where everyone lives; it is located on the western side of the atoll. There is a small passage through the leeward reef just to the north, which is used by small boats to ferry cargo and passengers from visiting yachts onto the island. The motu is densely-forested and the beaches are sandy with a few small areas of *kirikiri*. Electrical power is usually available between 0600-1400 & 1700-2300; there are a few streetlights. Vehicles include pick-up trucks, motorcycles and tractors; there are several aluminium boats with outboard-motors and one small barge for cargo. It takes about 15 minutes to walk from end-to-end of the motu.



NZMS 272/8/7 Palmerston 1986; Department of Lands and Survey, New Zealand. The westernmost motu is inhabited; sea turtle nesting occurred mostly on the four southern motu: Palmerston, Cooks, Toms and Primrose.


Left: Palmerston main street **Right:** green turtle nest laid in the bushes (2010)

North Island is at the right foreground, but of particular interest are the small sandbanks along the reef to its left; nesting was found on one of them (Kitsap Bank) in 2012

The Rufford Trust Expedition

The opportunity to conduct sea turtle research at Palmerston Atoll throughout April 2012 was made possible through a Nature Conservation Grant[45] from the Rufford Trust Small Grants Foundation [www.ruffordsmallgrants.org].

The scientific aims of the Rufford Expedition were to assess the status, abundance and distribution of sea turtles at Palmerston Atoll; to investigate their use of habitats; and to quantify any threats or impacts. Directly-encountered turtles would be measured, tagged and DNA-sampled: in order to improve the regional understanding of linkages between turtle stocks in Oceania; such data are rare.

Expedition planning and deployment

The author wishes to thank Josh Cole (Director), Jane Raymond (Administrator) and the Trustees of the Rufford Small Grants Foundation for funding this important expedition to Palmerston Atoll. This is the first sea turtle research on the atoll in 12 years, and it would not have taken place without your support. Our main findings should allow population trends to be determined in subsequent years. Meitaki Ma'ata, Michael.

The expedition was planned and implemented by Dr Michael White and Jessica Cramp. The provision of equipment supplies from overseas and additional sponsorship for the trip was achieved through the dedicated efforts of Jessica Cramp.

A research team sailed from Rarotonga onboard S/V Southern Cross (*Sail Rarotonga*) on 31st March 2012, arriving at Palmerston 3 days later. Several Palmerston Islanders joined the survey team on arrival. All planned fieldwork was completed on 28th April; and the off-island team returned to Rarotonga on 1st May 2012.

The timing of the Rufford Expedition's departure from Rarotonga onboard *S/V Southern Cross* on 31st March 2012 was constrained by the cyclone season (1st November to 1st April); our deployment was the earliest acceptable date for the yacht's owner. However, as it was unclear whether egg-laying would still be occurring in April, the research plan included alternative scenarios: i) direct monitoring of nesting females; ii) assessment of nesting activity based on physical evidence, such as tracks or body-pits.

The planned pre-deployment training could not take place because several team-members were unavailable until the day that we sailed; consequently training took place during the fieldwork.

Photographs in the remainder of this chapter are used with permission from: Dr Michael White, Jason Green, Tina Weier and Phil Bradshaw. Copyright remains with the photographers.

[45] [Rufford Small Grant # Dr Michael White- 10964-1].

The entire field team at the end of a very long day excavating hatched nests on Cook's Islet; Jason Green took the photograph

The Rufford Trust Expedition Team:

Dr Michael White
Jessica Cramp
Phil Bradshaw
Nerissa Bradshaw
Jason Green
Kelly Robinson
Tina Weier
Munokoa Goldeen Nikau
David Marsters
Marion Marsters
Simon Marsters
Alfred Marsters
[Edward Marsters, John Marsters and little John Marsters joined us for one day]

Terrestrial Surveys

A) Determining the suitability of habitats for sea turtle nesting:

All beaches around the atoll were visited to assess their suitability to support nesting. The research teams used a small motorboat to reach the various motu and then walked around the coastline of each one. Nesting had often occurred under the bushes or at the forest margin; there were very few nests laid mid-beach and only a few tracks remained.

i) The first two surveys were used as training exercises for the entire team, to ensure that comparable research data would be collected. Subsequent surveys were undertaken by two teams starting from a common point and meeting at the opposite side of each motu.

ii) The initial survey was a 2-hour walk around Palmerston Island: typical nesting sites, tracks of adult turtles on the beaches, and evidence of excavations were pointed out and explained. Vegetation was classified as 'low bush' or 'mixed forest'; ease of access onto beaches from the lagoon or reef was explained. Research assistants were shown how to compile field-data and GPS[46] use was demonstrated with emphasis on marking waypoints and delineating sectors.

Left: First orientation survey on Palmerston Island; **Right:** turtle tracks on Primrose Motu: nests are laid under low bushes behind the beach

iii) Waypoints were named as follows:
Initials of motu (e.g. PR – Primrose)
Survey team (e.g. East or West)
Sector # e.g. PRW1; PRW2 etc. [based on a shift in vegetation or substratum].

iv) The second training-survey was at Cook's Islet (southwest of the atoll): recent nests (i.e. those with tracks) were waypointed; and recently-hatched nests were also marked for subsequent excavation (to ascertain hatching-success). This motu was resurveyed later once the teams had gained experience and only the second data-set was used.

[46] (Garmin model GPSmap 78 www.garmin.com).

Evidence of nesting activity is reported from each motu <u>in order of importance</u>:

1. Cook's Islet

Bounding co-ordinates
Latitude: 18°04.45 to 18°05.15 South; Longitude: 163°11.45 to 163°11.25 West

Cook's Islet. L: Sites suitable for nesting are in yellow; unsuitable in red. **R:** Confirmed nest sites: areas with frequent nests are shown in yellow, occasional in red; blue rare; and none in purple zones.

This motu forms the southwestern part of the atoll. The leeward reef is to its western side there is access for turtles from the ocean through some small passages and also across the reef at higher water levels; the main lagoon is to the east, but a wide shallow area also extends to the reef in the south and southeast.

The coastal zone includes sandy beaches, *kirikiri*, hard and jagged coralline areas, sectors with small boulders, and some rocky pavement; an inter-tidal gully almost dissects the motu. Vegetation cover varies: the western side is mostly low bush; the eastern side has sections of mixed forest; the northern, northeastern and southeastern sections have dense bushy cover or trees that adjoin the waterline. The northwestern area is a hard and jagged inter-tidal zone that would not support turtle emergence or nesting (Type C).

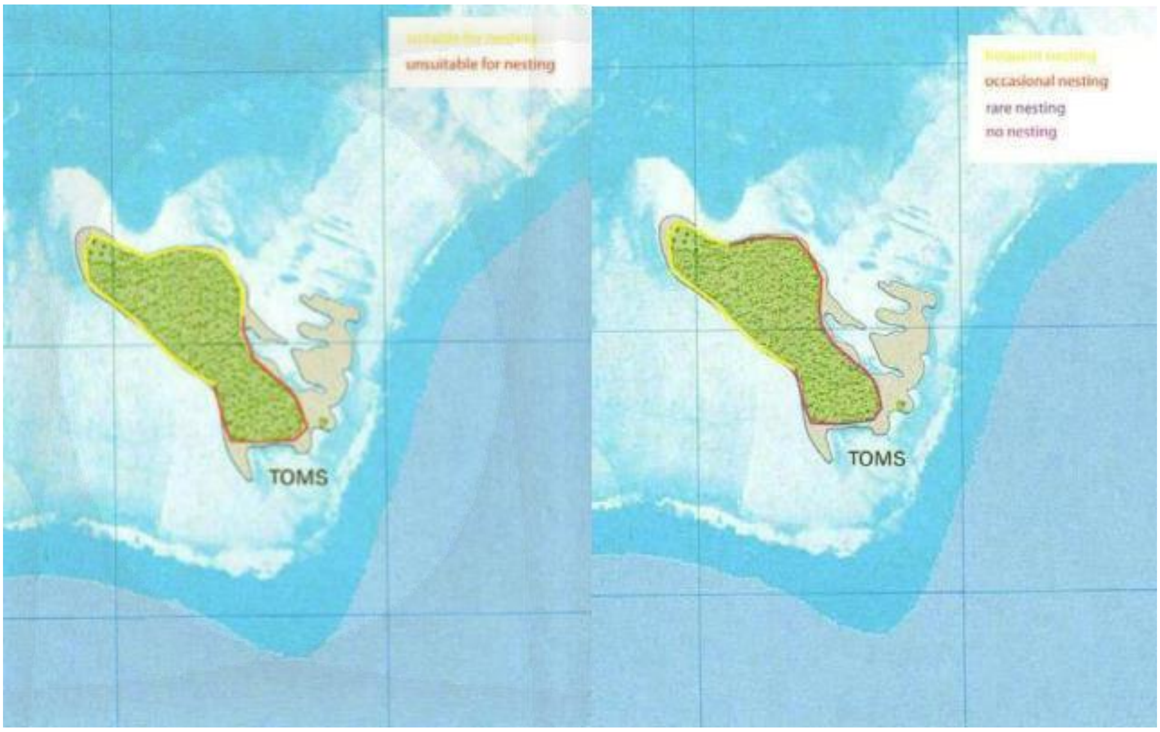
The majority of egg-laying occurred in the bushes at the back of the western beaches; a second important sector is a wide sandy beach on the eastern side; again the nesting was usually in vegetation. A nest was laid just southwest of the large gully during late-March or early-April, based on its track age. A long-dead disarticulated green turtle skeleton was also found on the beach here.

Nesting Summary for Cook's Islet:

Confirmed nests: 60 (38 on west side; 16 eastern beach; 6 around northern sectors)
Possible nests: 28 (25 on western beaches)
U-turns: 3
Attempts: 19

2. Tom's Motu

Bounding co-ordinates
Latitude: 18°05.12 to 18°05.32 South; Longitude: 163°11.05 to 163°10.30 West



Tom's Motu. L: Sites suitable for nesting are in yellow; unsuitable in red**. R:** Confirmed nest sites: areas with frequent nests are shown in yellow, occasional in red; blue rare; and none in purple zones.

This motu is in the southern part of the atoll to the east of Cook's Islet; the outer reef is to the south and east. Turtles can cross the reef at higher water levels. Access from the main lagoon is good along the western beach; the northern beach also has good lagoon access, however, there is a large intertidal sandbank (i.e. dry at times). The eastern shore has one good sandy section and a *kirikiri* section, but most lagoon access would be across sharp coralline rock. The southern side of the motu is unsuitable for nesting (rocky or steep boulder zones and dense thorny bush). Vegetation is mostly low bush or mixed forest; in places it adjoins the waterline. A very small, rocky, motu adjoins the southeastern tip.

Egg-laying occurred under the vegetation on most of the sandy sectors; one nest was laid mid-beach on the western side. There were recent tracks on the eastern shore, indicating that nesting had occurred in late-March.

Nesting Summary for Toms:

Confirmed nests: 48 (23 on west side; 15 eastern beach; 10 around northern sectors)
Possible nests: 12 (split equally between east and west)
U-turns: 1
Attempts: 4

3. Primrose Motu

Bounding co-ordinates
Latitude: 18°04.03 to 18°04.25 South; Longitude: 163°09.28 to 163°09.15 West

Primrose Motu. L: Sites suitable for nesting are in yellow; unsuitable in red. **R:** Confirmed nest sites: areas with frequent nests are shown in yellow, occasional in red; blue rare; and none in purple zones.

Primrose is on the southeastern side of the atoll; the windward reef is just to its southeast. A long intertidal sandspit extends from the western shore into the lagoon. The Palmerston map above shows '*Taenga's Sandbank*' to the south, but this seems to have disappeared. Vegetation cover varied: some sectors only had low bushes and others mixed forest: both types occurred in the northwestern sector; trees adjoined the waterline at its extreme tip (Type C). Lagoon access was across sand in the western, northwestern and northeastern sections; the latter then shifted to rock. Southeastern and southern areas are unsuitable for nesting.

Egg-laying occurred under vegetation in the sandy northwestern sectors; however, the most important area was the northeastern corner: where eggshell fragments were found beneath bushes; indicating that turtle hatchlings had emerged successfully. Recent adult tracks, three across *kirikiri*, also showed that nesting had occurred there in late-March.

Nesting Summary for Primrose:

Confirmed nests: 39 (19 in northeastern, & 20 spread around northwestern sectors)
Possible nests: 8 (5 east and 3 west)
U-turns: 0
Attempts: 3

4. Kitsap Bank

Bounding co-ordinates
Latitude: 18°01.03 to 18°01.08 South; Longitude: 163°08.41 to 163°08.37 West

Kitsap is a small raised bank in the northeastern part of the atoll **(see North Island map below)**. The motu's alignment is southwest to northeast. Much of the shoreline is *kirikiri* but there is sand underneath the rubble. Access from the lagoon would be over sand at the southwestern corner, and over rock for the remainder. There are rocky intertidal zones fringing the southeast, northwest and northern sections. Coconut trees have been planted here recently, so in future there will be partial forest cover; apparently it was forested in the past (probably destroyed during a cyclone). Some low ground-covering plants are present, but the entire motu is open and exposed.

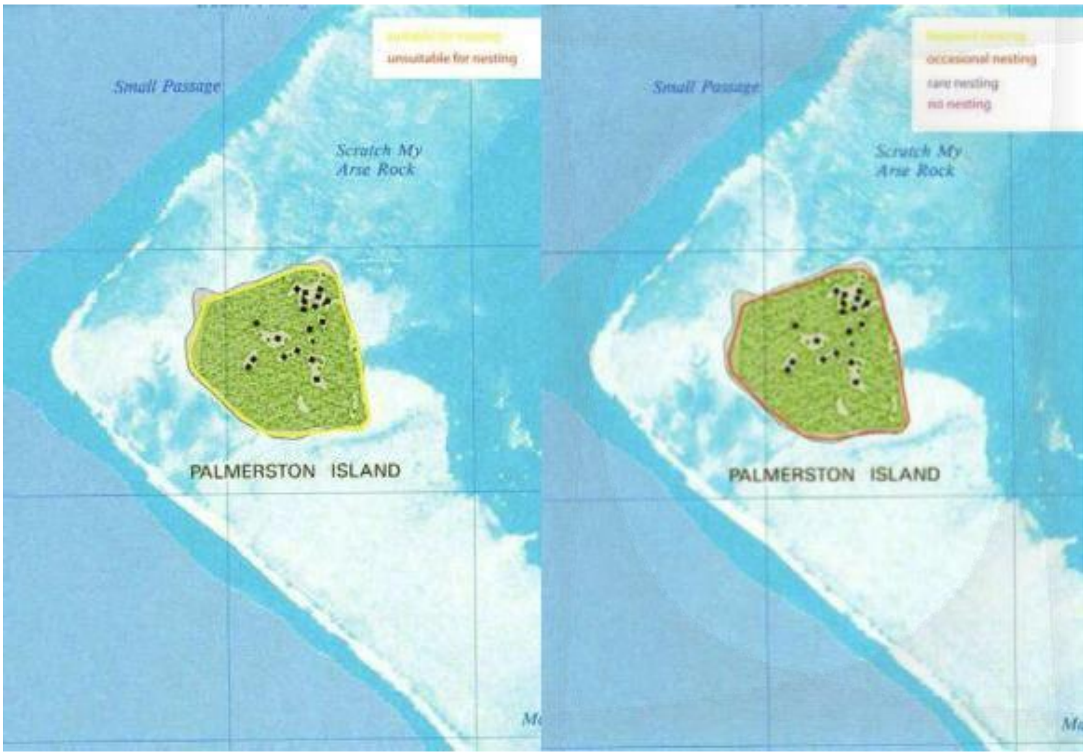
Nest construction occurred throughout the vegetation. Curiously, there seemed to have been no adult emergences from the sandier lagoon side. The track patterns that were still visible through the plant growth suggested all females had emerged over the windward reef and then swum through a shallow open area between two rocky spits to reach the motu. Five nests had recently hatched: giving a date-of-lay in late-January 2012.

Nesting Summary for Kitsap:

Confirmed nests: 15
Possible nests: 0
U-turns: 0
Attempts: 2

5. Palmerston Island

Bounding co-ordinates
Latitude: 18°03.20 to 18°03.40 South; Longitude: 163°12.54 to 163°12.25 West



Palmerston Island. L: The entire coastline is suitable for nesting (shown in yellow). **R:** Confirmed nest sites: all areas are used occasionally (marked in red); there were no high-density nesting zones.

This is the westernmost motu and was described in the introduction. Sharks are common near to the motu: they eat the discards when fish are being filleted. Egg-laying is possible all around the island; in common with the other motu most nesting occurs underneath the vegetation. Lagoon access is mostly over sand, but the reef side is rockier. A nest was laid at the back of the beach on the night of 20th April 2012; this was on the northwestern sector of the motu about 500 metres from our field-base. The female probably emerged across the leeward reef and traversed the ocean-side lagoon.

Nesting Summary for Palmerston:

Confirmed nests: 12
Possible nests: 3
U-turns: 1
Attempts: 4

6. Dicky Boy Sandbanks (n = 2)

Bounding co-ordinates (Dicky Boy north)
Latitude: 18°04.57 to 18°04.59 South; Longitude: 163°10.62 to 163°10.53 West

Bounding co-ordinates (Dicky Boy south)
Latitude: 18°04.64 to 18°04.66 South; Longitude: 163°10.56 to 163°10.52 West

These two small sandbanks are situated in the southwestern part of the atoll just north of Cook's Islet **(see Cook's map above)**. Substrata include sand, *kirikiri*, and rocky spits to the west. Turtles could access both sandbanks from the lagoon, but some approaches are sharp, rocky, and intertidal. Both sandbanks have partial vegetation cover (low bush), which is dense in places. On the northern sandbank some small trees adjoin the waterline.

Evidence for egg-laying was found on both sandbanks: some nests had been laid on the more-open western areas and others inside denser vegetation. Eggshell fragments were discovered under the bushes; some of which appeared to be from previous years.

Nesting Summary for Dicky Boy Sandbanks:

Confirmed nests: 9 (2 on north sandbank; 7 on south sandbank)
Possible nests: 0
U-turns: 0
Attempts: 0

7. Bird Islands

Bird Islands. L: Sites suitable for nesting are in yellow; unsuitable in red. **R:** Confirmed nest sites: areas with frequent nests are shown in yellow, occasional in red; blue rare; and none in purple zones.

Bounding co-ordinates (Main Bird complex, including Leicester)
Latitude: 18°01.52 to 18°02.32 South; Longitude: 163°08.34 to 163°08.00 West

Bounding co-ordinates (Small Cooks)
Latitude: 18°02.49 to 18°02.51 South; Longitude: 163°07.09 to 163°07.05 West

Co-ordinates (Karakerake)
Latitude: 18°02.52 South; Longitude: 163°07.15 West

The easternmost part of the atoll has a complex of small motu and sandbanks known as 'Bird Islands' (Leicester, Matavia, Small Cooks and Karakerake). These were generally unsuitable habitats for sea turtle nesting, although some small sections were sandy with access into the forest; a small amount of nesting evidence was collected.

The map shows intertidal zones but these effectively formed gullies, channels and muddy sections that separated the various vegetation-covered areas. The coastlines nearest to the reef were mostly sharp coralline rock; some areas had smoother rocky pavement that was submerged at high water, but approaches to the shore were still poor. The lagoon sides had some sandy sections where turtles could emerge, but the forest or bushes were quite dense and often reached the waterline; the ground inside the forest was damp and would be poorly-suited for successful nest incubation. Egg-laying could occur in some years. Two nests were confirmed on the western lagoon side; and there was also a U-turn near to a sandy spit (at *Suatumu*).

Karakerake motu is the best-suited for nesting amongst the Bird Islands and has several sandy sections, especially along its northern shore; there are some open spaces inside the forest where islanders camp occasionally. There were four possible nests, but their ages were unclear.

Nesting Summary for Bird Islands:

Confirmed nests: 2
Possible nests: 4 (on Karakerake)
U-turns: 1
Attempts: 0

8. North Island & northeastern motu or sandbanks

a) Bounding co-ordinates (North Island)

Latitude: 17°59.30 to 17°59.58 South; Longitude: 163°11.15 to 163°10.35 West

North Island and northeastern motu. L: Sites suitable for nesting are in yellow; unsuitable in red. **R:** Confirmed nest sites: areas with frequent nests are shown in yellow, occasional in red; blue rare; and none in purple zones.

There was **no evidence of nesting** on North Island or from the minor motu or sandbanks along the northeastern part of the atoll: apart from **Kitsap Bank**, which is reported above.

North Island includes a section called *Tara I Tokerau* that is separated from the main area by a muddy intertidal gully; the substratum is very soft and consists of some unidentified plant material, possibly some type of wort (olive-green with the consistency of wet cotton-wool); this was 25-cm deep in places). The southern beaches are soft sand with easy access from the lagoon, but no signs of adult emergence were found. A large sandy spit extends from the southwestern corner; this also has good approaches from the lagoon and leeward reef, but once again, there was no evidence to show nesting. The remaining coastline was Type C: jagged coralline rock, pavement, or small coral boulders; seawards access is possible and the northernmost part of the reef is located close by.

Vegetation was low bush or mixed forest, but species diversity appeared to be higher than on the other motu (e.g. there were many birds and the forest included ironwood as well as the more-common pandanus and coconut).

b) Bounding co-ordinates (Marion's Bank)

Latitude: 17°59.87 to 17°59.93 South; Longitude: 163°09.37 to 163°09.42 West

Marion's Bank is southeast of North Island; two sectors are Type A*****, sandy beaches with lagoon access. The remainder was Type C, but with lagoon or reef access. In places the ironwood adjoined the waterline. No evidence of nesting was found.

c) Bounding co-ordinates (Thistle Bank)
Latitude: 18°00.17 to 18°00.18 South; Longitude: 163°09.19 to 163°09.23 West

Thistle Bank is very similar to Kitsap Banks (see above). Thistle is a low-laying bank and has sand and *kirikiri*; there is a sandy spit at the northwestern tip. Access is possible from lagoon and reef sides; there is a rocky intertidal zone on the southern and eastern sides, but this can be traversed at high water. There are small ground-covering plants and also 10 rows of coconuts have been planted recently. No evidence of nesting was found.

d) Co-ordinates (Julia Cobb Bank)
Latitude: 18°00.59 South; Longitude: 163°08.95 West

Julia Cobb is similar to Thistle and Kitsap: low-laying with sand and *kirikiri*, a sandy spit to the northwest, and a rocky intertidal zone on its south side. Access is possible from the lagoon and across the rocky windward reef. Vegetation consists of low ground-covering plants and six rows of recently-planted coconuts. No evidence of nesting was found. The Palmerston map shows **'*Spar Bank*'** just to the north of Julia Cobb: it is possible that this has now disappeared. The remains of a small shipwreck are visible just below the surface (18°00.37 South; 163°09.20 West) at the approximate charted location; perhaps this is 'Spar' (it remains unconfirmed).

e) Bounding co-ordinates (Motu Ngangie)
Latitude: 18°01.71 to 18°01.80 South; Longitude: 163°07.91 to 163°07.99 West

This was different from the other motu and is covered in Ironwood ('*Ngangie*'). The trees adjoined the waterline in places, but inside the forest the soil was a very soft humus that could probably support nesting. The eastern side of the motu has a large flat area of very smooth pavement; there are rocky intertidal zones to the northwest and south; access is probably difficult from the lagoon because of the trees, but possible from the reef at high water. No evidence of nesting was found.

f) Bounding co-ordinates (Lee To Us)
Latitude: 18°01.98 to 18°02.14 South; Longitude: 163°07.50 to 163°07.70 West

Lee To Us is immediately northwest of Bird Islands; most of the habitats are Type C. The motu is densely-forested with trees often reaching to the waterline. Access is possible in some places from the lagoon and across rock on the reefward side. There are some small sandy areas that might support nesting; but no evidence was found at this time.

The final tally for nests around Palmerston Atoll was:

185 confirmed nests
55 possible nests
32 attempts
6 U-turns

Upper four photos show typical nesting habitats, eggshells at surface and an older track. Bottom two photos are of the final nest laid under low bushes on 20th April 2012

Top photos show unsuitable habitats with difficult access from the sea; Centre photo is Dicky Boys (North); Bottom: Kitsap Bank (15 nests in 2012): teaching an excavation

B) Nest excavations and hatching success rates:

Ninety-nine hatched nests were excavated and their contents inventoried to determine the success rates. Usually there is a visible depression in the sand or *kirikiri* where the hatchlings emerged from the egg-chamber; some of our local researchers became adept at locating nests, including those that were hidden under thick vegetation. The excavation procedure was to dig carefully down through the sand column (live hatchlings might still be in the sand above the nest) until the first eggshell was located. The measurement from the beach surface to the topmost egg was noted as 'distance to top of egg-chamber'. All eggshells and unhatched eggs were carefully removed and then the distance to the bottom of the egg-chamber was also measured. The distance between the top and bottom was the egg-chamber diameter.

Egg-chamber: Mean depth from the beach surface to the top of the egg-chamber was 41 cm (SD = 9.6 cm; range = 8-58 cm; n = 99 nests). Mean depth from the beach surface to the bottom of the egg-chamber was 55 cm (SD = 9.9 cm; range 25-86 cm; n = 98 nests*****). Mean egg-chamber diameter was 15 cm (SD = 5.5 cm; range 5-35 cm; n = 98 nests*****).
*****The depth-measurement to the bottom of one nest was forgotten.

Nest contents: Mean number of eggs laid per clutch was 90 (SD = 25.8 eggs; range 13- 183 eggs; n = 99 nests). Mean number of hatched eggs per clutch was 86 (SD = 26.3 eggs; range = 13-175 eggs; n = 99 nests).

The empty eggshells were counted: this shows the number of full-term embryos that had cut their way out of the shells. A total of **8895 eggs** were examined and only 429 failed to hatch (4.8%): i.e. **overall egg success was over 95%** (n = 99 nests).

Unhatched eggs (n = 429): were then opened and their contents examined to determine the cause of non-development or failure. The most common reason for non-development was that those eggs had not been fertilised (61%, n = 262 eggs). A further 71 eggs had some level of embryonic-development (eyespot = 6; early embryo = 12; mid-stage embryo = 15; late-stage embryo = 38). Another 92 embryos had died during the 'pipping' stage: i.e. as they cut their way out of the shell. In fact this was rare and pipped embryos were only found in 9 nests (6 nests had 1 pipped, 1 nest had 3 pipped, 1 nest had 4 pipped, and the final nest had 79 pipped). Three nests included a small-sized egg (about 1 cm diameter); these are not known to develop; there was also one double-egg.

Mean number of unhatched eggs per nest was 4 (SD = 9.6 eggs; range 0-94 eggs). Only one nest [TWH3] on the west side of Toms was broadly unsuccessful (79 dead pipped, 8 dead late-stage embryos, 1 dead middle-stage embryo, and 6 unfertilised eggs), however, there were still 19 successful eggs in this clutch (total eggs = 113; 17% hatching success).

In terms of overall hatching success: 14 clutches were 100% successful (i.e. all eggs had hatched). Mean hatching success was **95.2%** (SD = 8.9%; range 17-100%; n = 99 nests).

Seven live green turtle *Chelonia mydas* hatchlings were found in the sand column near to the surface during excavations (n = 3 nests); these animals were placed on the beach and then made their own way into the ocean.

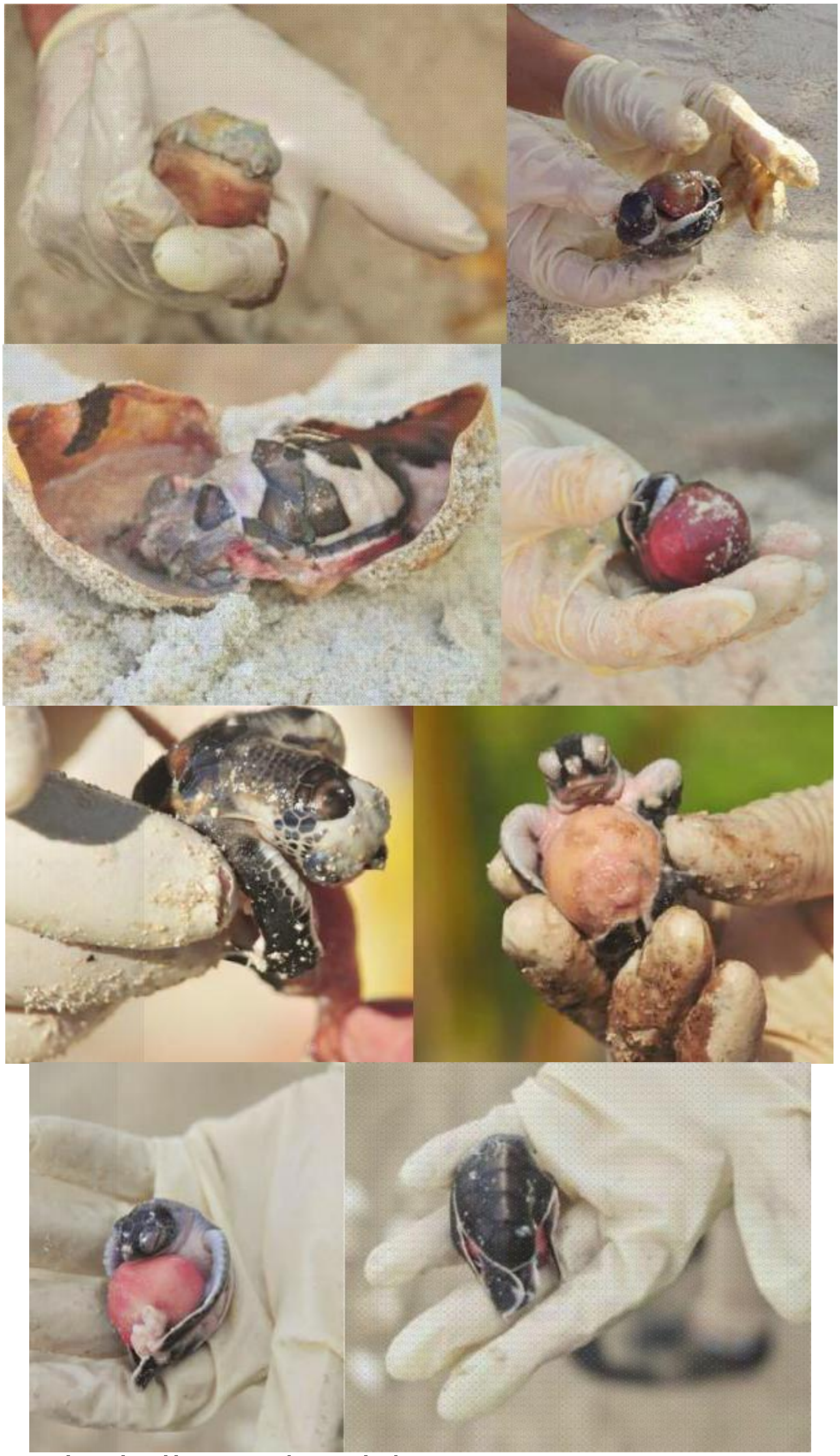
During excavations it was noticed that the colour of empty egg-shells varied. The bright white ones were assumed to be from the current nesting season (2011-2012); yellow tinged ones from perhaps two years ago; and the desiccated brown ones being from some even earlier period. This finding supports those from an ongoing study of decomposition rates at Tongareva Atoll (White *unpublished data* 2012).

Excavating the hatched nests in order to determine the egg success rates

Nests were laid in a variety of sites, many were under vegetation. Depth to top and bottom of the clutch was measured: distance between the two gives the egg-chamber diameter

Counting and examining the eggs. Empty shells indicate successful hatching; Top two photos show unsuccessful eggs; Bottom right shows a still-developing egg: this nest was reburied and hatched later

Carefully opening unhatched and unsuccessful eggs: some are unfertilised, others solidified, and some others had failed during embryonic development



Early, mid- and late-stage embryonic deaths

A total of seven live green turtle hatchlings were found in three nests during our excavations; these clutches would have been laid in early-February 2012

Marine Surveys

Snorkelling-surveys were conducted on 16 days: all research took place within the lagoon other than one on the leeward reef. Sea turtles swimming or resting underwater were observed in 13 surveys; occasional turtle sightings were made from the boat.

Sea areas

The optimum approach would have been to divide the entire lagoon into sectors, perhaps based on isobaths or habitat types (White 2007), and then compare the findings from each sector. The limited time available for in-water work during the present expedition meant that this was not done. Instead, each survey site was based on GPS waypoints.

Underwater habitats

The lagoon floor consists mainly of bare sand flats and sections of *kirikiri*; maximum depth is 30-m. B*ommies* (coral heads) occur throughout the lagoon. **Table bommies** are isolated flat-topped corals, rectangular in cross-section, that usually extend to just below the sea surface; in some cases the uppermost parts were exposed at low water. **Pinnacles** are isolated triangular-shaped coralline features that usually did not break the sea surface. There were also patch reefs, especially in the shallow water north of the village near to the boat passage through the leeward reef.

Underwater visibility

Underwater visibility varied from good to poor. Much of the lagoon floor is sand and this was often re-suspended as water currents moved through; the prevailing wind was usually southeasterly, but did shift to easterly, northeasterly, or north-northeasterly. The shape and orientation of the windward reef meant that lagoon areas adjacent to the more-open sections of reef, noticeably in the eastern sectors, tended to have poor visibility: two examples are between Toms and Primrose, and north of Bird Islands; because the water flow from the ocean was greater here. The southwestern area of the lagoon usually, but not always, had better sub-surface visibility. It was rarely possible to see the lagoon floor in the deep areas. Extensive cloud cover had a noticeable effect; limiting light availability underwater.

Habitat purpose

The marine environment was considered in terms of its suitability to support sea turtles. This was a combination of the type of habitat available and the turtle life-stages that were observed (i.e. adults, adolescents, juveniles or hatchlings). For instance, the presence of adult males and females means that mating might occur; whereas juveniles or adolescents suggest a developmental habitat. Foraging depends upon food availability.

Sea turtle foraging resources

Green turtles are herbivorous as adults (see Marquez 1990 and Hirth 1997 for commonly eaten plants); hawksbill turtles are spongivores (Meylan 1988) that exploit the reef environment.

The most important reason for considering marine vegetation in the present study was to see if any turtles were foraging on it; this was actually observed on two occasions.

Vegetation cover on the bommies and pinnacles varied, some supported a rich diversity (i.e. probably a good foraging resource), particularly in the southwestern areas of the atoll; whereas the easterly half of the lagoon tended to have mostly-bare coralline rocks; but underwater visibility was also poorer. Pinnacles were poorly-covered with vegetation. The sandy lagoon floor also was virtually devoid of vegetation; occasionally some algal growth had extended a short distance from the large corals nearby; but most photographs showed just a sand or rubble substratum. There were several instances of an unidentified algal ‘bloom’: this manifested as a brown discolouration across the lagoon floor, but it could also be suspended in the water column which further reduced visibility. Differences in the level of plant cover were observed, with the western sides of bommies tending to be more abundant than the windward faces; perhaps sunlight influenced this too.

No direct assessment of vegetation was carried out. We did field-test a simple measure of richness (i.e. absent, poor, good or abundant), but this was subjective, varied between surveyors, and was unsupported by quadrat-sampling. As mentioned above the intended pre-deployment team-training programme did not take place; a future study will include a marine botanist, and also have simulated plant-cover assessments as part of its training.

In-water surveys

The author’s original research plan was to waypoint the cardinal directions for each bommy, allocate them a serial number, and then note which ones were most used by turtles; using turtle behaviour to determine the habitat purpose (e.g. a resting or foraging spot). Time and logistical resources limited this. We had a maximum of 19 days for inwater work (swimming is not permitted on Sundays or religious holidays[47]; and we were not allowed to scuba-dive). Consequently, this expedition would not be a comprehensive underwater survey; instead the main research effort was focused on the higher priority of assessing nesting habitats and abundance.

The normal working routine was to conduct terrestrial surveys in the mornings, have a picnic lunch on a motu or in the boat, and then do snorkelling-surveys in the afternoons. A further limitation on boat use was the angle of sunlight: in the early-mornings and late afternoons it was difficult to avoid the bommies when looking sunwards; we usually tried to return to our base by about 1400-1500 in order to minimise this problem.

[47] Our expedition coincided with Easter.

We tried three different in-water methods of surveying: i) dropping pairs of swimmers in from the boat (using GPS to fix each start point) and snorkelling 500-800 metres towards a motu; ii) running a transect right across the lagoon from east to west (latitude line) and briefly investigating each bommy that was within 100 metres of our transect; iii) free swimming surveys in the areas where turtles were seen more regularly. Each method had pros and cons.

Individual starting points (i) had some merit in that, theoretically at least, transects should have been comparable in the distance swum (we also discussed timed-surveys e.g. 45-60 minutes). In practice we found that the different teams tended to converge as they neared the motu, and that bommies could be investigated by more than one team. A second issue was that a number of our surveyors were quite apprehensive about the presence of sharks. All team-members were good swimmers, but some became quite concerned when these naturally-curious apex predators were close by; especially when visibility was poor. The boat-crew had to maintain visual contact with three pairs of swimmers; often with several bommies between them and the surveyors. We tested this twice: once to Dicky Boys and once to Toms.

The lagoon-wide transect line (ii) was the least successful: it was very time-consuming. At each bommy enroute we stopped the motor, put in one or more teams depending on how close adjacent coral heads were, and then waited to recover the swimmers. In many places visibility was poor, especially in the eastern sectors and also in deeper water. Once the swimmers were back onboard the coxswain had to relocate the transect-line. We used two GPS units: one to plot the survey track, the other to waypoint each bommy. We tried this once: from south of Primrose Motu to Manunui Rock (south of Palmerston Island).

The third method was the most successful, and also closest to the original plan. We worked mainly in the southwestern and western areas of the lagoon. Although this biased our results – i.e. most sightings were from where we conducted the most surveys – the fact remains that we did observe different turtle species and life-stages; and also their behaviour. This meant that some conclusions could be reached about the purpose of underwater habitats. Turtle encounters were always chance events, but two green turtles were observed foraging on the sides of table bommies (filamentous algae). Green turtles were discovered resting on bommies: the first was on top of a large bommy; a second turtle was laying on an exposed sloping face, but the third one was hidden inside a small grotto; its head tucked under a protective crevice. White (2007) had reported that resting turtles usually protected their heads by facing a wall or using overhanging rock, their flippers were tucked beneath their bodies, which only left the carapace exposed to attack. Two turtles, a green and a hawksbill, were encountered whilst resting on the sandy floor of the lagoon; these animals maintained vigilance and could swim away if researchers approached too closely.

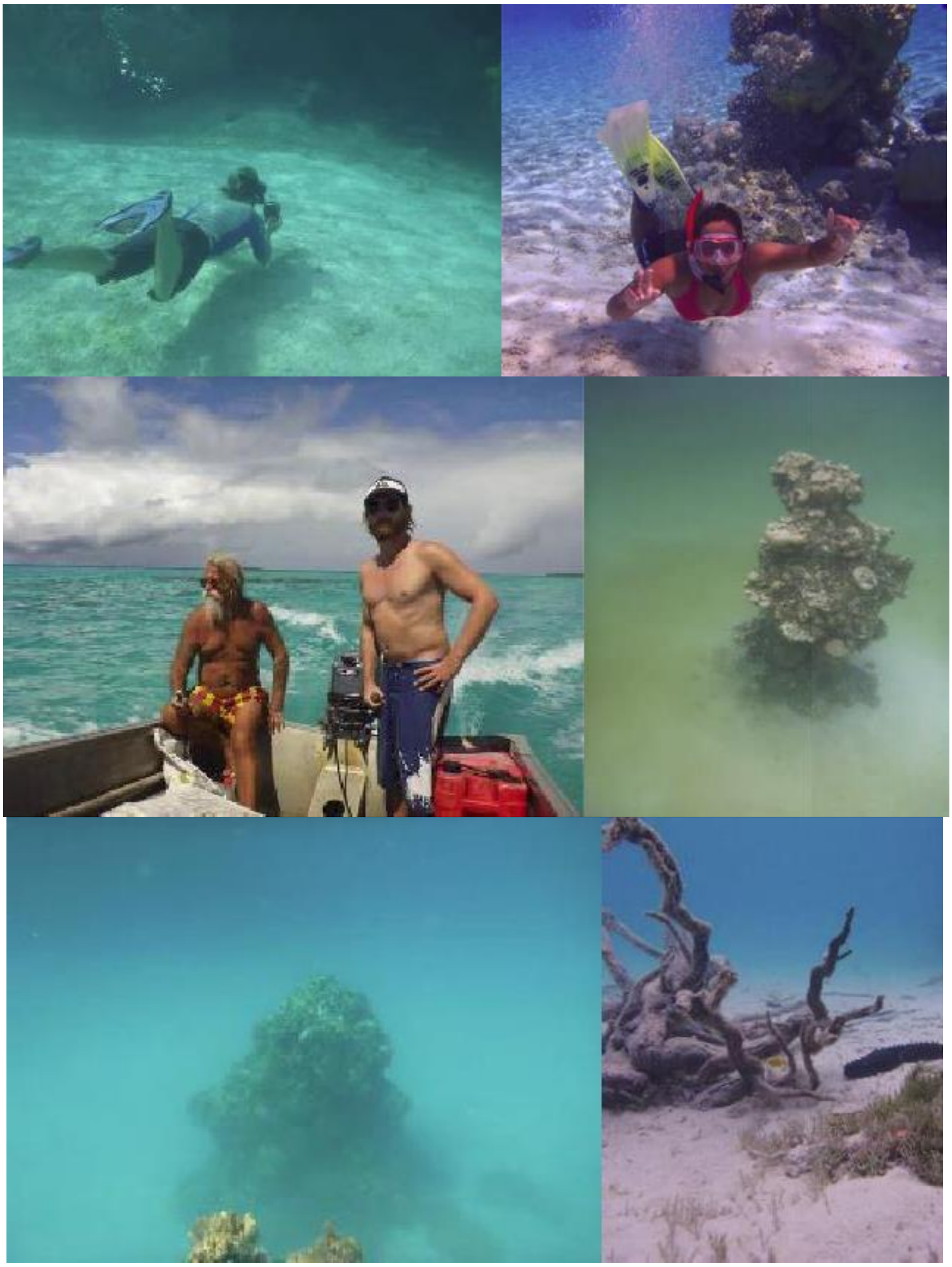
Five adult male green turtles were observed and also five adult-sized females. There was one sub-adult male and two medium-sized turtles that may be sub-adult females; and also three smaller juveniles. Most other marine sightings (n = 14) were spot encounters as a turtle raised its head above the surface to breathe; these locations were marked with a GPS waypoint when possible.

The purpose of marine habitats can be inferred as: foraging, refuge, and developmental. The presence of adult males and females suggests that mating could also occur; and additionally there is nesting onshore, which indicates a reproductive habitat. Although the total number of in-water sightings was small (n = 42), it seems likely that if subsequent surveys were to be undertaken during a nesting period then a greater number of larger animals would be present (females for egg-laying and males for opportunistic sex). Such a survey would also show if the lagoon was being used as an inter-nesting habitat: i.e. the area that females utilise between laying each successive nest (the inter-nesting interval is about 14 days); it is also possible that inter-nesting turtles use the ocean instead.

Three small juvenile hawksbill turtles *Eretmochelys imbricata* (critically-endangered) were observed. The first was seen resting on the sandy lagoon floor just east of Cook's Islet (21st April). It remained at rest for about five minutes – watching us carefully – before swimming off towards a pinnacle and then heading north (Dr Michael White & David Marsters *pers. obs.*). The other two were resting on the leeward reef, just northwest of Palmerston Island (26th April). This was our final in-water survey and also the first one on the outer reef. One hawksbill was resting in a long, narrow gully that led to the reef drop-off; we managed to obtain several photographs before it swam off. The second hawksbill was foraging near to the drop-off, but it also rested occasionally on top of the coral. The habitat was mostly composed of small flat-topped corals and rubble, but visibility in many places was poor; cloud cover also limited available light. These *E.imbricata* were definitely different individuals; one had flaking patches on both anterior costal scutes, whereas the other did not. These two final sightings suggest that we may have been looking in the wrong place for hawksbills. A future study by the author will include a more-comprehensive survey of the outer reefs using scuba-equipment (White *pers. com.* 2012).

The present study could not confirm any instances of site-fidelity: i.e. when a turtle is seen regularly in the same place. Although we did photograph several turtles underwater, these seemed to be different individuals. One small juvenile *C. mydas* would have been easily-identifiable, because its front right flipper was missing, but this turtle was not seen again.

The lagoon is very shallow in places; negotiating the coral bommies takes some skill



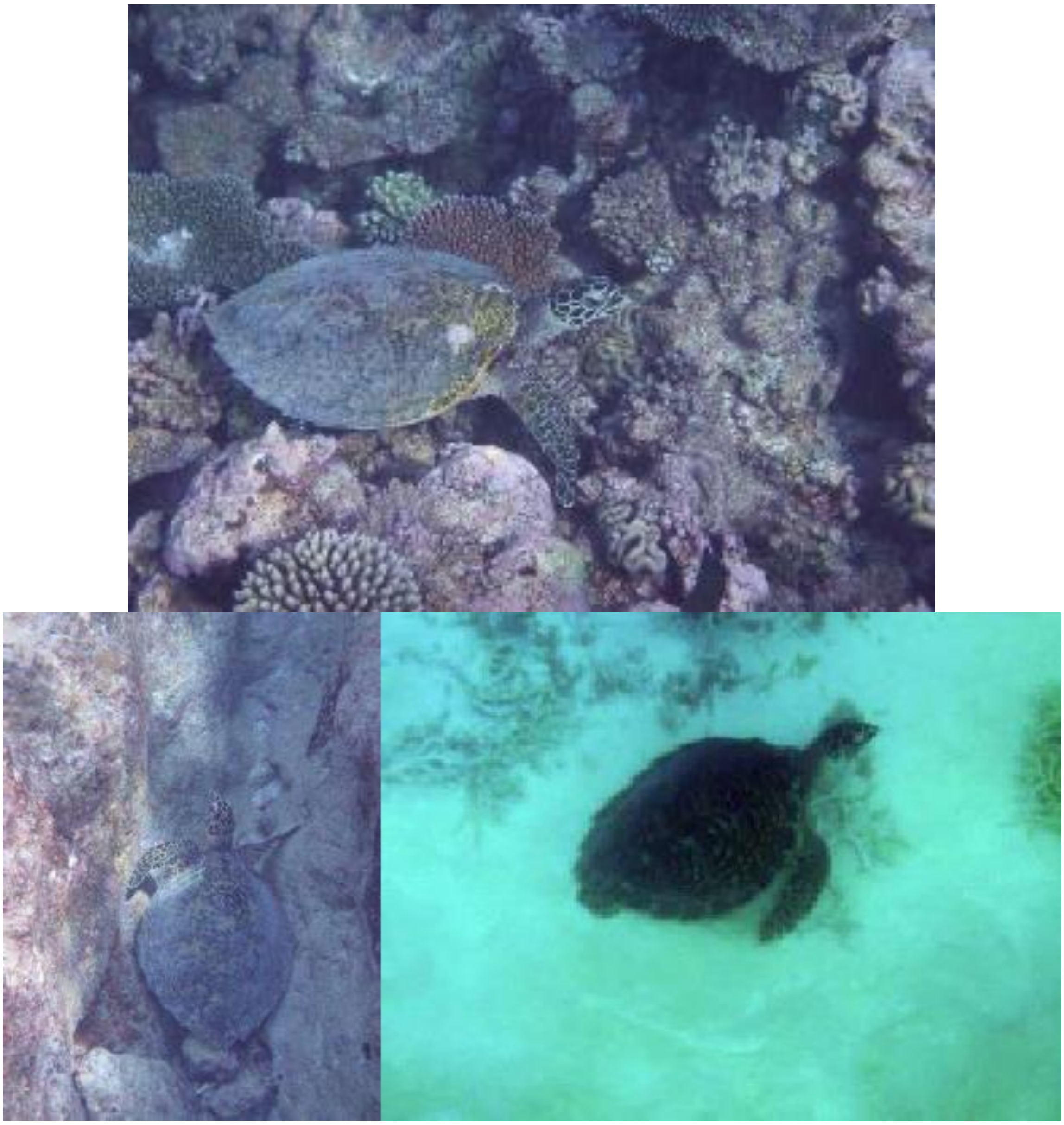
Visibility underwater varied: cloud cover had a noticeable effect; Centre right shows an algal ‘bloom’ near to an isolated pinnacle; much of the lagoon floor is bare sand.

Glare from the sun was a problem at times; corals could extend to the surface; it was difficult to see the lagoon floor in deeper water. Identifying turtles underwater was not always easy: Bottom left is probably a green, Bottom right is definitely a hawksbill

Surveying table bommies

Some bommies had a variety of algal species; these are utilised by foraging green turtles

Green turtles *Chelonia mydas* underwater. Top right is an adult male ~ easily identifiable by the long tail. Behavioural categories shown here are: swimming underwater (Su) and resting underwater (Ru)



The critically-endangered and very rare hawksbill turtle *Eretmochelys imbricata*. These were the only three encountered: all are small juveniles. A recognisable feature from the top photo is the flaking areas near the front of the carapace

Summary of marine surveys

There were 42 turtles encountered in the marine environment:

Green turtles = 31
Hawksbill turtles = 3
Unidentified species = 8*****

*****All unidentified sightings were definitely turtles, but they were either too far away, swam off too quickly, or the underwater visibility was too poor for the species to be confirmed.

Size-classes:

Small = 6
Medium = 8
Large = 11
Not known = 17*****

*****Size-classes could not be confirmed for 17 animals: this usually occurred when a turtle surfaced briefly to breathe and only the head was observed for a split-second.

Life-stages observed were:

Green turtles: juvenile (3), adolescent male (1), adolescent female (2), adult male (5), adult female (5)

Hawksbill turtles: juvenile (3)

Classifications were based on tail morphology and size-classes. Adult males are easily identifiable by their prominent tail; adolescent males show signs of caudal development. Large short-tailed turtles are assumed to be adult females; medium-sized ones adolescent females. The smaller sizes could be juveniles of either sex. We did not classify 23 turtles.

Recognisable animals:

A juvenile green turtle had lost the front right flipper [id # PLM 020; seen near to Table Bommy, south of Home Island].

Locations with turtle sightings:

Most underwater encounters with turtles were in the lagoonal areas adjacent to Cooks, Dicky Boys and Toms motus; and near to the large table bommies in the southwestern sector. As noted above, this was the sea area where most surveys were conducted.
Incidental sightings of turtles breathing could occur anywhere enroute.

Marine behaviour

Turtles observed in the marine environment usually exhibited more than one type of behaviour, e.g. resting then swimming, or vice versa. Respiration (Rs) usually consisted of a single breath, typically lasting for 0.5 s (White 2007). Obviously a turtle had to swim underwater in order to reach the surface. Behavioural summaries are shown below:

Su: Most observations were of turtles swimming underwater (n = 29 records). These events included transiting animals that swam past surveyors, as well as resting animals that then swam away rapidly.

Ru: There were seven instances of turtles resting underwater.

Cu: One juvenile hawksbill crawled across the lagoon floor before swimming away.

Fu: Foraging turtles were observed twice on table bommies.

Eu: One green turtle was observed eating algae (unidentified filamentous *sp.*).

CL: There were no observations of cleaning behaviour.

Rs: Respiration was observed on 14 occasions. Most commonly the turtles took a single breath (n = 11 observations). Mean number of breaths per breathing event = 1.3 (SD = 0.6; minimum = 1 breath; maximum = 3 breaths; n = 14 observations). Twice turtles were seen to take two breaths interspersed by a short period of surface swimming (Ss); another turtle took three breaths, remaining near to the surface between each of them.

***

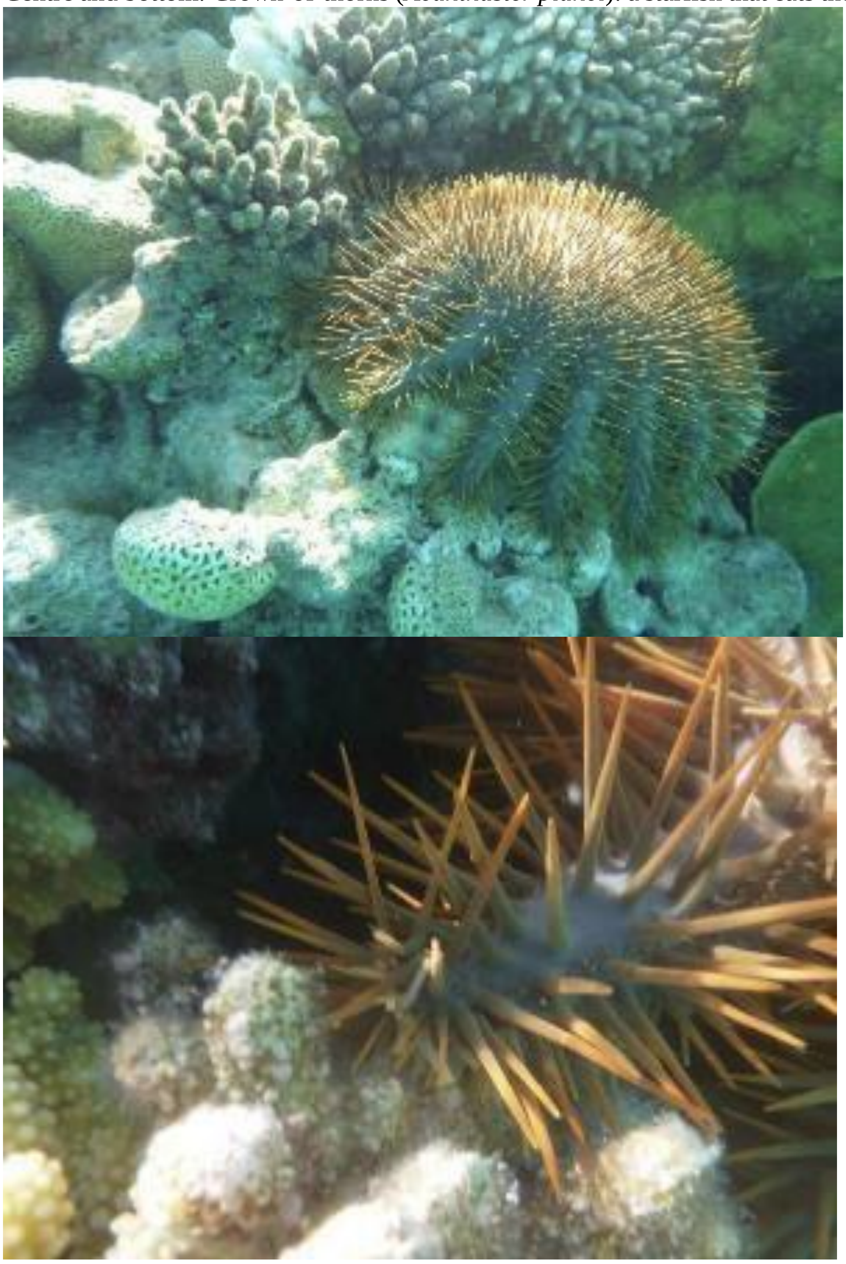
Two notes from the underwater surveys

i) Sharks are widespread around the atoll. Grey reef sharks (*Carcharhinus amblyrhyncos*) are probably the most common; they were encountered in most areas of the lagoon and their behaviour varied: the least aggressive are near to the village; these regularly eat fish guts that are discarded during filleting. In the southeastern corner of the lagoon the grey reef sharks tended to follow the swimmers; perhaps this was territorial behaviour. One tried to bite the boat propeller. White-tip reef sharks (*Triaenodon obesus*) were frequent in the northern section of the lagoon; they were also encountered on the western reef.
Their behaviour was non-aggressive and seemed to indicate greater curiosity.

ii) The Crown-of-thorns starfish (*Acanthaster planci*) was seen on five occasions in the lagoon. All sightings were of large solitary specimens (White *pers. obs.*); these animals are known predators of corals.

Top left: Grey reef shark (*Carcharhinus amblyrhyncos*); **Top right:** Whitetip reef shark (*Triaenodon obesus*)

Centre and bottom: Crown-of-thorns (*Acanthaster planci*): a starfish that eats the corals



Social and Educational Aspects of the Rufford Expedition

Palmerston Lucky School ~ this uses a homeschooling teaching system provided by a USA Fundamentalist Christian organisation: ACE (Accelerated Christian Education) that is based on individual study modules. Each student has a series of booklets to complete at their own pace; thus it was not possible, nor practical to introduce environmental material into the science curriculum as had been intended. A second limitation was that the Easter vacation coincided with the Rufford Expedition and so the students were not attending school. Nonetheless, Principal Yvonne Marsters arranged for us to have a half-day before Term II began. This proved highly successful.

The author gave a one-hour general presentation to the whole school (age range: 5-19) on sea turtle biology, ecology, and threats and impacts. We had two dead (preserved) turtles, which we used to show the differences between green and hawksbill turtles; and we had also prepared a photographic slide-show that was shown on a television monitor.

After a short break the students were allocated into three groups: the juniors made posters (based on sketches by Jason Green; aided by Kelly); the middle-school considered threats and impacts - discussion and making posters (Jess and Tina); whilst the seniors witnessed excavations of four nests that we had previously identified on a nearby beach.

Social integration

Throughout the expedition we encouraged community members to visit our field-base. After an initial period of shyness we received many visitors; these occasions proved to be an important aspect of awareness-raising. We also solved many of the community's longstanding problems, such as virus infections on personal computers.

We helped renovate the school: working with community members we replaced the *kikau* thatching (coconut leaves) along one side of the verandah, and also laid a large section of concrete. After work we had a *kaikai* (feast) to celebrate this endeavour.

Presentation of our research findings

At the end of the expedition we prepared a *kaikai* and invited the Palmerston community to a presentation of our research. The author led this event assisted by Phil Bradshaw and, very importantly, Goldeen Nikau and David Marsters. These two teenaged islanders did very well: presenting data on nesting excavations and clutch success rates. This was their first public presentation; the author considers it an important capacity-building measure: that the local community witnessed its own younger generation providing well-informed scientific evidence for the atoll's natural resources and endangered species – this will initiate a community-led project in the near future (White *pers. com.* 2012).

Various photographs from our 'Teaching Day' at Palmerston Lucky School.

Various aspects of Renovation Day at Palmerston Lucky School

Synthesis

The Rufford Trust expedition to Palmerston Atoll proved to be very successful, with most major objectives being achieved. The start of the egg-laying period was not confirmed and adult turtles were not encountered on the beaches; so tagging and genetic-sampling activities were not undertaken at this time.

The expedition members had not worked together previously and, in fact, did not actually assemble until the date of departure from Rarotonga. This meant that initial team-training had to be postponed until our arrival at Palmerston; and it became an important aspect at the start of fieldwork. Individual backgrounds and skills were diverse, but after about ten days a competent research team had been developed; this included five young Palmerston Islanders. Necessary research skills were introduced and developed through theoretical and practical training (four of us had some level of previous experience with sea turtles).

1. Suitability of habitats to support nesting

The first step was to survey all of the atoll's motu to ascertain their suitability as nesting sites. A variety of habitats exist on every motu with some areas being suitable for egglaying and other areas not. The best nesting sites had sandy beaches that were accessible from either the lagoon or over the reef. The less-suitable sections usually had a difficult approach e.g. hard or jagged rock, rocky spits, or were very shallow. The substratum was probably less important and nests were found occasionally in *kirikiri* (coral rubble); this concurred with the author's findings from elsewhere in the Cook Islands. In places the vegetation adjoined the waterline, so there was no useable beach; and on the southern side of Toms and Primrose the coastline consisted of small boulders that formed steep banks; these would be difficult for turtles to negotiate. The eastern approaches from the windward reef to Bird Islands were very rocky and would be hard for a turtle to cross. A second factor that could deter nesting was where the lowest vegetation formed a dense barrier preventing entry into the forest, even if there was suitable access from the sea onto a beach.

One of the research team (Jason Green) produced nesting suitability maps for each motu. These were based on digitised land survey maps[48] (LINZ 272/8/7 Palmerston 1986): the sectoral categories were highlighted using Adobe Illustrator (www.adobe.com). Because coastal environments are naturally dynamic it is possible that habitat suitability does shift occasionally; for instance, a known nesting site can be stripped of sand by large waves, whilst previously-unsuitable sites may have sufficient sand deposited on them to support nesting. The details presented here show the suitability of sites around the atoll to support nesting at the time of the expedition.

[48]Sourced from Land Information New Zealand data. Crown Copyright Reserved.

2. Nesting distribution

The second research task was to examine all motu for signs of nesting activity. Evidence included obvious signs of digging or disturbed sand (e.g. body-pits), adult tracks crossing the beaches ('crawls'), disturbed vegetation, turtle eggshells on the surface, or hatchling tracks. Signs of nesting were found on nine motu: there were 185 confirmed nests and a further 55 possible nests; it is likely that the latter actually were nests, but they may have been laid some years ago (see below). Assessments of habitat suitability and nesting abundance were made concurrently in order to minimise fuel use; we travelled to each motu by boat.

The author had indicated that the likely egg-laying period for turtles in the Cook Islands would be between September and April. Unfortunately the late-start of the expedition (constrained by the cyclone season) meant that nesting had probably finished by the time we deployed. Consequently we found few adult tracks on the beaches (they erode through weathering); the most recent one was on the northwestern part of Cook's Islet: the female probably nested in late-March. In contrast the places where eggs were actually deposited remained obvious for a long time; even those nests that were laid under bushes or beneath coconut or pandanus leaves.

The surveyors proceeded along the mid to upper beach and recorded any signs of digging activity, especially close to vegetation cover at the back of the beach. This contrasts with a more-common method used during the egg-laying period when surveyors walk along the water's edge to find and then follow adult tracks that emerge from the sea. In both cases the researchers assess whether a nest was actually laid.

The shape of excavations in the sand is different between a nest and an attempt (Schroeder & Murphy 1999). When the female lays a nest she tends to produce an area that is wider than her body as she moves around. During the beach-surface restoration phase (often called 'camouflaging') which follows oviposition, the female moves forwards throwing sand behind her. It is usually possible to determine the direction that a female entered and exited her nesting spot (the track patterns are uni-directional). An 'attempt' would be where the nesting procedure was abandoned at some point; perhaps the turtle encountered stones, rocks, or plant roots in the sand at the initial site. It is common for a turtle to then move a short distance and dig a new nest, otherwise she has to return to the ocean and re-emerge on another night; or else dumps the eggs at sea because her next clutch is starting to develop.

Most turtles nested successfully at their initially-selected site. Only 32 attempts were discovered; these had more than one body-pit or had been abandoned at an early stage.

U-turns were quite rare: only six adult-sized tracks showed that a turtle had emerged from the ocean and returned without making any attempt at digging. White (2007) noted that this can occur with neophyte nesters; but it is also possible that male turtles could emerge onto beaches to bask: adult males have been seen ashore locally at times (Simon Marsters *pers. com.* 2012).

The majority of nests were laid under vegetation at the back of the beach. In the sectors with low bushes the turtles had either crawled right inside the bushes to nest or excavated their body-pit at the margin between beach and vegetation cover. At forested locations some turtles had crawled into the forest and excavated their nests beneath fallen coconut or pandanus leaves. Nests laid mid-beach were very rare (n = 4); this concurred with the author's findings from atolls in the Northern Cook Islands.

Maps showing confirmed nesting sites were compiled (by Jason Green), using a similar approach to the habitat suitability maps mentioned above. It was unsurprising that most nests were laid in the more suitable locations (Type A or B sites). The main value of this approach, though, will be to understand if nesting habitats do shift over time: i.e. dynamic processes affect the coastal zone and then emerging turtles move from degraded to other, more suitable, nesting sites.

A second reason for shifts in nesting sites or densities is that the migratory nature of sea turtles means that different females may be present in different years, and that they each utilise a particular location[49]. For instance: Kitsap Bank was important in 2012; however, these smaller sites may not be used every year. It is possible that just one or two females utilise these minor banks and, depending on the migratory cycles of those individuals, it could be several years between nesting events on them. Perhaps Thistle and Julia Cobb Banks are used for nesting in other years; this will be clarified during regular surveys by our resident team in the future.

Unexpectedly, a nest was laid on Palmerston Island during the night of 20th April; this was only about 500 metres from our expedition base. Two of *Honu's* resident researchers monitored this nest, as well as one on northwestern Cook's Islet, and inventoried them once hatching was completed.

3. Nest success

Two important findings from Palmerston are that most emerging turtles nest successfully; and that most of the eggs (95%) actually hatch. The hatching success rate for eggs was determined by excavating nests and then inventorying their contents. Out of 8895 eggs counted only 429 eggs had failed; most of the undeveloped eggs (61 %) were unfertilised. The low incidence of people on most motu and a general lack of terrestrial predators are further positive attributes for Palmerston as a successful nesting rookery. Only one nest was broadly unsuccessful (West side of Toms) and this may have been affected by some environmental impact, perhaps being inundated by waves, because it contained 79 dead pipped embryos: i.e. these had developed fully, but then died; the nest was still partially successful (19 hatched eggs).

[49] Philopatry or 'natal homing' is when animals return to the place that they were born.

4. Nesting period

The overall egg-laying period remains unconfirmed. The live *Chelonia mydas* hatchlings found during nest excavations in April give an estimated date-of-lay in the first half of February 2012 (this is based on a 60-day incubation period); and already-hatched nests on Kitsap would have been laid in January. The latest nest was laid on Palmerston Island on the 20th April 2012; and prior to this the most-recent track, on Cooks Islet, was estimated to have been from the last days of March. As mentioned above, based on earlier anecdotal evidence (White *pers. com.*), the likely nesting period would occur between late-September and April: the present data support this, but the commencement date is not clear and could vary between years. The low number of adult tracks remaining on the beaches in April (2012) suggests that egg-laying is probably seasonal rather than year-round; perhaps with peak oviposition in January - the hatched nests on Kitsap would support this hypothesis. Future temporal data will be collected by Palmerston's resident research team under the author's guidance.

5. Age of nests

It is not known how long egg-shells take to completely disintegrate in the nests. The various shell colours noted during excavations suggested that the bright white ones were from the most recent clutches; this was because they were similar in colour to some still developing eggs (one nest contained eggs that were yet-to-hatch; these were reburied and the nest was monitored until it hatched in June). In several clutches the empty shells were tinged with yellow – this did not seem to be the same as a microbiological infection that kills an egg (even if the pathogenic organisms were the same), because these had already hatched – and so they are assumed to be from an earlier nesting period, perhaps two or three years ago. A few nests contained empty eggshells that were light-brown, fragmented, and desiccated – these were also the nests that had shallower egg-chambers and the fewest eggs – and so, presumably, these were the oldest clutches. A guess for their age would be perhaps five years old, but it could have been even longer as there had been no nesting surveys locally for 12 years (Hauser *pers. com.*). It is assumed that the beach structure would change over time through weathering, and so the decaying shells might have been moved from the original nesting depth, perhaps nearer to the surface; and that some of the *in-situ* eggshells may have already disintegrated. Experimental work is underway at Tongareva investigating the natural decomposition rates for egg-shells (White *pers. com.* 2012).

6. Importance of Palmerston Atoll as a nesting site

The Rufford Expedition can confirm that nesting by green turtles *C. mydas* is current and successful; however, the absence of trend data means that we have no knowledge of whether 2012 is a high, medium, or low nesting-density year. Also it is not known how many of the nests were actually laid in 2012. No evidence was found to suggest that loggerhead turtles *Caretta caretta* are present.

Nest excavation data, adult track-patterns, and the fact that no large hawksbills were seen during any terrestrial or marine surveys suggest that *Eretmochelys imbricata* may not have nested here in recent years. The presence of two small juvenile *E. imbricata* on the leeward reef, and a third in the southwestern lagoon means that, perhaps, this species may nest locally at some point in the future.

The author noted that many nests on atolls in the Northern Group had been laid under vegetation or within the forest at the back of the beach (White, *this report*). This is an important finding because the sex of marine turtle embryos is determined by the incubation temperature in the nest (e.g. Mrosovsky 1980, 1988; Georges *et al.* 1994). Faced with the prospect of rising global temperatures there is an increased possibility of turtle populations becoming skewed towards embryonic feminisation: this is already being reported (e.g. Godley *et al.* 2001; Kaska *et al.* 2006). Several of the nesting sites at Palmerston were also in shady places, which may thus increase the atoll's importance as a successful nesting site: i.e. it maintains the possibility of producing male hatchlings.

Harvesting turtle eggs for food seems to have gone out of fashion, despite being popular about 30 years ago (White *pers. com.*). Turtles are eaten occasionally, especially when no supply ship has visited for many months; nesting females are preferred.

7. Turtles in the marine environment

Two species of sea turtle were encountered: green and hawksbill. All life-stages of the green turtle were observed: hatchlings, juveniles, adolescents and adults. In contrast, only juvenile hawksbills were seen. The author had noted earlier that most hawksbill turtles on the reefs at Rarotonga, further to the south, were also juvenile. Local sea areas are used for foraging, development, as a refuge, possible mating; and nesting onshore.

8. Palmerston Community

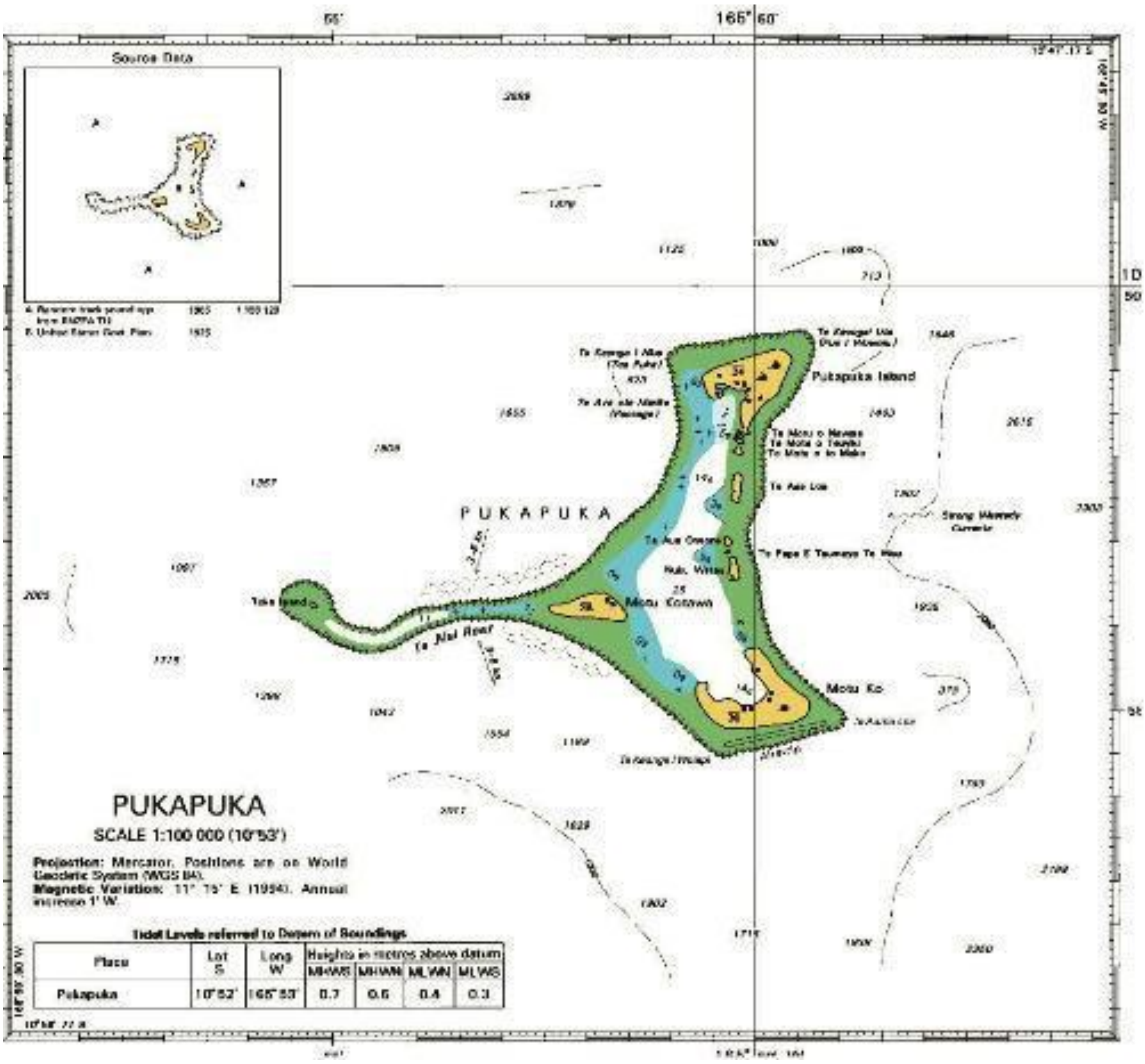
A particularly gratifying aspect of this expedition is that several teenagers worked closely with us. They are very keen to learn and have been excellent research assistants. Not only were they adept at locating nests, but they also taught other islanders during the mass excavation day on Cook's motu. These young Palmerston Islanders helped to present our research findings to the Community at our leaving feast in the final week. Three of them subsequently joined the author's research group *Honu Cook Islands*; this bodes extremely well for the future in the author's plans for establishing a network of local turtle monitors on each of the Outer Islands.

The Island Secretary (Tere Marsters) asked several important questions concerning what the community should, or could, be doing to protect, manage or conserve sea turtles and their habitats at Palmerston. These were answered by the author, with particular emphasis being placed on safeguarding adult females: these being the most important life-stage in terms of species survival, but also the most-commonly captured for food. The three most important nesting sites are the western side of Cook's Islet and Toms; and the eastern side of Primrose. Other recommendations are being discussed with the Island Council and will be reported to the Rufford Trust in due course.

And in conclusion: our deepest thanks to all of the Leaders and Community-members of Palmerston Atoll for allowing us to conduct this important research at your island home, and for your wonderful heartfelt friendliness and generosity. It has been a real pleasure living, working and sharing with you all. *Meitaki Poria e Kia Manuia,* Michael.

Pukapuka Atoll [10° 52 South; 165° 50 West]

Pukapuka Atoll has three main motu (*Wale, Ko, and Kotawa*) and several small ones (e.g. *Toka*). Everyone lives on *Wale* in three villages: *Yato, Roto* and *Ngake*. This atoll is somewhat different from the other Northern Group islands: its language appears to have a different origin, perhaps Samoan; and it usually has a larger population than the other atolls. Environmental awareness is strong, but controlled by *rahui*: *Motu Ko* and *Kotawa* are usually closed for harvesting, and when the *rahui* is lifted all three villages collect various natural resources; harvesting by individuals is prohibited. Sea turtles are apparently protected; with a $50 fine per person being levied for eating them (White *pers. com.*). Seabirds are a delicacy and usually protected by *rahui*.[50] A detailed assessment of threats and impacts has not been made.



Pukapuka Atoll (chart from NZ945)

[50]The seven Pukapukan students who participated in the Lifeskills programme on Manihiki (September 2011) probably ate 450 seabirds during the two weeks at *Tukao* and *Tauhunu*; there was no *rahui* in place for birds at Manihiki (White *pers. obs.* 2011).

Nesting was not assessed and all information was anecdotal. There are numerous beaches that are suitable for turtle nesting: with good access from the reefs and lagoon; substrata vary considerably. The inner lagoon between *Yato* and *Roto* villages appears eutrophic (White *pers. obs.* 2010). A nesting survey at Pukapuka is planned for 2015; travel there is possible on commercial freight vessels although transportation is infrequent. The usual mix of activities (turtle science and conservation at school; capacity-building; and *rahui*) will be included. Many of the children accompanied the author on his walking surveys and are interested in learning more about *'wonu'*.

Top: green turtles nest on this beach, but not the lower beach: presumably because of access from the lagoon, beach-slope and substrata composition

Pukapuka has a lot of sandy areas both on the reef-wards beaches and in the lagoons


Left: nesting was not found **Right:** test hole on a nesting beach

Rakahanga Atoll [10° 01 South; 161° 05 West]

"Akono te fonu ete Reo"

Each year a fortnight-long festival ***Te Maeva Nui*** is held on Rarotonga to celebrate the Cook Islands' Independence (1965). People from all of the Outer Islands, and expatriate Cook Islanders, especially from New Zealand and Australia, gather at *Avarua* to show off their homeland and culture. The 2012 theme was: ***"Our Language and our Homeland".***

Something remarkable happened at Rakahanga Atoll: the School Principal (Tuhe Piho) decided that his school would have a sea turtle *(fonu)* as the symbol for its float in the festival procession; and this also became the emblem for the whole island during 2012:

"Akono te fonu ete Reo" **[Save the turtle and our language].**

Their idea was to use the endangered status of turtles to highlight the threats to losing the Rakahangan language and traditional culture.
The author and his post-graduate researcher (Gemma Galbraith)[51] arrived on Rakahanga in early July (2012) to conduct a 2-month turtle survey. We were asked if we could make a sea turtle for their school float? We did! The first one was about 2-metres long and manufactured from wire-mesh and papier-mâché, with much help and glue from all the students. We were then asked if we could make a giant turtle – big enough to go on top of an articulated-lorry. This one was huge ~ its head was 2-metres long ~ and the Island's choir would sit beneath it as they sang their traditional songs during the parade.

These models were anatomically-correct, working within the limitations of our materials, and during construction we taught the islanders a lot about these endangered species and the threats that they face in our modern world. The *fonu* were shown to the Community – during their final chanting-practice before the *'Tere Party'* voyaged to Rarotonga; they were very pleased with our efforts. The giant turtle would be assembled at Avarua.

Rakahanga's population is only 89 people, and 50 departed for *Te Maeva Nui*, so during the research phase over the next five weeks we had the atoll largely to ourselves. We also became an integral part of the remaining community, which provided many opportunities for the two-way exchange of knowledge and experience. Usually it takes some time to become accepted into these isolated and close-knit communities, but by constructing the model turtles we had achieved this very early on. We could not implement our teaching programme at the school until the voyagers returned in late-August.

[51]University of York; MSc in Marine Environmental Management.

'Fonu' construction: Nari and Kau hard at work with the glue

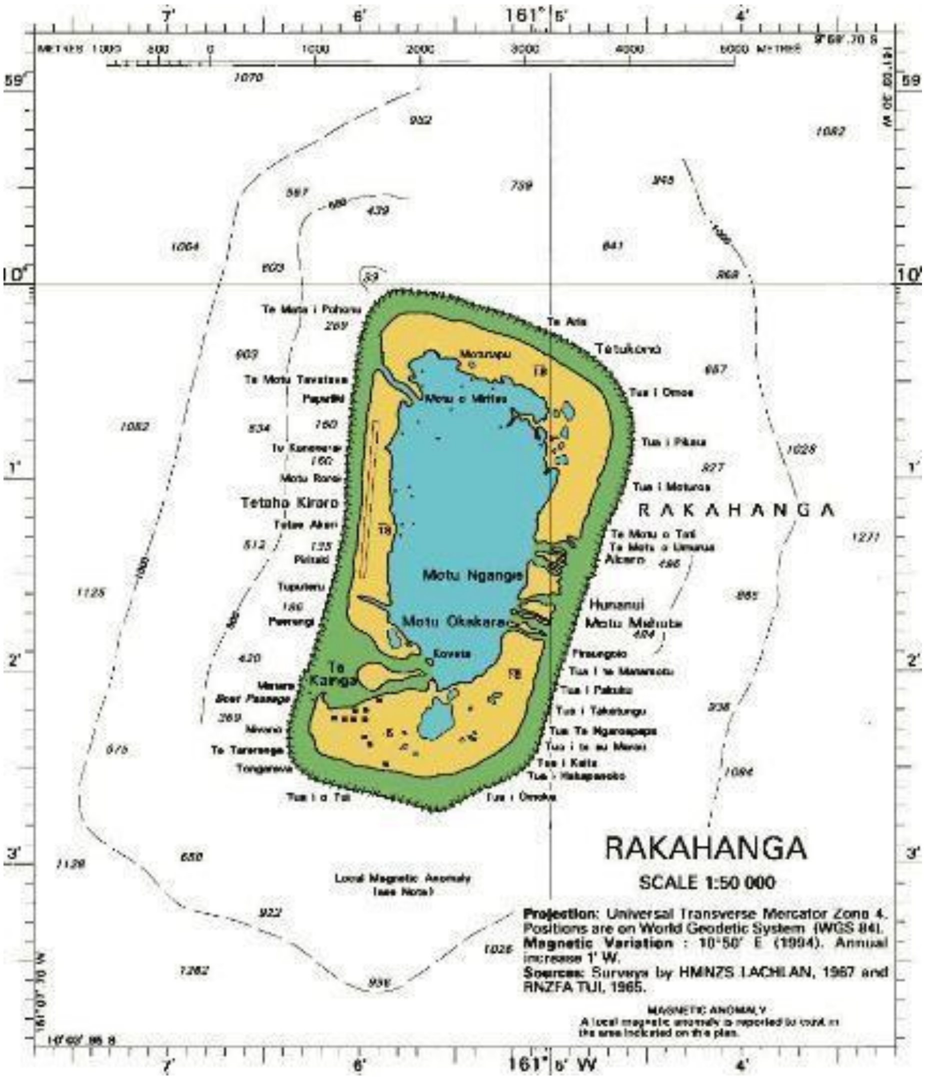
Gemma Galbraith and some of *'Team Fonu'* at Rakahanga School

Tuhe Piho looking at the author's idea for the giant *'fonu'*; Below: laying out the carapace scutes ~ a real green turtle carapace can be seen by V2 scute

Head shape and front flippers under construction: these were big!

Top: Giant *'fonu'* is given to the Community; **Below:** at the wharf waiting for the ship to come

The Rakahanga research was partially funded by the British Chelonia Group and the Ministry of Marine Resources, Rarotonga. With our deepest thanks.



Rakahanga Atoll (chart from NZ945)

Background story

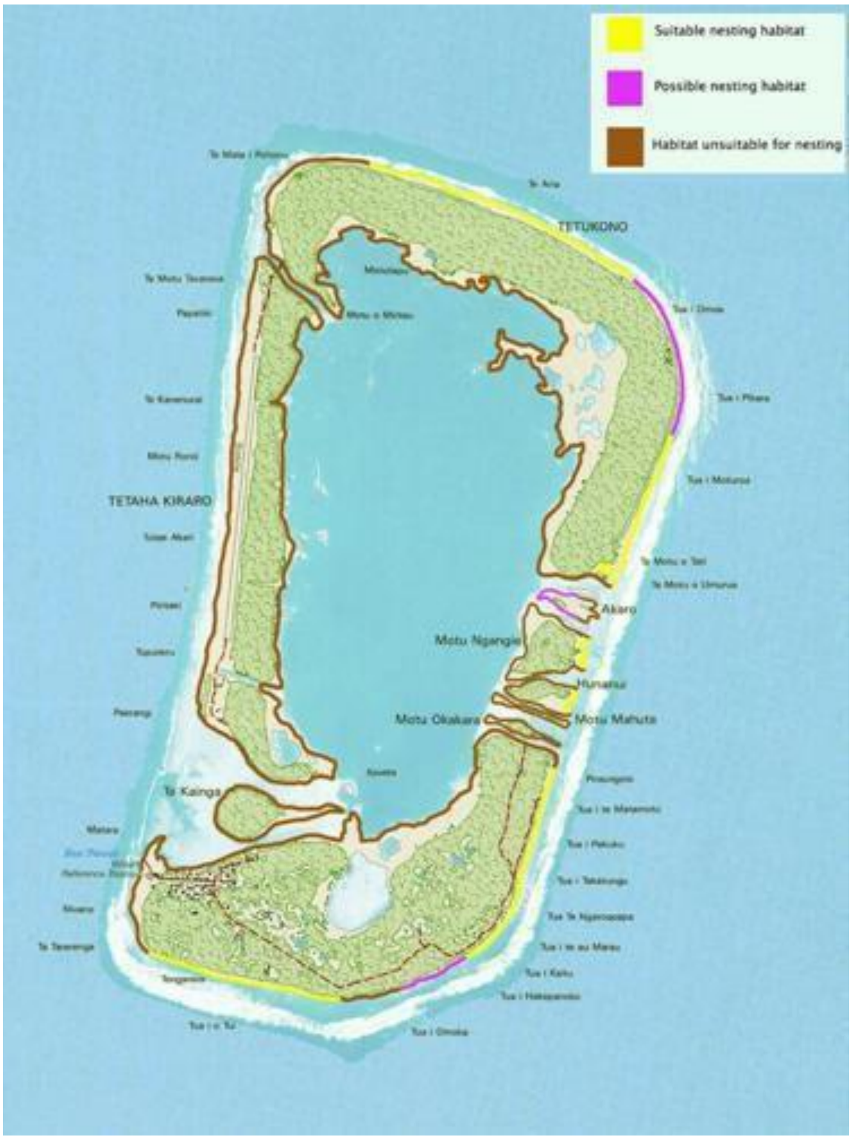
Sea turtle nesting has been known historically from Rakahanga Atoll (Balazs 1995), but the island has not been surveyed for about forty years. Balazs (1995) also mentioned that the northwestern part of the atoll was known as *Ti Mata i Pahonu*; which probably refers to sea turtles.

In December 2010, during a brief stopover to unload cargo from S/V Kwai, the author gathered anecdotal evidence that confirmed sea turtles *'fonu'* were present on the reefs and inside the central lagoon (White *pers. com.* 2010). Then, as a direct consequence of the author teaching two modules on sea turtles at the Lifeskills Expo in Manihiki (early- September 2011) Rakahanga's Principal was very keen for his school to become involved in turtle work (Tuhe Piho *pers. com*). This wish was granted when a green turtle laid a nest right on the school beach (27th September 2011); and he asked the author for advice about protecting it. Over the next six weeks there were three more nests and one attempt on the same beach (these are discussed below).

Rakahanga's southern beach: four nests were laid here in late-2011

Surveys of coastal habitats

The survey team investigated the entire coastline searching for signs of nesting activity or turtle tracks. There were 26 nests dispersed along the four sandy beaches around the atoll but no tracks were found, which means that nesting is likely to be seasonal and that it finishes earlier in the year. The inner lagoon was surveyed using small *vaka*: the lagoonal beaches are generally unsuitable for nesting (mostly Type C, but a few small Type B sections). The entire Western side of the atoll is Type C: almost all coralline rock.



Nesting suitability of habitats at Rakahanga Atoll: yellow suitable; pink possible; brown unsuitable. Map adapted from LINZ 262/8/12 by Gemma Galbraith.

The Findings

Seven coastal surveys were conducted: the first one was used to teach Gemma how to do beach surveys (on the southeast beach); the second one resurveyed that same beach. The third survey included the nests on the school beach, but then covered the unsuitable areas in the southwest, and all along the village lagoon-side beach and the fish-pond causeway: the village beach is sandy, but has too much human activity for nesting to occur; the pond and forests along the southeastern corner of the inner lagoon are unsuitable (mostly Type C: a few are sandy but these are very narrow, flat, and with dense vegetation reaching almost to the water's edge). The fourth survey was on *Te Kainga* motu – the islet in the southwestern outlet from the inner lagoon. This motu is densely-forested and mostly Type C, with a few small, narrow, sandy areas with dense vegetation cover.

The fifth survey focused on the motu in the central sector on the eastern reef: *Okakara; Mahuta; Te Motu o Tati; Huna Nui; Ngangie; Akaro;* and some very minor islets. It was very time-consuming as we had to wade across the narrow channels between each motu; these channels were generally hard coralline substrata, and could have considerable water flow through them from the windward reef. Sharks were common; mostly Blacktip reef sharks (*Carcharhinus melanopterus*). Several of the small motu are just long and narrow outcrops of coralline rock, with sparse thorny vegetation; it is unlikely that turtles could even access these as they are raised above sea level. Two motu: *Huna Nui* and *Ngangie* have small sandy coves on the windward side facing the reef: although the sand is perfect for nesting, and probably easily-accessible for the females, it is unclear if hatchlings would be able to exit from these coves. They are steep-sided (vertical rock) and the prevailing waves breaking over the reef flow directly into them; neonate turtles are positively-buoyant and would find it hard work to reach the ocean. We did categorise these beaches as Type A, based on the quality of the nesting zone, and in future should be able to determine their true status.

The sixth survey covered all of the northeast, north, northwest and western coastlines. It was a very long hard day, with the long walk on the western reef being particularly bleak. Much of the shoreline from the *Akaro* channel on the eastern side to the northwestern corner of the atoll is suitable for nesting; only the northeastern corner is unsuitable – the prevailing currents create a narrow, steeply-sloping ridge consisting of larger stones and *kirikiri*. Along the northeastern beach the reef drop-off is near (20-50 m) and the windward lagoon areas provide easy access to the shore; some areas are steep and several sections consist of larger coral rubble (coarser than *kirikiri*). Curiously, *Ti Mata I Pahonu** at the northwestern corner has poor access from the ocean and coarse substrata; however, the adjacent northern beach is a very good nesting site. Marine debris (mostly plastics) was present all along the eastern shore, but there was less on the northern beach; which was in the lee of the northeastern point.

*****Balazs (1995) wrote that *'honu'* is the local name for sea turtle; although on this atoll it is actually *'fonu'* (White *pers. com.*) ~ a literal translation is *'the eyes of the night of the turtle'* (Ru Taime *pers. com.* 2012). There is also a *'Pahonu'* on *Tokerau motu* in the north of Tongareva Atoll (White *pers. com.*).

Nesting

Nesting was not substantial (and is assumed to be *C. mydas*), but the main habitats are highly-suitable for egg-laying. Perhaps the local sea turtle population is only small; this is also discussed below under marine observations.

Rakahanga Nests

North beach = 7 nests
Northeast = 5 nests
Southeast = 10 nests
South = 4 nests
West = 0 nests

Total 26 nests

No tracks were found

Index Beaches

Two sites on Rakahanga were selected as Index Beaches: **1) The southernmost beach** at the school ~ this has several advantageous aspects:

i) The immediate area is uninhabited, other than the Principal who resides at the school
ii) Power on the atoll is turned off at 2300, so there is no light pollution overnight
iii) During the evening school-lighting is minimal, so the beach is in darkness
iv) The beach itself is steeply-sloping and of good quality sand
v) Access across the reef is fairly good, especially at high water
vi) The entire beach can be observed from the school playground; tracks are easily visible in the early-morning light and can then be investigated *in situ*
vii) The beach is kept clean as part of the normal way-of life: rubbish is picked up every day; and on Saturdays different sections are deep-cleaned and wild vegetation trimmed
viii) Nesting is usually in the vegetation and several areas are in shadow for much of the day; which means that this beach may still be a source for male hatchlings.

2. The northernmost beach has a few more nests, but is visited infrequently. This is a perfect nesting site: clean sand on a sloping beach; an easy crawl to the vegetation line; the reef drop-off is near and the ocean-side lagoon provides good access to shore. The forest is also an important seabird rookery (White *pers. obs.* 2012).

As the local team becomes more adept all four major beaches could be monitored easily (as at Nassau). A good surveyor, using a boat to traverse the eastern channels, can do the entire coastline in a day; but ignoring the western and southwestern Type C zones.

Rakahanga Atoll showing the four main nesting beaches: the North and South have been selected as Index Beaches. Photo courtesy of Ewan Smith, Air Rarotonga.

Lagoon by school beach at low water

Top: South side of Te Kainga Motu ~ Type C; **Below:** easy access over the eastern reef

Top: Southeastern beach ~ Type A; **Below:** crossing between motu on the eastern side

Top: Mahuta ~ Type C; **Below:** perfect nesting spot in the northeast of Rakahanga

Top: view to northeastern tip ~ access possible but nesting unlikely; **Below:** North beach

Te Mata i Pahonu. Top: north side of point; **Below:** around the corner on the western side

All the western shore is Type C. Top: northwestern sector; **Below:** long walk to the village

Top: inner lagoon survey; **Below:** typical Type C beach around the inner lagoon

Top: investigating northeast corner of the inner lagoon; **Below:** western shore of inner lagoon (the eastern motu can be seen in the distance)

Top & Centre: abundant foraging resources in the inner lagoon; **Below:** western reef ~ perfect for subsistence fishing

Marine Observations

Twenty marine records were collected between 12th July and 1st September 2012. **The overall number of *C. mydas* observed was 58**; some may be repeat sightings of the same individuals. **No *Eretmochelys imbricata* were encountered** during the 2-month survey at Rakahanga Atoll; fishermen have seen small ones near the northwestern reef.

The entire shoreline of the inner lagoon was examined during the final coastal survey (# 7); we paddled *vaka* around, periodically landing to investigate sites. Two *C. mydas* were seen: one in the northern shallows, the other in slightly deeper water (>10 m) to the west.

Most turtle encounters occurred on the western reef near to the two boat passages; three were on top of the eastern reef by the small motu. Turtles were mostly larger animals (30 large; 25 medium; 3 small). We can confirm at least four adult males; six adult-sized females; and three developing males. Turtles would come into the channel to the wharf; sometimes 3-4 large animals were seen at the same time by the reef drop-off. Sharks were also common: Blacktips (*Carcharhinus melanopterus*), Whitetips (*Triaenodon obesus*) and Grey reef sharks (*Carcharhinus amblyrhyncos*).

Chelonia mydas. Western reef of Rakahanga near main boat passage (Photo: Gemma Galbraith)

Rakahanga boat passage

The final observations:

On the 1st September at noon the author embarked on S/V Kwai to go back to Tongareva. We remained at anchor for two hours before sailing, and during that time there were 10 sightings of *C. mydas* within 200 metres of the ship. Some appeared to be the same animals, but there were at least seven individuals and only one was small (estimated CCL 45 cm); all sightings were as turtles surfaced to breathe. The presence of large animals suggests a reproductive habitat; the plant resources in the lagoon and on the reefs indicate foraging capability; the presence of smaller turtles shows developmental potential. The fact that successful nests are confirmed means that Rakahanga supports all life-stages of *Chelonia mydas*.[52]

[52]Recognising that the *'lost years'* phase will be oceanic.

From S/V Kwai at anchor near Rakahanga's western reef; a *C. mydas* surfaces to breathe (arrowed)

Close-up of Blacktip reef-shark (*Carcharhinus melanopterus*). (Photo: Gemma Galbraith)

Rakahanga's Science Project: Monitoring sea turtle nesting.

Shortly after the Lifeskills event, the Principal (Tuhe Piho *pers. com.* 2011) reported that two nests had been laid on his school's beach (**#1:** Tuesday 27th September; **#2:** Monday 10th October; "this was 25 metres from the first nest…both were laid under *hara* bushes, which were about 1 m high")[53]. To maximise success the author sent a detailed set of instructions for monitoring the nests; the island's policeman also advised Tuhe that as the nests are on school property he could implement any protective measures that he wished to.

The initial concern was to keep predators (e.g. pigs & land-crabs *'Tupa'*) out of the nests (Fowler 1979). Open-topped metal drums were placed over the nests; these were replaced with wire-mesh before each nest was due to hatch, and monitoring frequency increased.

A 3rd nest was laid on 21st October (two students counted the eggs: n = 104; see Limpus *et al.* 1979). A fourth emergence occurred on 3rd November, when tracks and digging activity were discovered, but, as no eggs were found, the author suggested it be noted as a *non-nesting-emergence* (NNE). The school was advised to maintain vigilance later on just in case eggs had been laid. **A 4th nest** was laid on 8th November, which, being only five days after the NNE, the author suggested may have been made by the same female; this time nesting successfully (it could equally be a different turtle).

The Island Council had given permission for a floating pen to be constructed in the lagoon, so that students could hand-rear some hatchlings for three weeks before releasing them into the ocean; it seems this happened in the past on Rakahanga (see Lebeau 1985). Information pertaining to feeding (hawksbill) hatchlings at Samoa and their incremental growth was provided by McVey (1972, cited in Balazs 1977); the present author also explained that the hatchlings may not eat for a few days until the egg-sac is reabsorbed.

Tuhe Piho provided the following data for a *Chelonia mydas* hatchling that was hand-fed on strips of fish for one week:

Incremental growth for a hatchling

25/11/2011: weight = 32.0 g; length (nose-to-tail-tip) = 8.0 cm
02/12/2011: weight = 39.3 g; length (nose-to-tail-tip) = 9.0 cm

***

[53][Author's note: New Moon 26th September; Full Moon 11th October].

Incubation period

Table 1. ***Chelonia mydas*****.** The period between date-of-lay and the first hatchling emergence is given for three of the four nests at Rakahanga; the 4th emergence was missed. Mean incubation = 58 days (SD = ± 2.7 days, range = 55-60 days; n = 3).

Nest #	Date-of-lay	First hatchling	Incubation (days)
#1	27/09/2011	21/11/2011	55
#2	10/10/2011	08/12/2011	59
#3	21/10/2011	20/12/2012	60
#4	08/11/2011	not known	DD

Hatchling emergence was reported for three of the four nests at Rakahanga School beach (Table 1). The first nest emerged after 55 days, the 2nd and 3rd took 59 and 60 days respectively (the 4th nest was not reported). The Mean incubation period is 58 days (SD = ± 2.7 days; range = 55-60 days; n = 3 nests). **It is believed that these are the first data reporting the incubation period for the Cook Islands. (White *pers. com.* 2012).**

***

Nest Excavations

During our fieldwork we examined these nests to determine their success rate. Gemma was shown how to excavate a nest and conduct the inventory and she then did the second one. We waited until the students returned from *Te Maeva Nui* before excavating the remaining two nests, and this was used as a scientific demonstration to reinforce the theoretical part of their course. We entered these data into Excel spreadsheets, performed simple statistics and designed different graphs to show the results; later these graphs were inserted into posters created with PowerPoint. The fact that we used real data was much appreciated by the students and they understood clearly how the whole process works: design a study; collect the data; analyse the results; and then present the findings.

Nest Inventories and Success Rates

As with other sites investigated in the Cook Islands, nest success is high: **Mean = 91%** (SD = ± 10.2%; range = 81-100%; n = 4 nests). Two nests were 100% successful; the others 81% and 84%.

Mean number of eggs laid was **76** (SD = ± 30 eggs; range = 43-106 eggs; n = 4 nests). Egg counts [& number hatched] per nest were 59 [59], 95 [80], 106 [106], and 43 [35].

Of 280 eggs only 23 failed to develop; Mean number of hatched eggs = 70 (SD = ± 30 eggs; range = 35-106 eggs; n = 4 nests). Nest # 2 contained 15 undeveloped eggs; but it was very difficult to determine the exact cause, because the yolks had degraded: they had the consistency of soil, had crumbled, and were full of ants and plant roots. Nest # 4 had 8 undeveloped eggs (7 unfertilised and 1 with an eye-spot).

Mean depth to the top of the clutch was 33.0 cm (SD = ± 7.0 cm; range = 23.0-37.0 cm; n = 4 nests). Mean depth to the bottom of the clutch was 52.0 cm (SD = ± 3.0 cm; range = 47.0-54.0 cm; n = 4 nests). Mean diameter of the egg-chamber was 18.0 cm (SD = ± 4.0 cm; range = 16.0-24.0 cm; n = 4 nests).

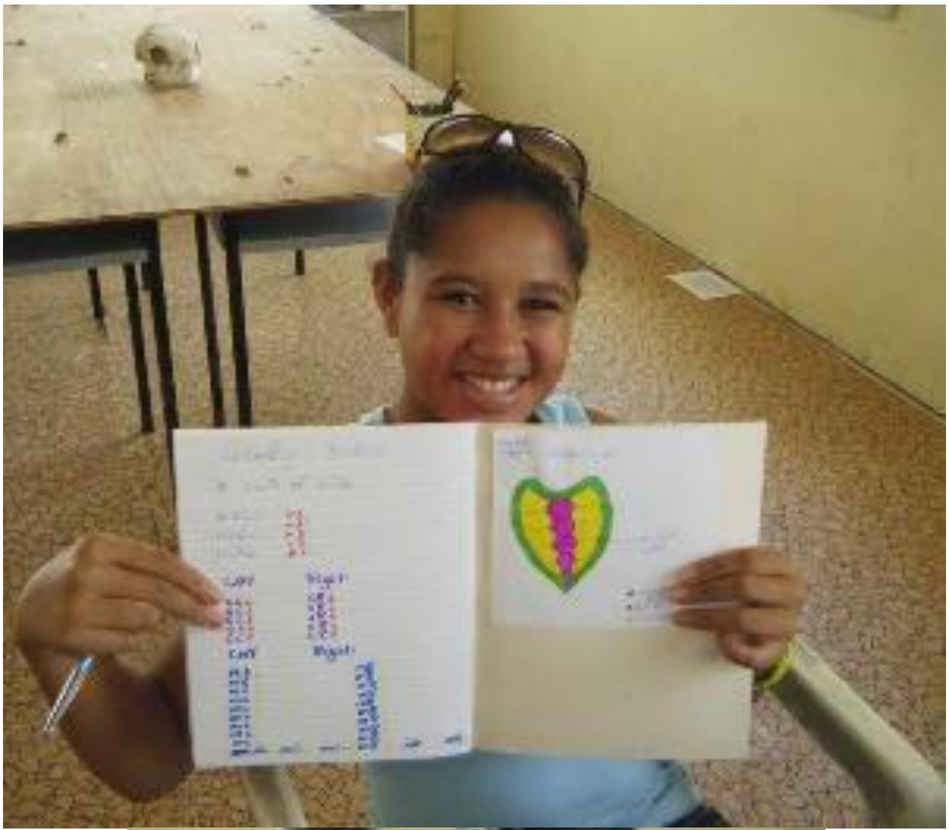
A point of concern during nest inventories is the suggestion that only egg-shells which are more than 50% intact should be counted (Miller 1999). When shells were found to be heavily-fragmented, this method would result in few, or perhaps even no eggs appearing to have been laid. This was resolved by reassembling the fragments to approximate whole eggs; and has particular utility when conducting the first surveys at a site (or if research has not been done there for many years) when older nests, containing degraded eggs, are likely to be discovered (see also Cruz & Frazier 2000; Galbraith 2012).

Community Capacity-Building

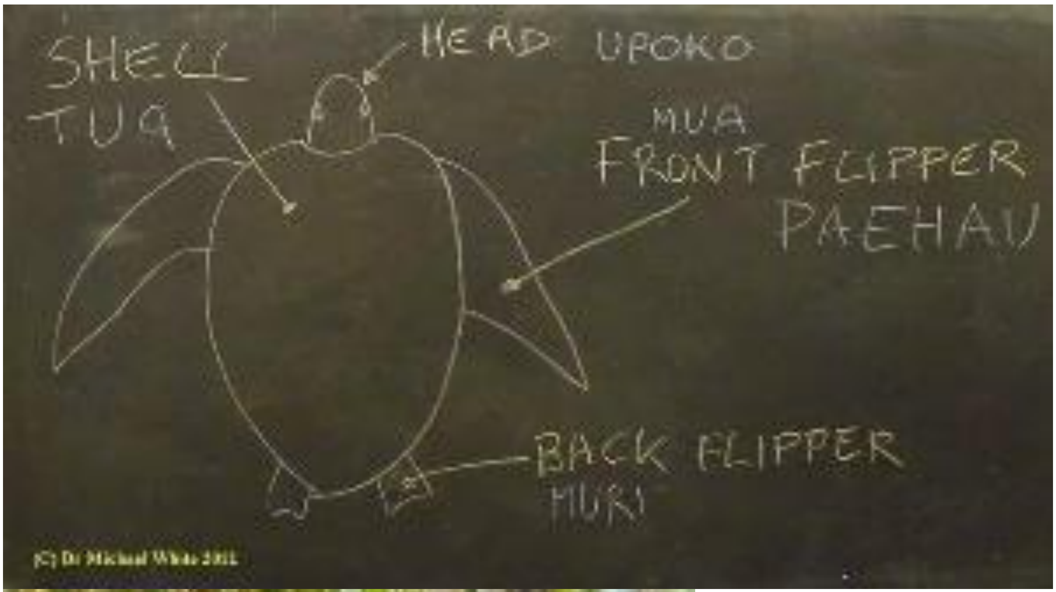
The capacity-building programme for Rakahanga was a little different from that taught on other atolls: the main reason was that there are very few older teenagers on the atoll; the majority of the students are also fairly young (<13 years old). Instruction focused on monitoring the southern and southeastern beaches, as these are in easy walking distance of the village, and also keeping them clean. Some of the adults will occasionally monitor the northern beaches (Apolo Piho, *pers. com.* 2012).

The teaching programme achieved a balance between academic requirements and the collection of meaningful scientific data. The students themselves are remarkably keen, quick learners, and able to think holistically. They were very good with nest excavations and soon became familiar with GPS usage. Nesting did not occur during the expedition, so training to work directly with sea turtles will be completed later. We did, however, use old carapaces to practice measurements on; procedures for flipper-tagging and genetic sampling were explained and the equipment was passed around. Altogether the author taught a 60-hour course that covered all aspects of sea turtle life. In common with other Northern Group atolls there are very few teaching resources in each language, so the author taught students how to make PowerPoint posters; they are now designing materials in their own language (*Reo Rakahanga*). The author sees this as a positive step towards mitigating the loss of island culture.

Academic assessment of the course was based on posters that the students produced. The marking scheme's criteria and possibilities were explained beforehand: i) *Excellence* (the item could be used in other schools); ii) *Merit* (posters could be displayed in the village); iii) A*chieved* (posters would be displayed in the classroom); iv) *Not achieved*.

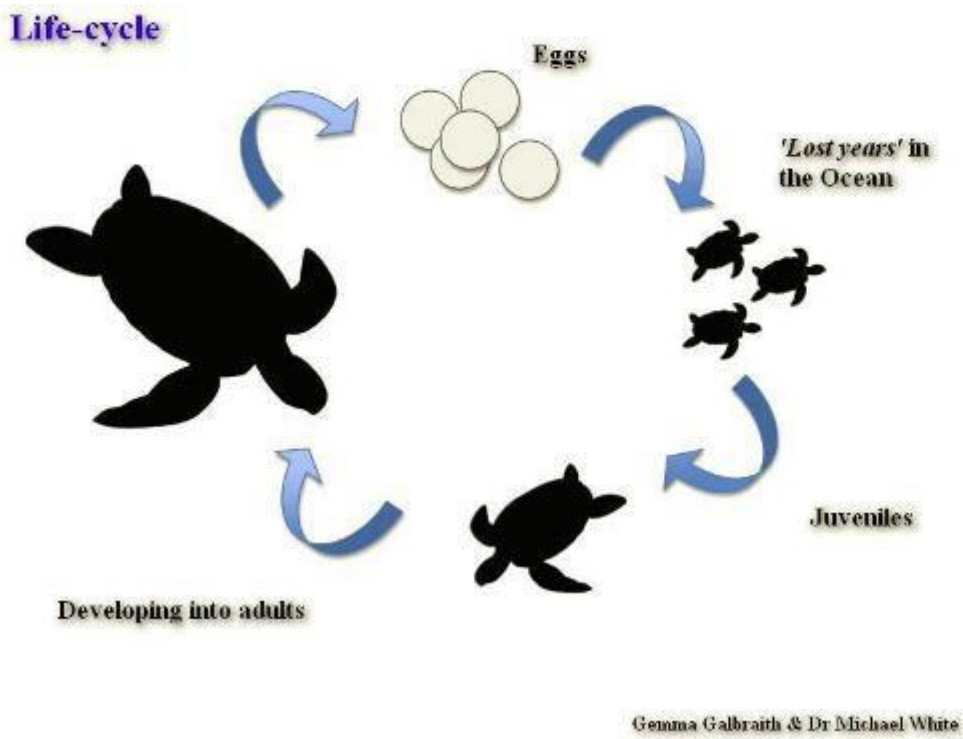


…And it could be fun! *Meitaki Korereka Vakahoa*



Blending Traditional and
modern ways of teaching:
Above ~ local names
Left ~ GPS use

Nest excavations: We didn't have latex gloves, so special attention was given to the risks of microbial agents, and careful hygiene



A variety of teaching resources were used: this is the ‘Harlech’ leatherback: the world’s largest sea turtle (Photo courtesy of the National Museum of Wales; September 25th 1988)

Our favourite mermaid and a dugong (Sydney Aquarium, Australia 2010)

The insidious aspect of plastic pollution. Special thanks to Chris Jordan

Beach clean: southeastern beach on Rakahanga

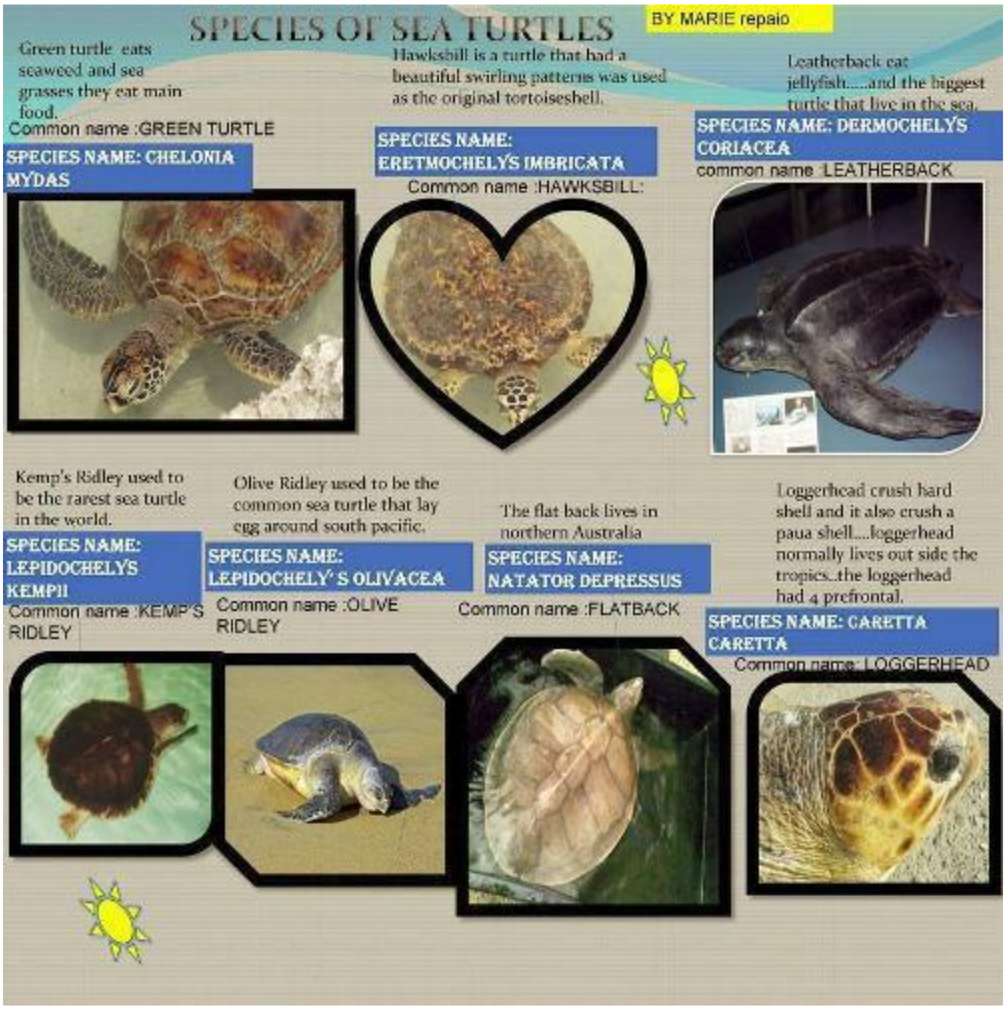
Rierson: Rakahanga School's youngest student cleaning the beach

A Message from Rakahanga Atoll to the World:

"We share our beautiful Paradise & abundant environment with you ~ You send us your rubbish"

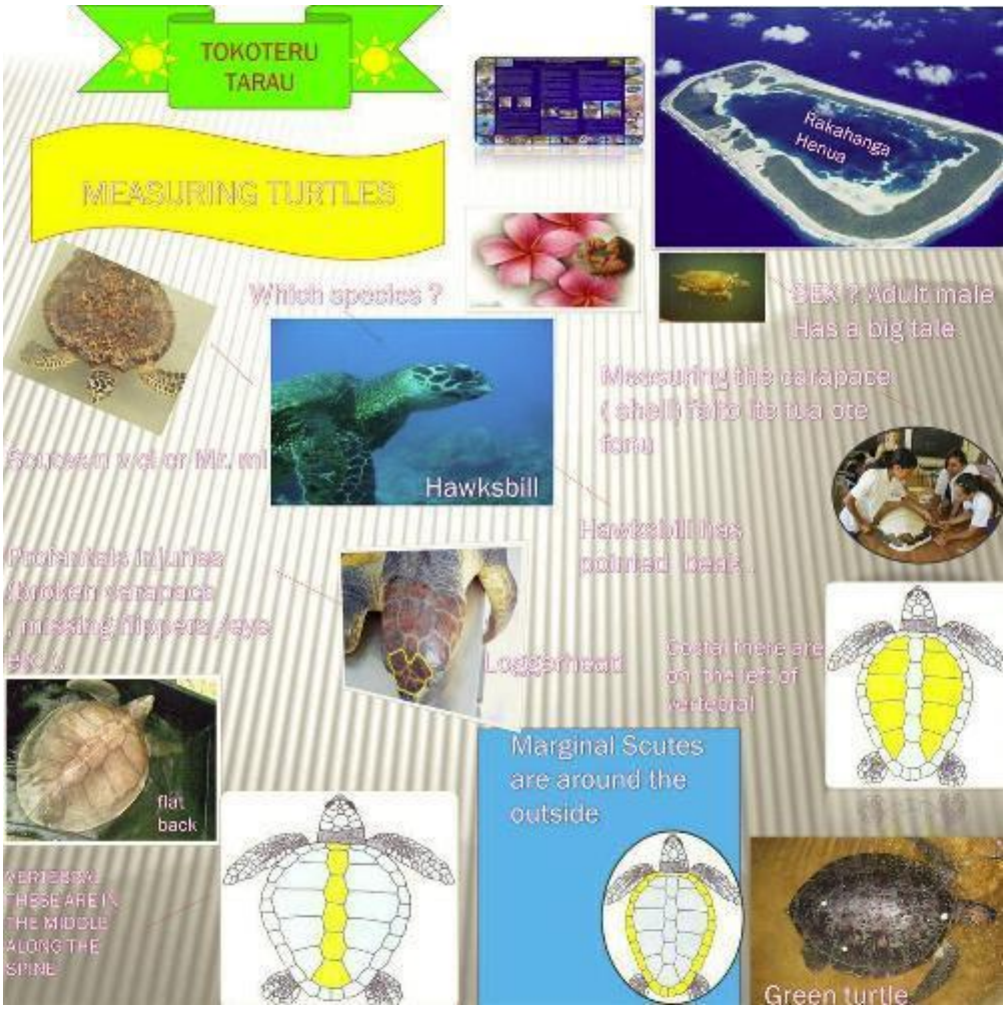
"PLEASE DON'T!"

Students had not used PowerPoint before, but they produced the following posters after only two day's instruction



Poster by Marie Repaio

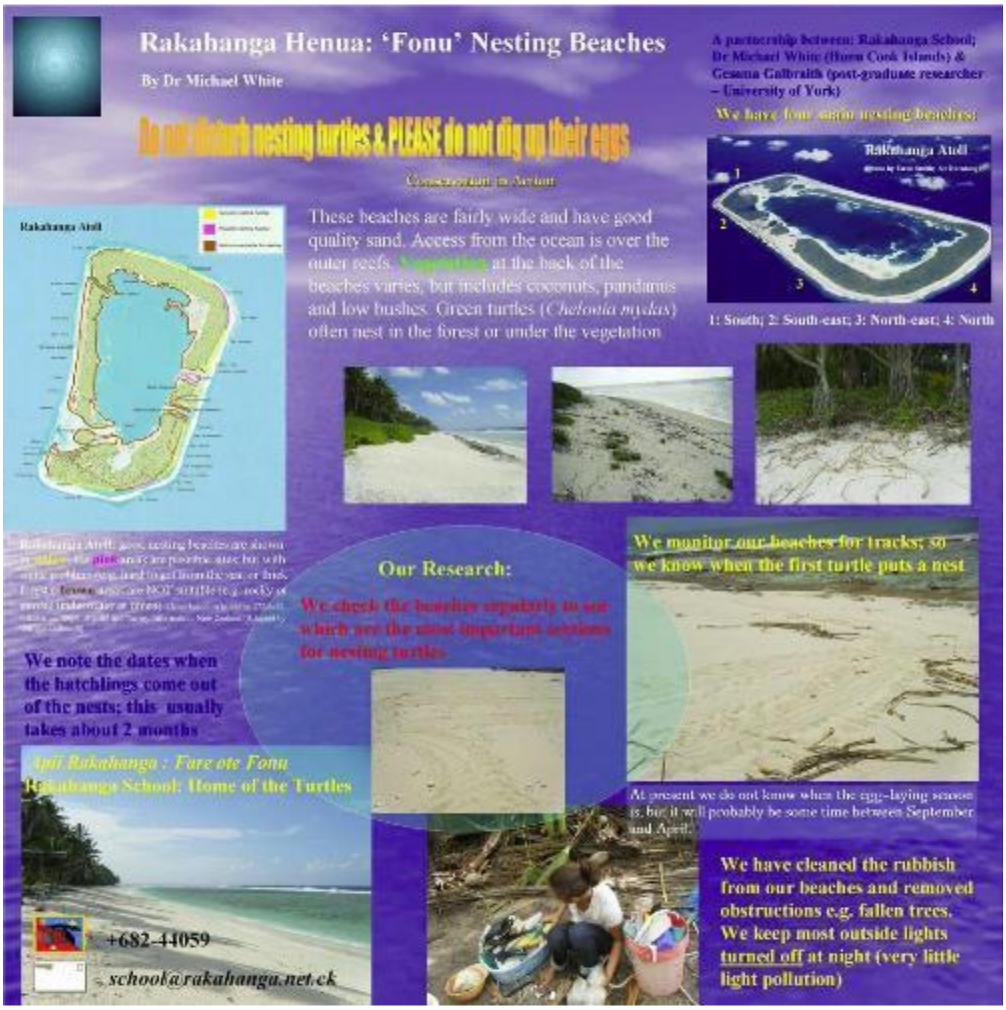
Poster by Grand Repaio



Poster by Tokoteru Tarau

(Thanks to Tom MacFarlane for the turtle drawings)

Poster by Bernado Matakere



Poster by Dr Michael White

Gemma Galbraith: Post-graduate researcher (University of York)

An important aspect of the Rakahanga expedition was to teach Gemma how to become a professional marine scientist. Building upon her previous experience, which included a visit to Millport Marine Biological Station, Western Scotland, and scuba-diving surveys in Egypt, the author explained many aspects of sea turtle biology; but more importantly, how to plan an expedition to a very remote site. Gemma was introduced to the staff in the Prime Minister's Office; Ministry of Marine Resources; National Environment Service; and also at the Ministry of Foreign Affairs and Immigration. We followed all of the steps necessary to work legally in our host country; and also how to manage when things get complicated: **communication is the key.** Go to the right people; explain clearly what the problem is and what needs to be done; get letters of support and pay any relevant fees; ALWAYS be polite and patient ~ success is highly likely.

The extensive resources at Rarotonga's Whale and Wildlife Centre were used during our pre-deployment week to enhance biological theory and the threats that sea turtles face. We also spoke with many knowledgeable local people, who provided Gemma with a good background to the traditions and ways of the Cook Islands.

Making notes at the Whale and Wildlife Centre, Atupa, Rarotonga.

www.whaleresearch.org

In the museum at the Whale Centre: the large carapace is from a green turtle killed during nesting at Palmerston in 2009

Members of the extended Marsters' family from Rotorua waiting to sail to Palmerston Atoll; for some of them this will be the first visit to their ancestral home




Top Left: expedition planning at Tiare Village; **Right:** Aro'a ~ a skilled Maori Weaver, who has links with Rakahanga. **Centre:** Mike Taveoni is sitting front right: he's a master carver: stone *'Tiki'*, builds *vaka*, and also tattoos. **Below:** Traditional Dancing ~ this is also taught in the school curriculum

Author's Note: Gemma participated fully in the Rakahanga Atoll research programme, utilising the principles laid out in the present manuscript. Her sociological survey has particular value and some extracts are included below.

Community-based marine conservation on a small island

(Galbraith 2012)

Abstract: *The application of ecological studies to implement successful conservation strategies is fundamentally dependent upon a dynamic balance between both social and ecological complexities. Contemporary conservation science inevitably involves people across all management scales, but in small isolated environments the influence of human activity can have monumental consequences for endangered species conservation, both positive and negative.*

All species of sea turtles are globally endangered, but many regions remain data deficient for accurate population abundance and distribution estimates to be made. Efforts to monitor the thousands of potential nesting sites on remote Pacific islands are limited by financial and human resources. Initiating community-led conservation projects is one way to overcome these limitations and establish long-term data sets.

An ecological survey of the nesting habitats at Rakahanga Atoll provides baseline information regarding turtle population abundance and distribution. These data contribute to the overall knowledge of sea turtles in the Cook Islands, and were also used to implement aspects of a community-led project that would continue monitoring nesting activity.

Community reactions to this local project were examined and are shown to be significantly more positive than attitudes towards large state-led conservation actions. Awareness and global vision are low in such small remote communities, but intimate environmental education programmes can impress the importance of biodiversity and ecosystem conservation within a context meaningful to the culture, practices and values of the community. As such this case study of community-based conservation offers an adaptive and socially flexible tool for effective environmental management.

Conservation science recognises that socio-economic and political processes are as integral to the success of environmental management as the fundamental ecological systems themselves (Brechin *et al.* 2002; Adams & Hutton 2007). Over the past two decades community-based conservation has developed as an important alternative to traditional state-led environmental management tools or fortress conservation (Horwich & Lyon 2007). Defined by Little (1994) community-based conservation includes "at least some of the following: local-level, voluntary, people-centred, participatory, decentralised, village-based management". The concept emerged from concerns associated with natural resource exploitation in developing countries, where the failure to incorporate "the human dimension of ecological issues" undermines biological conservation targets as a result of non-compliance by local peoples (Meyer & Helfman 1993). There are also practical benefits associated with conservation conducted by local people given the remote locations and limited scientific and financial resources (Campbell & Vainio- Mattila 2003).

Perhaps the most abstract driver of this people-centred approach is that of an ethical social compass. Western concepts dominate contemporary science (Zilsel 2003), however, many of the world's remaining pristine ecosystems and conservation priorities are located in regions where traditional indigenous cultures persist (Cincolta *et al.* 2000).

In the Cook Islands, the Outer Islands are dominated by subsistence lifestyles and livelihoods, and the associated values that stem deeply from direct dependence on natural resources. This said, island communities are not naïve to western influences and considerable social changes have occurred, altering some aspects of native Maori culture. One such example is the diminished perception of turtles as sacred animals. No longer revered as representatives of Gods on Earth as a result of Christian missionary influences in the early 1800s (Handy 1921), turtles are now used as many other marine resources (White *pers. com.* 2012); which has led to altered and increased patterns of exploitation in many Polynesian communities (Campbell 2003). Successful conservation of sea turtles will therefore require an acute understanding of individual communities to initiate conservation practices that not only achieve ecological goals, but also those of socioeconomic development and cultural preservation. Community-led conservation does present a means to achieving this, but requires substantial understanding of local knowledge, attitudes and values. Given the remote nature of many of the nation's constituent islands and the lack of permanent scientific monitoring, there is a critical role for local communities in contributing to biodiversity management and protection in the Cook Islands. The research activities and capacity-building efforts of *Honu Cook Islands* are the keys to realising this potential.

Methodology

[GF Galbraith Note: the habitat surveys, nesting success, and sea turtle behaviour are those given in the present document. Additional Aims and Objectives are given below]:

1) Identify local threats and impacts to sea turtles and their habitats.

i) Observe local subsistence activities

ii) Interview community members with regards to turtle exploitation
   - a) Quantification of turtle and egg take locally
   - b) Fisheries impacts and other anthropogenic activities
   - c) Degradation of nesting and marine habitats

2) Compare attitudes towards community-based conservation and national environmental plans.

i) Conduct social surveys prior to and post dissemination of expedition findings and conservation education.

3) Facilitate establishment of a community-led monitoring programme within the local community.

i) Disseminate the findings of biological survey work to the local community
ii) Undertake capacity-building and environmental education activities
iii) Implement community-led monitoring

Social Surveys and Community Education

Community Presentation

A presentation regarding the research findings and the global status of marine turtles was made during the final week of the expedition; the talk included the endangered status and broader global problems faced by sea turtles. We prepared and hosted a *kaikai* to generate interest and promote attendance.

Mention was made of the recent announcement by the National Government to create a 'Marine Park' (August 2012). This MPA (Marine Protected Area) will be the largest in the world and will cover an area of 1,065 million km^2 in the southern half of the Cook Islands EEZ (Exclusive Economic Zone). The IUCN (International Union for the Conservation of Nature) subsequently signed a Memorandum of Understanding with the Government of the Cook Islands to facilitate this process.

Community Interviews

A formal questionnaire was designed and interviews conducted over July-August 2012 (Galbraith 2012). The questions aimed to assess the opinions and attitudes of islanders towards turtle conservation, and also to quantify the local level of turtle exploitation. Of the 89 permanent residents at Rakahanga all those above 16 were interviewed, except 4 individuals who were absent or could not participate for health reasons (n = 60 respondents). Aspects of the questionnaire were then repeated after the final presentation to examine any changes in attitude as a result of the information disseminated. Of the original 60 individuals interviewed, 49 attended the presentation and were interviewed again.

Note: Quantification of attitudes was performed using a point system for possible responses. Responses to each question were given a numeric score (3 = agree; 2 = no opinion; 0 = disagree); all underwent square root transformation and the mean score for each statement was calculated. Paired and unpaired t-tests were used to compare attitudes before and after the presentation; and also attitudes towards community-led vs. state-led conservation projects. Methods after Mehta & Heinen (2001).

Informal interviews were also conducted throughout the expedition and qualitative information regarding the use of turtles and traditional management of resources on the atoll recorded.

Results

Habitat assessments, nest numbers, nest success rates, and in-water sightings are those reported above. Key points from the sociological surveys follow (for detailed results see Galbraith 2012):

Community-based turtle conservation ~ Attitude Statements:

1. Monitoring sea turtle nesting on Rakahanga will benefit our community.

	Pre-presentation	Post-presentation
No. of respondents	60	49
Agree	5	34
No opinion	36	15
Disagree	19	0

2. I am happy that a turtle monitoring project is starting on Rakahanga.

	Pre-presentation	Post-presentation
No. of respondents	60	49
Agree	32	46
No opinion	26	3
Disagree	2	0

3. I like the idea of the turtle project.

	Pre-presentation	Post-presentation
No. of respondents	60	49
Agree	42	47
No opinion	12	2
Disagree	6	0

Cook Islands MPA ~ Attitude Statements:

1. The marine park will benefit Rakahanga.

	Pre-presentation	Post-presentation
No. of respondents	60	49
Agree	0	0
No opinion	17	18
Disagree	43	31

2. The marine park will benefit the Cook Islands.

	Pre-presentation	Post-presentation
No. of respondents	**60**	**49**
Agree	**3**	**2**
No opinion	**15**	**13**
Disagree	**42**	**34**

3. I would like Rakahanga to be included in the marine park.

	Pre-presentation	Post-presentation
No. of respondents	**60**	**49**
Agree	**4**	**1**
No opinion	**10**	**17**
Disagree	**45**	**31**

4. I like the idea of the Cook Islands marine park and support its formation.

	Pre-presentation	Post-presentation
No. of respondents	**60**	**49**
Agree	**5**	**5**
No opinion	**23**	**25**
Disagree	**33**	**19**

Attitudes toward the idea of a community-based turtle monitoring project being established on Rakahanga were significantly more positive both pre ($t = 11.7$; $p<0.001$) and post the community presentation ($t = 13.7$; $p<0.001$) compared to attitudes toward the Cook Island's MPA.

After the presentation, attitudes regarding a benefit to the community on Rakahanga from the turtle project increased significantly ($t = 9.01$; $p<0.007$), whereas those towards the MPA and any potential benefits did not ($t = 1.07$; $p = 0.24$).

Overall, attitudes were more positive towards the small-scale community-based turtle monitoring project, both with and without any form of environmental education, than the marine park. The significant increase in mean attitude towards the turtle project after the presentation also suggests that environmental education and dissemination of information has significant effect on creating positive attitudes toward conservation projects amongst local communities.

Sea turtles are frequently seen by most members of the Rakahangan community. Whereas only 62% of people said that they had heard of the government plans to designate the large MPA across the Southern Group. Familiarity with the ideas and concepts involved in these two different conservation strategies is likely to affect local attitudes towards them (Wossink & van Wenum 2003).

Sea turtles

Only 37% of the adult community agreed with the statement *"turtles are an endangered species…"*; the response to which only increased by 21.3% post-presentation. A common response following this question was an expression of the abundance of turtles seen in the waters of Rakahanga.

When asked *"will you eat turtles again?"*: 90% of the adult community agreed before the community presentation; and 80% concurred post-presentation[54]. Sea turtles are an integral part of normal food resources (White *pers. com.* 2012).

In contrast to the adult community, when asked, 83% of children at the school did not want to eat turtle. This opposing trend in attitudes towards consumption perhaps reflects a lost connection with turtles as a traditional food source amongst the younger generation. Backdoor transmission of information and pro-environmental attitudes to parents via their children is suggested as a mechanism for influencing pro-environmental behaviour in adults (Evans *et al.* 1996); and is the approach commonly used by *Honu Cook Islands* (White *pers. com.* 2012). Not only may this contribute to changing current community actions regarding sea turtle use and conservation, but it also has significant implications for future community management and conservation practices; because current children are the future island leaders.

It is important to recognise the persistence of cultural values even after initial environmental education within indigenous communities (Borrini-Feyerabend *et al.* 2004). Far from encouraging attempts to change local practices by institutional enforcement, responses to educational education which do not attain "successful" outcomes are useful for identifying more effective culturally-sensitive directions for community involvement in a conservation project and educational curricula. In this way compliance with the eventual form of community-based conservation is likely to attain greater long-term social and biological success (Holt 2005).

[54] Despite showing evidence that explained the endangered status of sea turtles globally, only 6 people changed their response to this question following the presentation.

Environmental awareness

[This section was not repeated after the presentation due to time constraints]

Q1. Do you think the marine environment on Rakahanga is healthy? 80% Yes.

Q2. What do you think threatens the marine environment: a) On Rakahanga? 75% said there are no threats (modal response); b) In the whole of the Cook Islands? 53.3% said fishing by foreign vessels (modal response).

Q3. Do you think that the marine environment in the rest of the Cook Islands is healthy? 55% Yes.

Q4. Do you think that human activities can ever seriously threaten or damage the marine environment here? 41.7% Yes.

"It is … widely believed that traditional communities use their resources in a sustainable manner. This belief is based on the fact that traditional communities lived at low densities, had limited technology, and practiced subsistence rather than commercial utilisation. Unfortunately, given growing population pressure, increased access to modern technology, increasing market orientation, and steady erosion of traditional cultures, there no longer are guarantees that biodiversity objectives will be any more likely to be achieved if resource control is placed in the hands of indigenous peoples" (Kramer & van Schaik 1997). Although the community on Rakahanga does exhibit subsistence marine resource use, and has low population numbers, there is the potential for considerable environmental degradation on the atoll (see Galbraith 2012) as traditional management systems were not designed to cope with the environmental stresses of the modern world (Johannes 2002).

Sea turtles were seen as important to native culture by 96.7% of the community; however, 82% of the adult community supported the expansion of a commercial fishery, which would present considerable threat to the local turtle populations.[55] Given that traditional management of the island's fisheries involves no quotas for what an individual may take (Taripo *pers. com.* 2012), increased unchecked exploitation of local fish stocks driven by commercial activities will eventually lead to fish stock depletion and the consequential ecosystem effects, as has been the case in much of the world (Jackson *et al.* 2001; Folke *et al.* 2004; Roberts 2007). When asked why they thought this expansion was a good idea, many people perceived depopulation as the key driver of cultural erosion on Rakahanga, expressing hopes that commercial fishing activity on the atoll would create financial incentive to prevent younger generations leaving the island in search of better social and economic prospects. Rather than assume a "resurgent protectionist" stance (Wilshusen *et al.* 2002) to the developmental desires of indigenous peoples, adaptive management incorporating sustainable development goals should be integrated into conservation projects.

[55] This idea involves procuring a commercial deep-freeze unit and then exporting reef fishes. A larger freezer had been considered at Palmerston Atoll and was subsequently rejected as a bad idea (Bill Marsters *pers. com.*)

conservation projects. In this way both culture and biodiversity can be protected whilst not limiting community development: as "people are more likely to respond to suggested changes in resource use if these changes are founded on their own values and customs" (Johannes 2002).

School Journal article

In late-August (2012) Gemma prepared an educational article on our sea turtle research and community outreach endeavours at Rakahanga. On her return to Rarotonga Gemma met with staff at the Ministry of Education, and they will now produce the document as a Cook Islands' resource for all national schools; but furthermore it has been submitted to the New Zealand School Journal ~ and will be disseminated widely through Australasia and much of Oceania.

Synthesis

Rakahanga is particularly interesting in that many people in the community are willing to become involved in the work of *Honu Cook Islands*. The human population is small and most families are related in some way. Many students are keen to learn about *fonu* and they enjoyed our turtle lessons in August 2012. They have also taken direct responsibility for keeping the beaches clean and monitoring any nesting activity**: this is a great result.** The people on Rakahanga will continue to eat turtles occasionally: this was very clear from our sociological survey reported above. Few of the children eat turtles, which is similar to the other Outer Islands, so in decades to come direct take will probably cease, or be very rare. Egg-take is already rare.

The main threats, other than incidental hunting, are sand-extraction from the beaches and the presence of feral pigs and cats. Options for building-sand will be discussed with the Island Council. The Council has already started to shoot and eat the wild pigs (Giovas 2006). Cats seem mostly to associate with people as food-providers; they keep the rat population in check.

Discussion from Galbraith (2012):

Effective sea turtle conservation requires comprehensive conservation strategies that span considerable chasms between social, cultural and biological agendas. Despite the efforts of large-scale international marine environmental management and protection, if important nesting-aggregations are not protected possible local extinctions may occur, with serious ramifications for global stocks

Community-based projects facilitate a culturally-sensitive approach to conservation, especially when enforcement is limited. In this case, enforcement may not be required at all if all actions and processes behind the management plan are made transparent and the needs and desires of local communities sufficiently included within conservation plans.

The concept of regional management units (RMUs) for sea turtle populations seeks to overcome wide ranging geographical distributions and varying spatial threats to distinct population units (Wallace *et al.* 2010). Whilst this multi-directional approach does offer several important methods for addressing ecological components of stock management its application is limited in regions where there are considerable challenges for regular and long-term monitoring (Heppell *et al.* 2000).

Contemporary conservation science inevitably involves people across all management scales, but in small isolated environments the influence of human activity can have monumental consequences for endangered species conservation, both positive and negative. Sea turtle populations should therefore not only be defined by their ecological and geographical characteristics, but also the relationship with local human populations. Human exploitation activity is not purely a threat, but also an opportunity to engage communities with conservation actions integrated with modern conceptions of traditional values (Infield & Namara 2001). This then has the potential to attain sustainable resource use patterns. For this to happen, substantial time and effort must be made to gauge appropriate approaches to environmental education in order to obtain optimal success and support for a project. This is not always practical or possible, given resource, time and financial limitations for biological conservation.

For this reason community-based projects and the influence of local people should not be underestimated as a substantial component of sea turtle RMUs. Small-scale projects like this one undertaken on Rakahanga Atoll (see Keegan *et al.* 2008) can also influence provision of benefits for conservation in neighbouring communities by spreading knowledge and positive experiences of working with external groups and professional scientists. Strengthening people's capacity to determine their own values and priorities and to act on those is critical to globally-threatened turtle populations; conservation must strive to incorporate local-use of this traditional resource into projects, lest a whiff of neo-colonialism permeate the air of good intentions (Galbraith 2012).

Conclusion

This is a wonderful example of community involvement and it has also triggered a quest by the islanders for knowledge about turtles (*'fonu'*); which had been largely ignored: for instance, the people of Rakahanga did not known that sea turtles are endangered (IUCN Red List). Several islanders have contributed traditional knowledge for turtles, which should deepen our understanding

(Newman & Moller 2005) as the author tries to relate ethnozoology with modern science[56].
We are also preparing a science paper for Testudo (British Chelonia Group), and our new Turtle Rangers may well hold the key to avoiding depopulation, and its attendant loss of culture, as well as finding a financial alternative to poorly-thought out development plans: they could be paid a small stipend for managing their natural resources sustainably and contributing data to the national biodiversity assessment.

[56]Dr White is developing a module that includes traditional knowledge and practices alongside modern scientific concepts.

Although many people believe that science is important, it is probably the small day-to-day things that we do during fieldwork that make the difference; just our willingness to become involved in the life and work of each community. This is particularly true on small isolated atolls, such as Rakahanga. Some photographs are included below that show what life is like in a subsistence-based culture:

Community presentation and practice

Gemma and friends; Papa Danny Piho lives in New Zealand, but for many years was the Fishery Officer at Rakahanga: a great source of knowledge

Church

School







Food

Music



The Tere Party: Loading Lady Naomi & Farewell Prayers

Rarotonga [21° South; 159° West]

Overview

The mountainous island of Rarotonga is in the Southern Cook Islands, the national capital *Avarua* is on its northern shore. The island 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; although there is a small lagoon with vegetation covered sandy beaches by *Motu Toa*. The eastern coastline consists mostly of coralline boulders and rubble; in several places the reef drop-off abuts the land, and access from seawards is very difficult (e.g. *Ngatangiia* and *Matavera*). Sandy beaches and the widest lagoons are located in the southeast (*Muri*); south (*Vaima'anga*); southwest (*Aro'a*); and west (*Aorangi*). The beaches at Blackrock, in the northwest, are mainly stones or gravel (*kirikiri*); although beach access from the lagoon is good. The airport is nearby.

In 2009 the author assessed all of Rarotonga's coastal habitats to determine their nesting suitability; the various sites were revisited in 2010 and 2012: there is a ring road close to the shore and the entire coastal zone is inhabited **~ no sea turtle nesting was found.**

There were no scientific data for sea turtles at Rarotonga, although they are often present on reefs and in lagoons. The first information was collected by the author during in-water surveys at Papua Passage; subsequently scuba-diving clubs were asked to contribute their turtle sightings.

Terrestrial surveys

Between 9th November 2009 and 29th March 2010 (assumed to be in the nesting period) all of Rarotonga's coastline was assessed to see if sea turtles had nested, or if nesting was likely. There were no signs of turtle emergences onto land: i.e. no tracks on the beaches, nor any evidence of nesting-activity. Beaches were resurveyed in November-December 2010, and again in May-June 2012, but no signs of emergence or nesting activities were found at any site. Egg-laying might possibly occur in some years (e.g. at A'aroa beach in the southwest); however, most areas seem unsuitable for several reasons.

The eastern shoreline is mostly coralline rocks/fossils with little or no sand; access from seawards is also very difficult (e.g. *Matavera* and *Ngatangiia*). Parts of the northern coast are also rocky and the lagoon is narrow or nonexistent, but there are a few small areas with sand, particularly near to the airport (a place called *Turama* (*Motu Toa*) has a small lagoon and a suitable beach). Blackrock beach has many small stones in the sand, but turtles are known to nest in coarse substrata (White *pers. obs.*). Much of the western coast has resorts built on the sandy beaches. The best places are likely to be along the southern coast; where the lagoon is also widest, but there are other problems here. The first is that the depth of sand may be insufficient for a turtle to dig down 60 cm or so to deposit her eggs. The roots of plants may form a latticework through the sand, and these might deter a turtle from completing the egg-chamber; underlying rock would have a similar effect. A further limitation is that some of these beaches are submerged at high water, which would terminate embryonic-development (turtle eggs are soft-shelled to facilitate oxygen and carbon dioxide gas-exchange)

A strong reason for the absence of nesting on the island is from people and our activities. Most of Rarotonga's coastal-zone is inhabited; roads are often adjacent to the beaches; light pollution and people moving nearby are major deterrents for nesting turtles. The female usually selects a quiet, dark place to emerge onto land; it takes about one-and-ahalf hours to complete the egg-laying process. Sea turtles are adapted to life in the marine environment, the paddle-shaped fore-limbs are adapted for swimming, not walking; they are large animals and the effect of gravity is probably considerable (they are neutrallybuoyant in the water) and movement on land is likely to be difficult; and they are very vulnerable to predation. Light, particularly white light has a major disorientating effect on marine turtles (their retinas are adapted for seeing underwater) and they may be unable to find their way back from a brightly-lit beach to the sea.

The four motu in *Muri* lagoon also have complications: *Koromiri* probably has the best sand, but is the heaviest used of the four islets (the hotels and Captain Tama's cruises visit and have barbeques there); also the lagoon is very shallow, so tourists might wade across at night, which could deter turtles from emerging. *Motutapu* has many rocks in the sand; and its eastern side is all rock or *kirikiri*; the sand-depth is probably insufficient to support nesting. The channel between *Motutapu* and *Oneroa* is very shallow, just a few centimetres deep at times, so it would be difficult for turtles to pass through here. *Oneroa* motu seems to be generally little-visited. There is a large flat area of fine-grained sand on its inland side, but unfortunately this is underwater for much of the time. The remaining beach is very narrow (1-2 metres wide) and adjoins the tree-line; there are plant roots in the sand that would interfere with nesting-activity; although hawksbill and green turtles are known to nest amongst the vegetation (White *pers. obs.*). *Ta'akoka* motu is rocky and its single beach has no sand depth.

Historically, nesting may have occurred where resorts have been built at Muri Beach; this is because there is some depth of sand available there and it is also above the High Water mark; nesting may still occur sporadically along Vaima'anga Lagoon.







Top: unsuitable beaches on east & north coasts; **then** possible nesting spots at Blackrock & *Turama*; **below** shows *Vaima'anga* and QR's residence ~ both beaches are submerged at HW; **left** shows the coast-road and a narrow beach at *Vaima'anga*.

Marine surveys

1. SEA TURTLES IN PAPUA PASSAGE

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 continually break over the reef into the lagoon; consequently the current flow in these passages can be considerable at times. The author conducted a daily snorkelling-survey at Papua Passage for seven weeks in November-December 2009.

Top: Rarotonga; Bottom: Papua Passage ~ the yellow arrow is the approximate position of the *'inner narrows and rubble slope'*. Photos courtesy of Google Earth.

The study site

Papua Passage [21°156 South; 159°456 West] is the smallest of the three passages. The landwards (northern) end of the passage is a u-shaped gully with a sandy floor (*inner gully*). The steep-sided ravine extends southwards through three sets of narrows (*inner, middle and outer*); these narrows are inter-linked by wider areas, referred to herein as: *the rubble-slope*; *middle deep; & outer gully*. Papua Passage breaches the reef to the south (approximate dimensions are: length 250 m; maximum width 30 m, depth 15-18 m).

Survey mode

A snorkelling-survey was conducted every afternoon between 13th November and 29th December 2009. Surveys typically lasted 2-3 hours and all turtle encounters were noted; some surveys included a dedicated underwater photographic session. All research began from shore: the swim across the lagoon to Papua Passage was 700-1000 m depending on point-of-entry; this was chosen daily to suit current-flows in the lagoon. On reaching the passage the western side and adjacent reef-top lagoon were assessed first, by swimming slowly along the edge of the ravine from north to south searching for turtles and other megafauna, including sharks; the eastern side was surveyed in a similar manner. If sharks were present the passage was traversed at the landwards-end of the *inner gully*; if sharks were absent the passage was crossed quickly at the *inner narrows*.

Safety considerations

Conditions in the passage could be dangerous and careful preliminary observations from shore were an important aspect of every survey plan. A good understanding of the lagoon hydrodynamics (e.g. differences between spring and neap tides; drying and submerged areas; and the influence of wind speed and direction on the current-flow, waves and tidal heights) was achieved. Underwater visibility was usually good, but could reduce under certain weather conditions (e.g. south westerly winds & current-flows).When the outflow through the passage was strong, it was unsafe to survey the outer half of the study site as the researcher would have been carried out to sea. A decision on whether to continue seawards was made each day, based on the flow-conditions at the *inner narrows/rubbleslope*. Most surveys were conducted near to low water as the outflow was usually, but not always, at its weakest then.

Findings

Two species of sea turtle were encountered at Papua Passage (Table 2): green *Chelonia mydas* and hawksbill *Eretmochelys imbricata*; *C. mydas* was the most common, being observed on 35 days; *E. imbricata* was seen on 15 days. *****Occasionally the species could not be confirmed, because of poor underwater visibility or a turtle was too far away. Turtles were seen entering or leaving Papua Passage and so they obviously use other habitats nearby, including other passages, the outer drop-off, and perhaps even the open sea; so the true count of turtles is likely to be higher.

Table 2. Species encountered per survey day.

Turtle species encountered	Number of days
Green turtle only	18
Hawksbill only	1
Green and hawksbill	14
Green and unidentified species*	3

Based on the size-class guidelines in TREDS (www.sprep.org) all turtles encountered in Papua Passage are assumed to be juveniles (<65 cm CCL); apart from two maturing male green turtles ~ based on their tail morphology (Casale *et al*. 2005; White *et al*. 2011, & 2013 *In Press*).

Table 3. Daily count of sea turtles in Papua Passage.

Number of turtles per day	Number of days
7	2
6	2
5	3
4	7
3	5
2	9
1	8
0	11

Sea turtles were encountered on 36 of 47 days in total (77% of surveys). The number of turtles observed during a survey ranged between zero and seven (Table 3); no turtles were seen on 11 days. (Mean count of turtles on days with sightings = 3.06; SD. ±1.77 turtles/day; minimum = 1, maximum = 7; n = 36 days with sightings).

The total count of turtles during all surveys was 110. Of these, 17 individual turtles (10 *Chelonia mydas* and 7 *Eretmochelys imbricata*) were seen on one or more occasions.

Identification code: individually-identifiable turtles were given a code number e.g. RP1 None of the turtles had been tagged and so their carapace and facial markings, behaviour, and any evidence of site-fidelity were used in the recognition process.

Table 4. Individual turtles encountered regularly.

Individual turtles (ID Code)	Number of days seen
Green (RP1)	15
Green (RP2)	7
Green (RP3)*	26
Green (RP5)	16
Green (RP6)	5
Hawksbill (RP12)	5

Five green turtles and one hawksbill were seen regularly in Papua Passage (Table 4).
*****One green turtle (RP3), a sub-adult male, was encountered on 26 surveys.

Habitat purpose

Habitat use was determined through behavioural observations: turtles were seen feeding, resting, swimming and being cleaned by fishes. Site-fidelity was confirmed using photo recognition evidence and behavioural characteristics.

Throughout these surveys encounters with turtles occurred entirely underwater (Berkson 1966). Breathing appears to be very infrequent (only 12 instances of respiration were observed in 47 days; in each case only a single breath was taken (duration 0.5 s) followed by another extended dive; this agrees with the findings of White (2007).

Resting underwater: several individuals had preferred resting spots, sometimes remaining at rest throughout the survey period.

RP3 (sub-adult male *C. mydas*): his regular place *'the pinnacle'* was a small, southwards facing, grotto near to the top of a coral outcrop (8 m below the surface) with a clear view seawards. This male wedged himself in by pressing his carapace against the overhang and flippers against suitable rocks; and was able to resist even the strongest currents. Another site *'the balcony'* was close to *the pinnacle*, but faced west; the turtle was only observed there once.

RP5 (juvenile *C. mydas*): this small turtle preferred to rest on the passage-floor or on the top of large boulders, where it jammed itself in against suitable surfaces depending on the current-flow; sometimes it rested inside small grottoes in the passage wall. The *rubble-slope* was used by different turtles for resting; it was occasionally used by

RP1 (a medium-sized, short-tailed *C. mydas*), although this green turtle was encountered mostly in the water column.

On three occasions juvenile hawksbills were observed entering small grottoes in the walls of Papua Passage; it is possible that on other days some animals were already at rest in such caves and their presence would not have been known.

Interaction between individual turtles: these were rare; on two occasions a smaller turtle tried to rest next to a larger turtle, but would be pushed away by the latter. In another instance a medium-sized green turtle was at rest on the *rubble-slope*, when a larger green crawled across and forced it (by biting) to move away; and then settled into the vacated spot. All other sightings were of individual animals using a shared habitat (i.e. the same locations, but at different times).

An important observation was made on 15th December (2009): five juvenile hawksbill turtles were encountered in the *outer gully* resting on coral pavement (depth about 16 m); although these animals were within a few metres of one another, their behaviour was that of individuals utilising favourable water conditions (i.e. they were not part of a group). Another hawksbill (RP12) was foraging along the passage wall and a green turtle (RP1) was in the water column nearby: <u>so seven different turtles were seen at the same time</u>.

Foraging behaviour

Hawksbills were observed foraging in the reef walls; the prey could not be determined. Typically a foraging hawksbill would have its head inside a crevice, whilst paddling with its flippers. No green turtles were observed feeding, and it is unclear what they actually eat locally (presumably some algal species, as seagrass beds are absent at Rarotonga).

One hawksbill (RP12) was observed to use an almost identical foraging route through Papua on different days. This turtle rested on the reef top by the *outer narrows* and then dived to the bottom of the *outer narrows*, foraging along the walls into the passage; it continued into the *middle narrows*, over the top of a ridge on the eastern side and swam just above the *rubble slope*, round by RP3's pinnacle - and through a cleaning station – continued to the *inner gully*, then back along the western wall; through a second cleaning station, and returned via the *middle & outer narrows*. The route took about 45 minutes to complete, depending upon the amount of time spent being cleaned.

Cleaning behaviour

Two types of cleaning behaviour were observed: i) self-cleaning, during which a turtle would rub its carapace back and forth against a rocky overhang, slowly changing position to maximise the effect; a hawksbill turned laterally through a full 360° so that its entire carapace was abraded; ii) a symbiotic process when the turtle was cleaned by one or more fish species, notably: Adult Emperor angelfish (*Pomacanthus imperator*), **<u>which is a new record</u>;** and

Striped bristletooth (*Ctenochaetus striatus*)[57].
Symbiotic cleaning was divided into 'algal-grazing' from the carapace (bristletooth), or removing ectoparasites from the flippers and soft tissue (Emperors and bristletooth). Symbiotic cleaning occurred in three different modes: i) cleaner spp. visited a turtle at its resting place; ii) turtles visited a 'cleaning station' (i.e. where the cleaners resided); iii) incidental encounters in the water column. In these midwater examples a cleaner would follow a passing turtle, which then usually stopped swimming so cleaning could occur.

[57]See also Losey *et al.* 1994.

Hawksbills and green turtles were observed in all three symbiotic cleaning scenarios, as well as self-cleaning. Turtles were observed cleaning the tips of their own fore-flippers with the beak. Symbiotic cleaning (by bristletooth) and self-cleaning could occur together (i.e. the turtle was scraping its carapace against a rock, while fishes were removing ectoparasites from the limbs or head). When a turtle was at rest, *C. striatus* cleaned the carapace and flippers; smaller-sized fishes cleaned the ventral surfaces by swimming beneath the turtle. Both green and hawksbill turtles allowed the neck, head and face to be cleaned - by both fish spp. The Emperor angelfishes tended to clean turtles in the water-column, by swimming beneath them and eating parasites from the soft tissue, especially around the tail, cloaca, and rear limbs.

Top left: resident hawksbill [RP12] it has an easily-identifiable notch in its carapace (arrowed); right: resident sub-adult male green turtle [RP3]
Centre: green & hawksbill turtles being cleaned by an adult Emperor angelfish *Pomacanthus imperator* ~ <u>this is a new record</u>
Below: green turtle being cleaned by Striped bristletooth *Ctenochaetus striatus*

2. SEA TURTLES IN RAROTONGA'S NEARSHORE WATERS

The author had been recording sightings of sea turtles during scuba dives at various sites around Rarotonga; this was limited by the number of places that could be surveyed at any one time. One aim was to determine if any turtles showed fidelity to particular sites, or if known individuals were found at different locations. In early-2010 a graduate biologist – Rhia Spall – (University of Hull, UK) came to Rarotonga as a diving-instructor and to assist with the turtle research. The two of us gave presentations at each of the dive-clubs around the island, and asked if they would be willing to contribute their turtle sightings.

There were some issues concerning confidentiality of business information: proprietors did not want the state of their businesses to become known to the other dive-schools; our solution was to regard all information as in-confidence, other than the turtle data.

The advantage of including data from other divers is that a larger underwater area can be surveyed on any particular day. At times the dive-groups are working in the same general area; dictated by wind and sea conditions, but often we are at opposite sides of the island; which clearly means we are not seeing the same turtles at that time. All dive-leaders were familiar with the local sea areas and could identify sea turtle species underwater. Dive groups might have different names for the same dive-sites.

Findings

Between 9th March and 31st December (2010) dive-groups made 158 reports; one group (**Reef-to-See**) provided 32 more in early-2011. The total count from all sides of the island was **341 turtles** (228 greens, 91 hawksbills, 22 unidentified); some of these records are repeat sightings of previously-encountered individuals. (Table 5)

Table 5. A total of 341 turtles were reported by scuba-divers from Rarotongan waters between March 2010 and February 2011; some of these are repeat sightings of individual animals. Species counts were: 228 green turtles; 91 hawksbill turtles; 22 unidentified. Table Legend: **RTS** Reef-to-See; **RS** Rhia Spall; **CID** Cook Islands Divers; **DC** Dive Centre; **DR** Dive Rarotonga; ***Cm*** *Chelonia mydas* (green turtle); ***Ei*** *Eretmochelys imbricata* (hawksbill turtle); **?** Turtle species was not confirmed.

Group	Records	*Cm*	*Ei*	?
RTS	109	188	49	11
RS	43	15	27	9
CID	14	16	5	0
DC	13	10	2	1
DR	11	3	8	1
Totals	**190**	**228**	**91**	**22**

Table 6. Synopsis of the most important locations where turtles were reported from Rarotonga. The upper three rows of data are from various sites in the North, West or South; the lower three rows are the passages in Vaima'anga Lagoon: Papua, Ava'araroa, and Rutaki – these are clearly important sites for turtles. Legend: ***Cm*** *Chelonia mydas* (green turtle); ***Ei*** *Eretmochelys imbricata* (hawksbill turtle); **?** Turtle species was not confirmed.

Dive sites	Cm	Ei	?
North	16	28	5
West	9	0	0
South	14	5	0
Papua	114	34	6
Ava'araroa	53	10	3
Rutaki	12	4	6

Turtles were observed all around Rarotonga, but the most important areas are reported in **Table 6**. The general directions, e.g. 'North' include different dive-sites, such as *'the boiler'* and *'Edna's Anchor'*. The three south-coast passages: *Papua*, *Ava'araroa* and *Rutaki* in Vaima'anga Lagoon are very important habitats for green and hawksbill turtles. There were another 22 incidental reports of turtles. Altogether **341 turtles** were reported: **228 greens; 91 hawksbills; and 22 unidentified**.

Size categories for turtles

The majority of turtles reported were of small or medium size. Larger sizes were rare: 12 *'big'* green turtles (sex unspecified); two adult female and four adult male hawksbills. Some records are probably repeat sightings: e.g. an adult male hawksbill was seen on two different occasions at *'Paradise buoy'*; it may have been the same turtle, but photographs were not taken.

Conclusions

Taken together these two studies show that *Chelonia mydas* and *Eretmochelys imbricate* are encountered throughout the year in the nearshore waters around Rarotonga. This is an important finding, given the previous deficiency of data for the Cook Islands (e.g. Maison *et al*. 2010; Woodrom Rudrud 2010; NMFS 2010).

Juveniles of both species, and immature male *C. mydas* were seen at Papua Passage, but adults were not encountered during that research phase. Repeated sightings of identifiable

green and hawksbill individuals over several months[58] showed that those turtles appear to

[58] ~~Papua Passage was re-surve~~yed by snorkellers on 5th March 2010 (following a two-month absence, surveying elsewhere in January-March). Three turtles were encountered (RP3; RP4; RP14) during this swim: all had been seen at this site since November 2009; a period of five months.

be resident, even if only in the short-term. These findings are of particular importance for the critically-endangered hawksbill turtle; these are rare animals.

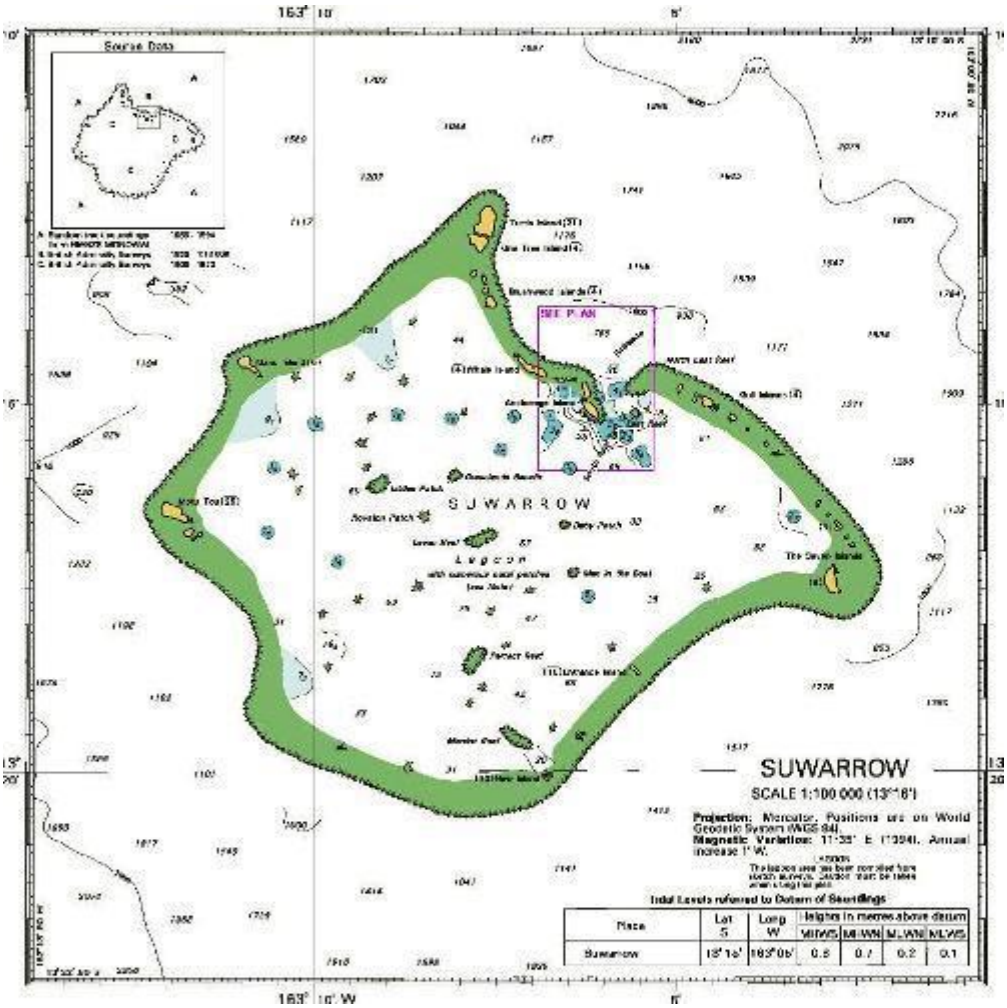
There is no doubt that a far more comprehensive assessment has been achieved using the reports from Rarotonga's commercial dive-operators. It is appreciated that data-collection is not the primary concern for dive-schools, nonetheless, the sightings have been reliable, and all group-leaders were able to identify both turtle species underwater. By working cooperatively we have investigated most of the nearshore habitats in a short space of time; effectively becoming a large research team. The reports of turtles being present at various dive-sites concur with the author's own research findings from those same sites; the passages are of particular importance (White *pers. obs.*). '**Reef-to-See'** deserves special commendation for their efforts; reporting data in every month since March 2010. *Meitaki Poria*.

In Rarotonga's nearshore waters there appears to be a ratio of just over **2 green turtles : to 1 hawksbill** [67% green turtles; 27% hawksbills; 6% could not be identified (poor visibility or too far away)]. This is similar to the Papua Passage study [91 *C. mydas*; 27 *E. imbricata*; 5 unidentified]. The sightings of hawksbill juveniles are most encouraging as there are fears that the hawksbill is close to becoming extinct in the Eastern Pacific. The Cook Islands therefore has an excellent opportunity to support these critically-endangered animals; which in turn will benefit the South Pacific region by acting as a reservoir for hawksbills. Most turtles encountered underwater locally were juveniles or sub-adults, which, if we link this to the lack of suitable nesting-beaches around Rarotonga, suggest that reproductive animals probably will be elsewhere in the archipelago.

Suwarrow Atoll [13°15 South, 163°10 West]

SWOT
THE STATE OF THE WORLD'S SEA TURTLES

Suwarrow Atoll[59] (Northern Cook Islands) is very remote and not on any commercial inter-island shipping routes; it was only visited in 2009. Hawksbill turtles are commonly associated with coral reefs (Meylan 1988) and the author has observed them swimming underwater in Suwarrow lagoon (May 2009). Nesting was confirmed from several motu when the warden returned to the atoll in April 2009; having been withdrawn during the cyclone season (John Samuela *pers. com.* 2009). No information was provided for when the nesting season begins, but it may extend until at least April. Threats and impacts have not been assessed. An expedition is now being planned for 2014.



Suwarrow Atoll (chart from NZ945)

[59]Suwarrow Atoll is a National Park (1978) administered by the Prime Minister's Office and the National Environment Service at Rarotonga. A warden is based at Suwarrow for about five months each year.

Tongareva Atoll [09° South; 158° West]

Overview

An initial assessment was undertaken on some of the motu at Tongareva Atoll; this began on 1st January 2011 and was partially-funded by a SWOT grant; studies continued for 15 months. Research concentrated on track-counts and nesting evidence, but was constrained by a lack of transportation around the lagoon; a small *vaka* was used because a motorboat was unavailable and fuel in very short supply. Nightwork was not conducted, primarily for safety reasons: the author was working alone; weather can change very quickly; some of the survey areas are remote and have wild pigs on them; it was wise when paddling in a *vaka* to return during daylight so that coral bommies and sharks were visible; logistical support was not available.

One motu – ***Mangarongaro*** – was discovered to host substantial *Chelonia mydas* nesting, this may, perhaps, occur year-round: **525** nests were found in a 5-km section during 2011; the southern-half was not surveyed, but is probably also used for nesting (Shibata 2003). This motu was selected as the first ***index beach*** in the Cook Islands; ongoing monitoring is expected to elucidate population trends.

The second research-phase began in September 2012: this is a 3-year nesting-census and genetic-sampling programme based on *Mangarongaro*, with periodic surveys of the other motu. This research has been funded by the US Federal Government (National Oceanic and Atmospheric Administration) and includes provision to train local researchers.

The study site

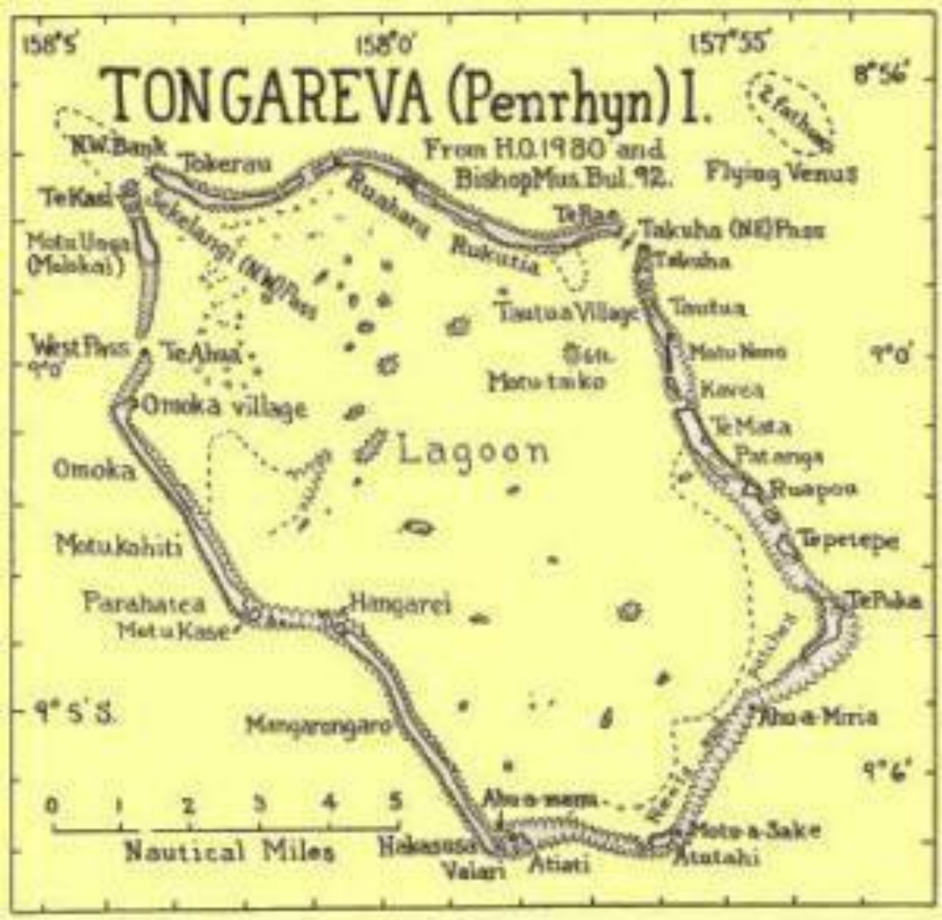
Tongareva Atoll[60] is the northeasternmost of the Cook Islands; it has the nation's largest lagoon (area 233 km2) and about 77 km of coral reef intersected by three passages *'ava'* (*Siki Rangi, Taruia* and *Takuua*). The deepest part of the lagoon is 64 m; the surrounding ocean varies in depth from 400-3000 metres (NZ 945). The atoll consists of numerous motu: all are narrow (200-500 metres wide), a few extend several kilometres (*Moananui*, *Tokerau*, *Ruahara*, *Pokerekere*, *Temata-Patanga-Tepuka, Mangarongaro*), some of the others are smaller (e.g. *Painko, Tuirai, Kavea, Atutahi & Atiati*), but there are also several minor islets; some of which have now disappeared (e.g. at *Ahu-A-Miria* only three of nine that were mapped now remain; and none at *Ahuapapa*). All motu are low-lying: the highest elevation is approximately six metres above sea level; this is a bank immediately west of the airfield on *Moananui*[61]. The two villages are: *Omoka* - on the western motu of *Moananui* (about 110 people); and *Tetautua* on the eastern motu of *Pokerekere* (about 30 people); all other motu are now uninhabited. Water is only from rainfall and there are extended periods of drought. Transportation is rare, perhaps 3-4 ships a year; aircraft are infrequent and dependent on a fuel supply being available for the return flight; this fuel is delivered by sea and may be unavailable. Electrical power comes from a diesel generator

[60]Other names include: Mangarongaro, Hararanga, and Penrhyn Island (LINZ 272/8/4)

[61]Sometimes known as Motukoiti or Motukohiti

and, because fuel is often in short supply, usually available for 14 hours per day; but may be reduced if necessary. Telecom and the Marine Resource Centre have limited solar power capability; there is one privately-owned wind-generator (Latham, *pers. com.*). Telecommunications are by satellite-link to Rarotonga and may be disrupted; there is no mobile-phone network. The atoll is just north of the cyclone belt, but can suffer heavy weather; and, in fact, many buildings were badly damaged by *Cyclone Pat* in 2010; which subsequently destroyed much of Aitutaki.

Balazs (1995) noted that in reports from the 1960s and 1970s, green turtles were known to nest at Tongareva Atoll, but there were no data on abundance or trends available; this was still the case in January 2011 (White *pers. com.*).



Tongareva Atoll. Map from Bishop Museum (Bul. 92; H.O. 1980)

Mangarongaro

This southwestern motu is by far the most important nesting site on Tongareva Atoll[62]:

The eastern lagoon-side shore is low-lying and generally unsuitable for nesting. There are several sandy areas, but these beaches are very narrow and vegetation commonly reaches the water's edge. Some beaches are inter-tidal and would require a long crawl across the drying corals if turtles tried to reach them at low water. The lagoon itself is so large that it acts as an inland sea; waves can be considerable at times and these turbulent, well-aerated waters have enabled another small coral drop-off to form (i.e. a second 'windward reef'). Sub-surface visibility is almost-always poor because of the suspended sediment. Tracks and nesting-activity were not observed along the motu's eastern side, although there were two anecdotal reports of tracks from its southeastern corner (Karika *pers. com.*; Maretapu *pers. com.*).

In contrast the western beaches (leeward reefs) are high-energy dynamic habitats that are used by nesting green turtles. Beach structure varies from place-to-place, but is usually steeply-sloping: some sections have fine-grained sand (e.g. *Manoro* and *Mahera*); some are *kirikiri* (e.g. *Tevete*); other areas have large coralline-rocks or boulders; and a few had a semi-exposed underlying coralline pavement; the final type was a rocky inter-tidal zone that would be unsuitable for emergence or nesting. Substratum coarseness appears to be related to the wave energy impacts: finer grains at low energy sites and large boulders at the highest energy sections. *Mangarongaro* is approximately nine kilometres in length; the northernmost one kilometre is 'Type C' but was re-surveyed occasionally. The main nestable zone along the western side was split into three sectors:

Northern: ***'Mahera'*** (3 km in length)
Central: ***'Te Toto'*** (2 km in length)
Southern: ***'Hakasusa'*** (3 km in length)

Author's note: for practical reasons only the northern and central sectors were surveyed in 2011: a two-way journey by *vaka* paddling from *Moananui* (Omoka) usually took 2-4 hours depending on the wind-direction and sea-state; then the 5-km nesting-beach survey from *Mahera* to a rocky section south of *Te Toto* and back again took 6-8 hours: this is all that was achievable in a day.

Nesting emergences and nest locations

Several areas had concentrations of nesting: e.g. 10-15 nests being laid fairly close to one another (within 30 m): these concentrations of adult emergences tended to be near small passages (*ava*) through the reef; individual nests were also interspersed along the beach; including at places that had very poor access from the ocean. Typically, 80% of nesting emergences were on sand, 15% over *kirikiri*, and 5% across pavement or rocky sections.

[62] An order of magnitude greater than the other motu.

Most nests were laid in vegetation at the back of beaches (Mortimer 1995a); this cover varied from place-to-place, but included coconut-groves; sections of *hara*; mixed-forest of *hara, tausunu, hano* and *ngangie*–and very occasionally a *tamanu* tree. Nests were often laid underneath *hara* or coconuts and covered over with *nikau* (palm-fronds) and *hara* leaves; occasionally turtles had ventured about 15 metres inside the forest before nesting, but more usually the nests were laid within 1-5 metres of the beach.

In those sections where vegetation consisted of low-lying shrubbery *(ngasu* or *tausunu)* at the rear of the beach: nests were either laid along the margin, or else turtles pushed their way into the bushes before digging the egg-chamber. Occasionally females searched for some time to find a suitable nest site (i.e. a long up-track), but there were no non-nesting emergences (i.e. a turtle failed to find a suitable nesting site) and only one U-turn[63] (i.e. a turtle crawls onto the beach, but then returns to sea without making any effort to excavate a nest): in other words if females came ashore they appeared to nest satisfactorily. Very few tracks had more than one body-pit (only seven in 2011). Digging multiple body-pits usually occurs when a female encounters some obstruction, such as a rocky layer, during the first attempt, but then she moves a short distance away and often nests successfully at this second site. A small number of nests (2%) were laid mid-beach (n = 15 in 2011); these might possibly be overwashed during high tides.

An important observation from *Mangarongaro* was that turtles stranding from the ocean around high water would only have a short distance to crawl before locating a suitable nesting spot (see Allen 2007). At times the upper strand-line reached the bushes, although more usually it was a few metres away from them. It is assumed that the beach-slope provides sufficient drainage for the sand at nest-depth; sediment water-content was not measured, but some test-holes were dug to nesting-depth and the sand felt suitable for the successful development of eggs.

A second advantage for emergent females would be that access over the reef, especially when traversing nearshore ridges, would be much easier close to high tide; and it appears likely that the time needed to lay eggs and return easily to the ocean could be achieved around this period. It would also explain those nests laid in areas with poor ocean access: turtles crossed the raised barrier on the rising tide. Local anecdotal evidence suggests that turtles nest at New and Full Moons: this would actually coincide with spring tidal-range (i.e. higher HW and lower LW); however, Witzell (1983) reported that more [hawksbill] turtles nested at the neap tides (i.e. Quarter Moons). In either case a 2-week inter-nesting interval is biologically accurate.

In late-August 2011 a *tsunami*-effect caused excessively-high waves for four days (it was also reported from Manihiki Atoll). One unfortunate consequence of these huge waves is that some nestable-sectors were stripped of sand, leaving only rocks or pavement. This is the opposite scenario from that noted in the methodology, however, it does provide an opportunity to study beach-dynamics: i.e. how long does it take for a nesting-beach to recover from such an impact? [**About a year.** White *pers. obs*. September 2012].

[63] The first U-turn was found on 6th January 2012 and it appears that the turtle re-emerged about 30 m south and nested successfully; this was based on the track characteristics.

A variety of habitats on *Mangarongaro*: the *'ava'* are important emergence spots for females: the substratum appears to be of secondary importance compared with ease of access from the ocean

Multiple emergences; these sites will be marked with GPS in the 2013 research phase

Top: Female came over the rocky foreground area, headed towards a boulder zone, then came back to the left and nested in the shrubbery at the back of the beach; **Bottom:** Uptracks can be quite extensive as the female searches for her nesting spot (not shown), downtracks to the ocean are usually more direct

C. mydas nesting sites: many are in the shade apart from in the late-afternoon

Top: turtles crawl through the vegetation margins into the forest; **below:** nest laid under *hara*

Nests laid mid-beach are very rare: 15 out of 554 nests in 2011

Some nesting-beach sectors have nearshore coral barriers on top of the reef, but these can be submerged at high water allowing turtles to swim over them

Top: close to low water; waves indicate the drop-off; **Below:** close to high water

Top: strand line can be seen to the right, very near to the bushes where eggs are laid;
Below: *tsunami* at the end of August 2011 created very high waves for four days

The nesting species

In 2011 most, if not all, tracks made by emergent females were those of green turtles. Six tracks (4 were found on 3rd January 2011; & 2 more on 6th January 2012) may have been made by hawksbill turtles, because the patterns suggested asymmetrical locomotion had been used, rather than the simultaneous shifting of both fore-flippers favoured by green turtles. It is possible that some individual *C. mydas* use asymmetric movements on land. No hatchlings were found either; which would have confirmed the reproductive species.

The two left-hand pictures show the symmetrical movement normally associated with green turtles (& leatherbacks): as they move both fore-flippers simultaneously. In contrast the righthand images suggest that the more-usual asymmetrical reptilian gait, where diagonally-opposite limbs are moved together, might have been used; this form of terrestrial locomotion is used by the five other sea turtle species, of which the hawksbill seems most likely at Tongareva Atoll

Using the age of tracks to determine the nesting period

Given that the nesting period is unknown, tracks found on the beaches were used as a guide to show when egg-laying may have occurred; this was especially important during initial surveys when evidence from previous years might still be visible. It was usually possible to determine the approximate age of adult tracks, and some supporting evidence is shown below. Tracks that crossed *kirikiri* sections required greater observational skills; and obviously imprints were not left on the rocks or pavement.

Very recent and very clear emergence track

Top: track is about 3 weeks old. **Below:** recent track crosses an older one on the right and another recent one to the left

Top: left-hand track is 2-3 weeks old; the adjacent right-hand one is about 7-8 weeks old; **Below:** the nearest track is also 6-8 weeks old

Top: track is probably over two months old; **Below:** nest is about 6-7 weeks old

Top: up-track and down-track over *kirikiri*; **Below:** nest in coarse substratum (notebook A5)

Some survey details from *Mangarongaro*:

The initial survey (3rd January 2011) found 91 nests, as well as some egg-shells in the vegetation (some of these looked to have been on the surface for about five weeks; which suggests a nest-date of October 2010 (based on 60-day incubation). The following survey was five weeks later (5th March 2011) and noted 106 new nests: the oldest 16 tracks were not included to avoid possible duplication of data from 3rd January 2011 (i.e. there were 122 track-pairs identified in this survey).

The next survey was conducted several months later (13th August 2011) and found 55 more nests. The absence of a survey in June means that the least clear period was mid- March to late-April. In August there were recent signs that turtles had been captured or killed (confused turtle tracks, human footprints and signs of scuffles) and there was also one nest that had been dug up and the eggs removed (this was definitely done by a human and not animal predation). It is likely that some nests laid during this winter would have been lost in the *tsunami* at the end of August (four days with very high waves); there was also considerable rain during October and November. Ian Karika (*pers. com.* 28/09/2011) reported five more nests.

The most interesting survey was on the **16th December 2011** - based on the age of tracks: 165 nests had been laid since the start of November. This means that there are at least 55 female turtles laying just on the northwestern half of Mangarongaro (i.e. if each turtle had laid three nests during the six-week period: n = 165)[64]; there is a good possibility that there are more reproductive females than this; and it is the focus of the phase 2 research. The final survey of phase 1 was made on 6th January 2012. There were 50 new nests and also the first U-turn track was noted: the turtle had crawled about 15 metres up the beach and then reversed direction and returned to the ocean (no digging had been attempted). The track pattern was very similar to a second track about 30 m south, and so the same female may have re-emerged there and nested successfully.

If hawksbills are actually nesting at this site then December seems to be the important month (4 asymmetric tracks being found in early-January 2011; 2 more in January 2012). A better understanding of the nesting species will be gained during the latest phase.

Table 7. Tracks of emergent females that led to nests are reported for three motu. Most emergences were *C. mydas*; however, six tracks***** may have been made by *E. imbricata*; this is unconfirmed and so perhaps all nests were laid by green turtles. The three nests at Matunga were reported by Ian Karika during a bird survey; the species was not confirmed.

Motu	Green	Hawksbill	Unidentified	Total
Mangarongaro	519	6*	0	525
Moananui	26	0	0	26
Matunga	0	0	3	3
Grand total	545	6*	3	554

[64] The inter-nesting period for marine turtles is typically around two weeks between successive nests.

Table 8. Estimated dates-of lay. Track-age, egg-shells and assumed incubation period were used to show when nests may have been laid. The first survey in Phase 1 was 03/01/2011 & the final one 06/01/2012; due to a lack of transport surveys were limited in the middle part of 2011 (March was data-deficient DD). Two further surveys were conducted in September 2012

	Estimated number of nests			
Month	**2010**	**2011**	**2012**	**Total**
January	x	8	15	23
February	x	107		107
March	x	DD		DD
April	x	1		1
May	x	40		40
June	x	32		32
July	x	18	14	32
August	x	5	44	49
September	x	5	40	45
October	17	6		23
November	1718	100		118
December	1885	97		182
Totals	**120**	**419**	**113**	**652**

Based on the available evidence (tracks, nests and hatched egg-shells in the nesting-zone) and using an assumed incubation period of 60 days it is possible (Table 8) that **nesting may occur all year-round, but probably not at all sites.** (March 2011 was datadeficient, but green turtles were still observed in the lagoon at that time; the author was at Manihiki in September). These data show the Phase 1 findings from just three motu: with 525 nests in the northern half of Mangarongaro alone (Table 7 above). The author left Tongareva in March 2012 and returned in the September for Phase 2: when the initial survey at *Te Toto* found 38 nests; and then 60 nests were counted a week later at *Hakasusa*. Subsequent data will be included in the 2013 report to NOAA.

Top: First survey of phase-2 (September 2012) found three nests laid overnight ~ damp sand has not had time to dry and broken leaves still fresh; **bottom:** another fresh nest, but with an older track beneath it.

Moananui

The western (leeward) shore was subdivided into three sectors:

1) Northernmost sector: this is adjacent to Omoka village and consequently people are often on the beach (fishing on the reef, collecting marine gastropods, feeding their pigs, which are usually housed nearby; and making charcoal in the sand). The northernmost part (*Motu Ngangie*) is rocky and mostly dry; an often-exposed reef that continues north to motu *Seniseni* is also rocky and unsuitable for nesting. Some places are covered in boulders, but a few sites have good quality sand of sufficient depth for egg-development. Vegetation was mostly coconuts and a few small areas of natural forest (e.g. *hano, hara, ngangie, tamanu*). Sand extraction occasionally takes place here. No tracks or nests were found in this sector; however, *Seniseni* (by *Taruia Passage*) does have an occasional nest.

2) Central sector: this starts at a boulder-covered zone (about 80 m long) that adjoins the Northern sector. It then continues southwards as far as the airport, and mostly comprises sandy beaches. There are several buildings, but these are mostly clustered together and include: Telecom’s satellite-dish, the power-station, the hospital, and Marine Resources Centre; there are also some houses, but far fewer than at Omoka. Several areas have good quality nesting sand and reasonable access over the reef, but in some places a raised coral barrier (1-2 m high) is present that runs parallel with the shore. Vegetation is more mixed with areas of coconut, *hara* and flowering shrubs (*ngasu* and *tausunu*); considerable amounts of garbage were found in the forest nearby. No tracks or nests were seen in this sector; which seems curious given that the sand appears to be suitable for nesting and access from the ocean is good in many places.

3) Southernmost sector: this section starts by a small constructed wall adjacent to the airport’s Radar buildings, and continues southwards to the end of the motu. There is only one other building; which is a half-built shack in the forest near the southern end. Sand and gravel extraction occurs very occasionally; a bulldozer drives through the forest onto the beach at two places beside the runway. Vegetation is much more variable, with some sections of coconut, others with just *hara*, and still others with *ngasu*: all nests observed on *Moananui* were laid in this sector, and mostly in its southernmost kilometre. Between December 2010 and May 2011 there were **26 nests**, the last three being laid in May 2011. They hatched successfully in late-July: unfortunately this fell between two surveys and so no hatchlings were seen. Only two tracks had two body-pits, and none of the tracks were asymmetrical, so they are all presumed to be *C. mydas*.

It is unclear why this motu has such a low abundance of nests compared with the northern part of *Mangarongaro*; these sites are approximately 4 km apart by sea. Sand quality and ease of emergence from the ocean appear similar at both places. The underwater habitats on the leeward reef have not yet been examined and perhaps these will provide important clues; the author has planned scuba-diving surveys on these reefs in the future.

Moananui: Northern sector before and after the *tsunami*

Moananui: Central sector ~ Tins and lead-acid batteries dumped in the forest nearby

Southern sector: tractor access & a good nesting area

Matunga-Tekasi

Much of the shoreline consists of hard, sharp, coral with some areas being inter-tidal (e.g. between *Matunga* and *Tekasi*); there are a few sandy areas on the western side (leeward reef) leading into the forest; nesting may occur here in some years. The only evidence seen was two disturbed areas of sand that might possibly have been tracks, but they were several months old and ill-defined. On the eastern side by the lagoon the trees mostly came to the water's edge and so nesting is unlikely. Two little beaches on the south coast are sandy with access from the lagoon, but these were narrow, water-logged, heavily covered with fallen vegetation, and poorly-suited for nesting. *Tekasi* is smaller, rockier, and sand-depth tends to be quite shallow. Most sites on these motu are Type C, but there are a few Type B areas; so nesting is possible but unlikely to be substantial.

Ian Karika (*pers. com.* October 2011) reported seeing tracks on the reef-side of *Molokai*[65] during his bird surveys (late-September 2011, nests not quantified; & **three** more **nests** in mid-October 2011). Species were not identified.

Matunga: narrow water-logged beaches with dense vegetation; unsuitable for nesting

Notes:

i) Matunga is sometimes called *'Motu Unga'*.

ii) The author's *vaka* was frequently rammed with great force by sharks, especially in sea areas to the north of *Taruia Passage*; it was holed and sunk in March 2011. During the initial survey of *Matunga* nine such incidents occurred during a six-hour period: most of the attacks (n = 7) were made by black-tip reef sharks (*Carcharhinus melanopterus*), but the species was not determined in two other strikes.

[65] This name does not occur on most maps, but refers to the southern section of Matunga (Bishop map).

Pokerekere-Tuirai-Veseru-Takuua

Tetautua village is sparsely-populated (usually 30-40 people) and situated mostly in the northwestern part of *Pokerekere*. The eastern shorelines of these motu have the windward reef drop-off close to shore (15-25 metres away), hard and jagged inter-tidal zones, and then steeply-sloping shorelines composed of medium-sized coral boulders; the denselypacked vegetation adjoins the narrow boulder-zone and there are very few places that allow access into the forest. As with *Matunga* motu mentioned above there are occasional areas of sand that could support nesting in some years; and also some sections of *kirikiri*.

Typical eastern shore of Tongareva Atoll: the windward reef is close to shore

The inter-tidal zone between each motu is hard substratum; even at high water these are shallow and would be difficult for a turtle to swim over

A sandy area on the eastern side by a small semi-enclosed lagoon would have been the motu's best nesting site; but because of easy vehicular-access, it is used extensively for sand-extraction to meet the island's building needs. *Pokerekere's* second nestable area would be a small beach just across from *Kavea* motu.

Unfortunately this is heavily polluted with anthropogenic waste, particularly **disposable nappies** (diapers); the author wrote to the PM's Office advising an environmental review of waste-disposal arrangements in the Outer Islands (White *pers. com.* 2011).

Pokerekere's southern beach looking towards *Kavea*; the yellow box shows disposable nappies.
The chart from NOAA gives a biodegrading time of 450 years for disposable nappies!

The leeward lagoon-side beaches are very narrow and water-logged; thus poorly suited for egg-development; a small road runs beside these beaches and sand-extraction occurs. This part of the lagoon has a sandy substratum with very little marine vegetation and few coral bommies; it is not an ideal foraging or resting habitat for turtles; but **hawksbills** are seen occasionally underwater by fishermen. Therefore, nesting on these eastern motu would occasionally be possible, but is unlikely to be substantial.

Direct-drop ‘dunny’ at Tetautua

Temata-Patanga-Tepuka

A similar situation to *Pokerekere* above, the eastern windward coastlines of these motu tend to have the reef drop-off close to shore (often 15-20 metres away), hard and jagged inter-tidal zones, some sections of *kirikiri* and steeply-sloping shorelines composed of medium-sized coral boulders; there is one section of very shallow lagoon with patch reefs to the southeast of Tepuka. The adjacent ocean is about 1500 m deep; prevailing winds and seas are usually northeasterly, easterly or southeasterly. This complex consists of several adjacent motu with gaps in the vegetation cover; there are a number of inter-tidal areas; some islets are small, perhaps rocky, with low thorny scrub; there are a number of saltwater ponds and Type C sectors going onto the reef. Nesting was not found, but has occurred historically: with emergences only along the lagoon side (Tini Ford *pers. com.* 2012); several of these beaches are Type A***** sites although quite narrow; and some of the motu have fine sand in the forest, with easy access from the lagoon; so egg-laying may even occur in the interior. The absence of nests on *Pokerekere* just to the north of here is probably due to it being inhabited; the lagoon habitats are broadly similar to these at Patanga.

Top: Windward-reef intertidal zone; **Below left:** no nesting area under vegetation; **right:** submerged at high water and no sand-depth.

Top: no place to nest; **bottom:** good sand & easy access from lagoon, but beaches are very narrow

Clean soft sand inside the forest at Patanga could support nesting; **below:** lagoon side of Tepuka

Tokerau-Painko-Ruahara

The ocean by these northern motu deepens quickly (1000-2500 m) and the reefward sides are poorly-suited for nesting (mostly Type C). Occasionally nesting has been observed in the past along their lagoonal beaches and turtles have also been encountered inside the forest (Tini Ford *pers. com.* 2012), but **no nesting activity** was found during 2011 (White & Karika *pers. com.*).

Siki Rangi Passage. Northwest of Tongareva looking to southeast (diagonal distance is about 21 km). From the passage the motu along the left foreground are: *Tokerau, Painko* and *Ruahara*. To the right: *Tekasi* and *Matunga*; continuing to *Taruia* boat-passage and *Seniseni* motu. [Photo: Ewan Smith, Air Rarotonga].

Ahu-A-Miria, Atutahi, Moturakina, Atiati & Vaiere

Several small motu extend across the southernmost part of the atoll's reefs. *Ahu-A-Miria, Atutahi* and *Moturakina* have yet to be surveyed. *Atiati* and *Vaiere* form a small complex immediately to the east of *Mangarongaro's* southern tip. These are mainly forested with coconuts and some *ngasu*; and support considerable seabird nesting colonies. No signs of nesting were found: beaches are narrow and can be overwashed, but, because access for turtles from the lagoon is good, occasional nesting may occur. There are patch reefs, and accessing these motu by boat can be challenging as the water depth over the corals is very shallow. Subsurface visibility could be the best in the entire lagoon; visibility is mostly poor (0.5 to 5 m) because of suspended sediment, although on rare occasions the lagoon floor is visible in shallow waters.

The *Vaiere* and *Atiati* complex of motu: coconut forest, *ngasu*, and narrow beaches

Incidental observations of turtles in the marine environment

There were 58 incidental observations of *C. mydas* and three of *E. imbricata*. Green turtles were seen regularly in the lagoon, often quite close to shore, most sightings were single animals: there was one record of *C. mydas* mating at *Taruia* passage (13/02/2012) ~ the male was an extremely large animal (about 1.8 m overall length). Otherwise group behaviour was not observed, but occasionally two turtles were within about 30 m of each other. Fifteen sightings were from boats, one whilst snorkelling; the rest were made from shore. 46 records occurred as the turtles surfaced to breathe.

Only three hawksbill turtles were seen during almost two years of study i) an adult-sized female foraging in the lagoon east of the airport (13th August 2011); ii) a small juvenile hawksbill was caught by some children playing near to *Motu Kasi* (5th January 2012) and retained for a few minutes before being released again (A. Maretapu *pers. com.* 2012) ~ the author arrived about five minutes later from another survey and questioned all of the witnesses; definitely a hawksbill; iii) a small juvenile swimming through *Taruia Passage* (27th September 2012). **Author's note:** a respondent at *Tetautua* said that he *'regularly'* saw small hawksbills underwater in the eastern lagoon when he was fishing; but there are no details.

***

Additional information

Not all sites have been visited yet: the lagoon is a considerable size and the southeastern corner, in particular, is quite remote. The author does not have a motor-boat and fuel was generally in short supply for approximately eight months (in two periods); so there was little boat traffic. Initially the author used a *vaka*, but this sustained damage following shark attacks and sank (5th March); it was not repaired until early-August; consequently Mangarongaro was unsurveyed during that period. Ian Karika found some turtle tracks during his bird-nesting surveys; these included three nests on *Matunga Motu* (Table 7). The beaches of Moananui were still walked regularly, but no tracks were found after May 2011. The author was at Manihiki Atoll during September 2011 (Lifeskills) and then departed from Tongareva in late-March 2012 to lead the Rufford Trust Expedition to Palmerston Atoll; there was no return transport north until early-September 2012.

Incidental captures & mortalities

Two turtles have been tagged (Table 9): both were *Chelonia mydas* juveniles that were captured for food (Table 10); on each occasion the hunters ate a larger one, but allowed the smaller turtle to be measured, tagged and released; thus providing an educational opportunity. DNA-samples were not collected as juveniles are not presently a regional priority for genetic characterisation (Irene Kinan-Kelly *pers. com.* 2011).

One dead green turtle was discovered on the eastern shore of Mangarongaro (6th January 2012): its cause of death was not ascertained. The carapace was split in two along the spine and the internal organs were visible, also three of the flippers were missing; but this could all have occurred post-mortem. The head was still intact.

Table 9. *Chelonia mydas*. Two juvenile green turtles captured for food were tagged and released at Omoka, Tongareva Atoll in 2011.Curved carapace length and width (CCL & CCW) are reported in centimetres. # Kentucky inconel tags were inserted into the anterior flippers.

Record	Date	Time	Site	CCL	CCW	Left #	Right #
TOR001	15/02/2011	21:30	Omoka	53.0	47.5	RI00501	RI00502
TOR002	14/08/2011	09:00	Omoka	51.5	47.0	RI00504	RI00503

Table 10. *Chelonia mydas*. Known instances of turtles captured for food, Tongareva (2011): [a] the smaller turtle was netted and then released (Table 9, TOR001). Mangarongaro is the major nesting beach on Tongareva; so those turtles were females taken during nesting. CCL was estimated as being 48.0 & 65.0 cm for the two juveniles in TOK002***** [The author knows all of the hunters, but this is in confidence for the present].

Record	Date	Time	Site	Capture	No.	Size	Sex
TOK001	14/02/2011	Night	Mangarongaro	Hand	2[a]	Adult	F
TOK002	02/07/2011	Night	Lagoon	Net	2	Juvenile	?*****
TOK003	12/08/2011	Night	Mangarongaro	Hand	1	Adult	F
TOK004	23/08/2011	Night	Lagoon	Net	1	Adult	F

Dead green turtle found on the eastern shore of Mangarongaro (06/01/2012)

Threats and Impacts

i) Predation:

Some islanders do catch and eat turtles, with nesting females being preferentially targeted (they are turned upside-down while nesting and then killed later): at Tongareva Atoll hunting was intentional or opportunistic; at Palmerston it tended to be opportunistic. Some animals were captured (by net at Tongareva) or speared at sea; usually shot through the head. At Rakahanga Atoll turtle take was opportunistic: animals were encountered incidentally whilst spear-fishing; there were no instances of ceremonial or special occasion use (Galbraith 2012). Turtles were **not** caught as bycatch in subsistence fisheries. Egg-take now seems to have largely gone out of fashion (White *pers. obs.*); there was one instance noted at Mangarongaro; early-August 2011. On some atolls pigs (*Sus scrofa*) appear to excavate nests occasionally for the eggs (White & Karika *pers. obs.* 2011); and on Manihiki feral pigs have been known to attack and eat nesting female turtles (Jean-Marie Williams *pers. com.* 2010). Dogs seem to be absent[66] from the northern atolls (also see Hamann *et al.* 2006). Other potential terrestrial predators include rats (*Rattus exulans*; *R. rattus*), crabs, particularly the Butcher Landcrab (*Cardisoma carnifera* **"tupa"**); and probably some seabirds do eat hatchlings. Large fish (grouper & tuna spp) are reported to gather near nesting beaches when hatchlings enter the sea (several people mentioned this during casual conversations; White *pers. com.* 2012).

ii) Pollution:

The distribution and impact of anthropogenic pollution is a global issue, especially in the marine environment (e.g. Stefatos *et al*. 1999; Sherman 2000; Derraik 2002; Moore 2008; Barnes *et al*. 2009; Gregory 2009; Ryan *et al*. 2009; Thompson *et al*. 2009; White *et al*. 2009). There is also serious concern that the functioning of the marine ecosystem is being altered; as well as its ability to recover (Sherman 2000). Impacts of waste on sea turtles are well known; particularly for plastics, persistent chemicals, environmental oestrogens and heavy metals (e.g. Fritts 1982; Balazs 1985; Gramentz 1988; Schulman & Lutz 1995; Godley *et al*. 1998, 1999; Tomas *et al*. 2002; Maffucci *et al*. 2005; Witherington & Hirama 2006).

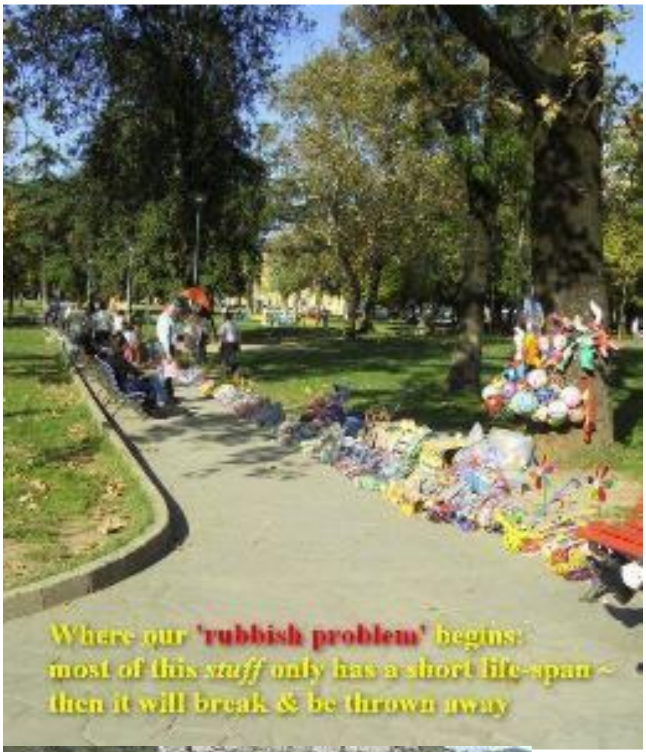
The extent of this impact in the Cook Islands is unclear. The author raised the issue of persistent/hazardous waste, especially plastics, in the atolls with the PM's Office; the National Environment Service is investigating options for effective waste-disposal from these remote locations. A research yacht – *Sea Dragon* – visited Tongareva in May 2011 and presented some findings from the Northern Cooks, including Suwarrow (they towed a fine-mesh plankton-net to obtain sea-surface samples): samples were heavily polluted with plastic fragments (Emily Penn *pers. com.* 2011). A Canadian yacht crew (*Camdeboo* www.camdeboo.ca) found widespread plastic waste on Suwarrow Atoll (removing some); and also many spirits bottles that probably came from a cruise-liner (the labels were reversed so that they would be readable on an optic; C. Good *pers. com.* 2011).

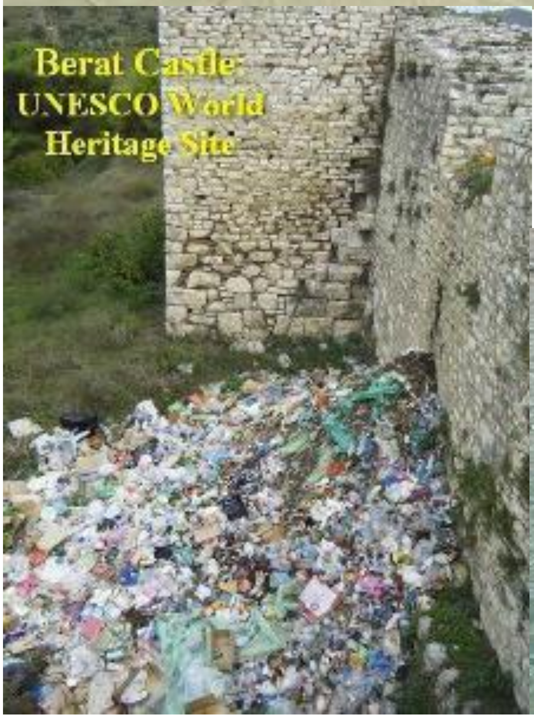
[66] Anecdotes suggest that dogs were prohibited as they were believed to be vectors for leprosy.

Fortunately the Cook Islands do not suffer to this extent[67]: BUT anthropogenic waste is a major global problem and people need to become aware of their role in this impact. Our studies have shown that most of the debris came from the ocean; very little was derived locally ~ and, in fact, on the Outer Islands everything is precious - plastic bottles or bags will be used many times over and passed around the community (White *pers. obs.*). BUT: we still end up with the rubbish from elsewhere. It appears unlikely that people really understand what happens to their waste: they throw it away; it is then collected and taken elsewhere … then what? A substantial amount obviously ends up in the oceans.

Waste begins its journey near to human habitations: these photos show it then becomes river-borne; the rivers flow into shallow coastal seas; and this *marine* debris is distributed through the global oceans. Much of this waste is manufactured from plastics

[67]This bay (above) extends for more than 40 kilometres; most of the debris was manufactured plastic items.


Where our 'rubbish problem' begins:
most of this *stuff* only has a short life-span ~
then it will break & be thrown away


Berat Castle:
UNESCO World
Heritage Site

All of this and much more was collected from **Rakahanga's** southeastern beach. The cleaned section is only 800-metres long and between 20-50 m wide. All the debris had come from the ocean (the prevailing waves impact here): **94% of the 1595 items** were made of some type of plastic: this has serious long-term effects given the biodegradation periods involved (see above under Tongareva). A further problem locally is that the only realistic option is to burn the rubbish: these atolls are only a metre or two above sea level, so insufficient depth for a land-fill site.

"Green tides"

Twice during 2012 Tongareva's lagoon suffered from widespread algal blooms (Georgia Langdon & Mataora Marsters *pers. com.* 2012): the cause was unclear. Samples were sent to the MMR laboratory at Rarotonga; accompanied by some photographs.

During the author's survey of Temata-Patanga-Tepuka on 17th October 2012 a large area immediately west of Tepuka motu was found to be in a similar condition (**photo**). There is no farming activity on Tongareva and no terrestrial run-off, so presumably these events are triggered elsewhere? (White *pers. com.*)

iii) Fisheries:

Industrialised-fisheries are a known cause of incidental capture, injury and mortality of sea turtles (bycatch). This occurs from both entanglement and the animals eating the bait directly (e.g. Henwood & Stuntz 1987; Skillman & Balazs 1992; Aguilar *et al*. 1995; Hall 1996; Gerosa & Casale 1999; Panou *et al*. 1999; Polovina *et al* 2000; Starbird & Audel 2000; Lewison *et al*. 2004; Casale *et al*. 2005; Moloney 2005; McCarthy *et al*. 2006; Lewison & Crowder 2007; NMFS 2010). Long-line fisheries were shown to impact mostly on smaller turtles (e.g. Crouse *et al*. 1987; Laurent *et al*. 1998; Heppell *et al* 2005; White 2007). Cook Islands territorial waters are fished extensively by other countries, which provide an important source of revenue for the nation. However, this also means that endangered species are killed or injured in Cook Islands waters by fisheries of other

nationalities[68].

The extent of sea turtle bycatch, and subsequent mortality levels, is unclear for Cook Islands waters, although limited data are collected by MMR (Ministry of Marine Resources) from the offshore-fisheries (P. Maru *pers. com.* 2010). NMFS (2010) reports that the US pelagic-longline fleet, based at PagoPago, has caused green turtle mortalities in Cook Islands territory; and furthermore they calculated the post-hooking mortality rate to be 92%. The author interviewed fishing-vessel captains about their sea turtle bycatch and sightings whenever the opportunity arose. Two longliners visited Tongareva briefly during 2011, both provided information about their sea turtle bycatch:

i) 04/01/2011: *Viking Spirit* ~ operates out of PagoPago (American Samoa) and has only caught one turtle in the last decade: a juvenile green turtle (CCL 40 cm; 2008). Fishing depth varies, but mostly the sets are deep; down to 600 m.

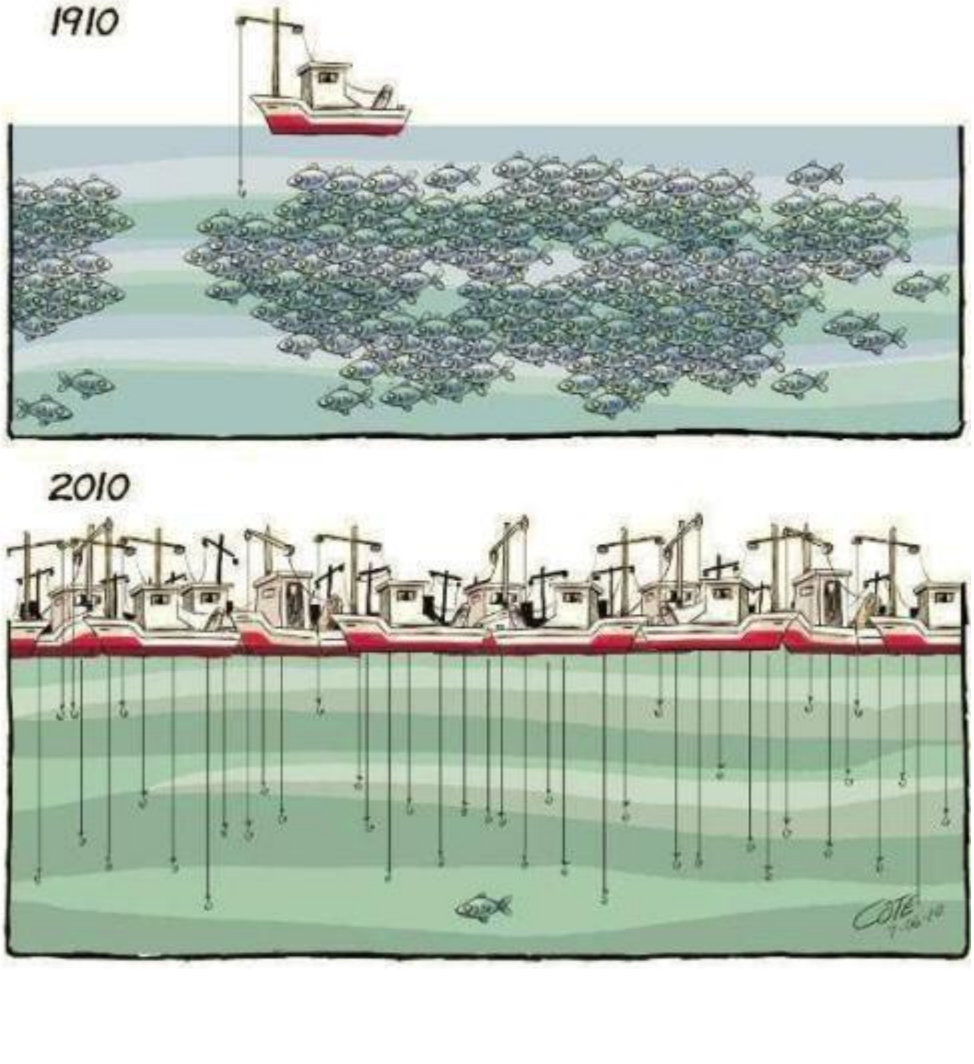
ii) 25/08/2011: *Leah Dawn* ~ works mainly in the Southern Cooks. No turtles have been caught and they are rarely seen either (one a year is considered to be a lot); fishes deeper than 150 m.

iii) Discussions were also held with Allen Mills at Aitutaki (fishing@aitutaki.net.ck) and he said that his long-liners working in the South Pacific have not caught sea turtles either.

Given the global reach of intensive-fishing operations (Roberts 2007) it seems likely that the true impact on sea turtles is considerable (White 2007 & **endnote v**)v. The two images below were sourced from colleagues via www.FaceBook.com (accessed in October 2012).

Upper ref: 189867_10150123752693034_544958033_6806034_6019088_n.jpg.
Lower ref: 402399_10150520096797135_605347134_8841226_1336810887_n.jpg.

[68] US longliners from American Samoa fish in an area spanning: latitude 03° to 32° South; longitude 155° to 180° West: this encompasses the entire Cook Islands EEZ (NMFS 2010).


1910
2010

iv) Climate change:

The actual effects of global climate change on sea turtles are still unfolding (e.g. Hawkes *et al*. 2007, 2009; Chaloupka *et al*. 2008, 2008a; Witt *et al.* 2010), although recent biological trends appear to have been significantly influenced by climate-change phenomena rather than through natural variability (e.g. Lascaratos *et al*. 1999; Parmesan & Yohe 2003; Trenberth *et al*. 2007; NMFS 2010). There are very few studies or data available from the South Pacific Island Nations (NMFS 2010). Several impacts have been identified that include: loss of nesting sites through sea level rise (e.g. Sem & Underhill 1992; Fuentes *et al*. 2009; Webb & Kench 2010); altered ocean chemistry and temperature, which may also cause changes to coral reef and seagrass ecosystems (habitats that are known to be used by sea turtles for resting and foraging); changes in food availability (e.g. Brodeur *et al*. 1999; Attrill *et al*. 2007); temporal changes for egglaying (Solow *et al*. 2002; Weishampel *et al*. 2004); increased frequency of cyclones (Webster *et al*. 2005; Pike & Stiner 2007); and elevated sand temperatures (e.g. Fuentes *et al*. 2009a): this latter point means that sex ratios of turtle populations may shift towards female-dominance. The process of sex-determination[69] in certain reptiles (e.g. chelonians & crocodilians) is now well understood (e.g. Bull 1980; Mrosovsky 1980, 1988; Yntema & Mrosovsky 1980; Limpus *et al*. 1983; Davenport 1989, 1997; Georges *et al*. 1994; Miller 1997); and some sea turtle nesting populations are already becoming skewed towards producing a majority (60-99%) of female hatchlings (e.g. Chan & Liew 1995; Godfrey *et al*. 1996; Marcovaldi *et al*. 1997; Binckley *et al*. 1998; Godfrey *et al*. 1999; Godley *et al*. 2001; Oz *et al*. 2004; Kaska *et al*. 2006; Zbinden *et al*. 2007; NMFS 2010). So a second route to extinction for turtles would be an absence of males; or an absence of females for crocodilians (White 2007).

The thermal regime in developing nests is unknown for the Cook Islands and so *Honu* is undertaking some experiments, initially as part of the Phase 2 study at Tongareva, but then at other sites. Temperature data-loggers will be buried at nesting-depth to determine the thermal profiles at various locations. It may be that the nests laid in the forests will be capable of producing male embryos, thus increasing their conservation importance.

El Niño and La Niña events

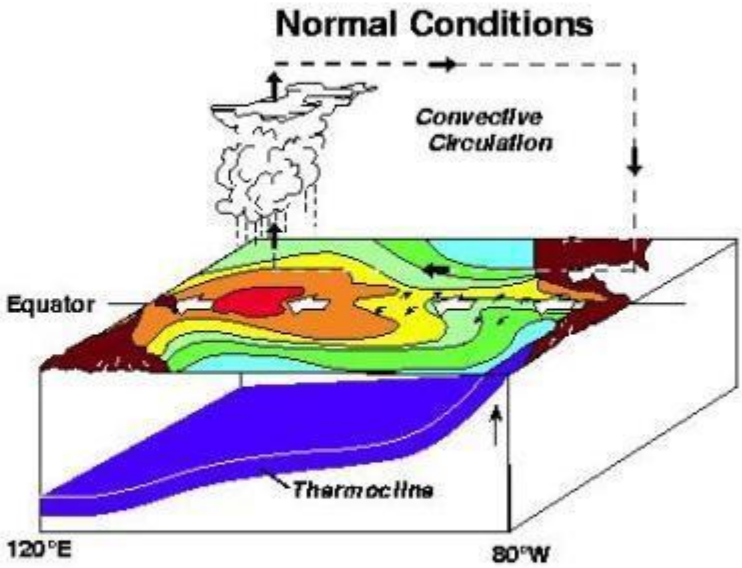
One of the author’s objectives is to report differences in turtle abundance over the years; it may be possible to relate changing numbers with the globally-important fluctuations in weather patterns that occur during the ENSO events (El Niño Southern Oscillation).

El Niño and La Niña are naturally occurring oscillations across the equatorial Pacific Ocean, caused by a complex of thermodynamic atmospheric and oceanic mechanisms, that may cause the sea level to change by as much as 50 cm, and the sea temperature to change by as much as 5°C. The time taken for a full cycle from El Niño to La Niña and back again varies from 2 to 7 years, with an average of about 4 years (www.sprep.org).

[69] The sex of developing embryos is determined by the proportion of time that the eggs spend above or below a ‘pivotal temperature’ during the middle-third of incubation: for turtles more females are produced at higher nest temperatures, more males at lower temperatures; crocodilians are the reverse.

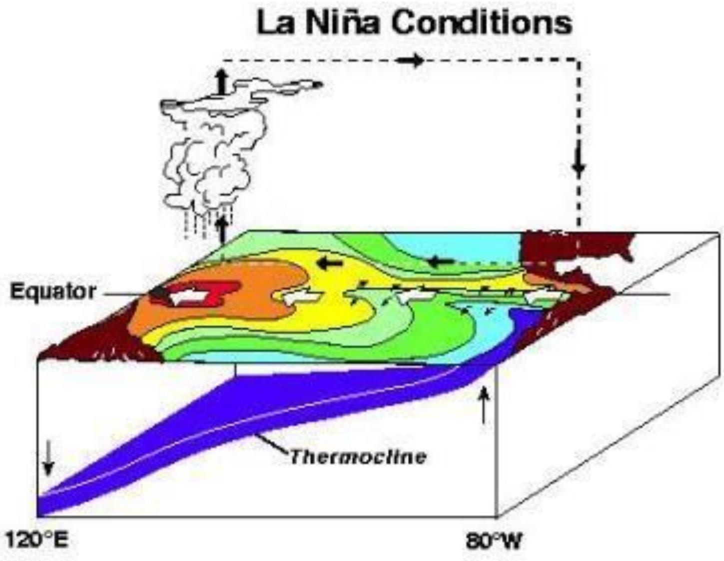
Regional meteorological departments: NOAA (National Oceanic & Atmospheric Administration), SPREP (South Pacific Regional Environment Programme) and NIWA (New Zealand's National Institute of Water and Atmospheric Research) are monitoring different oceanic and atmospheric parameters (e.g. air pressure, sea surface temperature, and sea level height) in order to understand and better predict the likely impacts of ENSO events. The diagrams and text below were provided by NOAA and SPREP:

i) During normal conditions, easterly winds blow across the equator. This pushes warm surface water (heated as it travels from east to west across the Pacific at the equator) towards the Western Pacific, around Papua New Guinea, the Solomon Islands, and the Federated States of Micronesia. The warm surface water in the Western Pacific makes the atmosphere moist and warm. This causes the air to rise (convection) and then drop its moisture as rain.



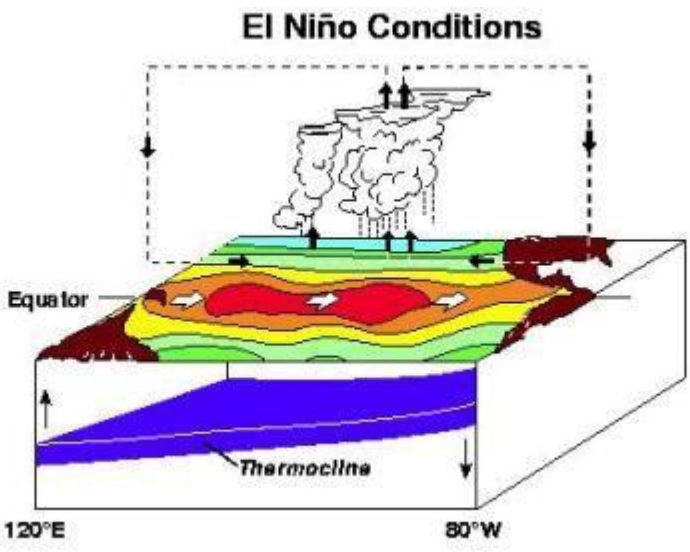
[Source: NOAA Pacific Marine Environmental Laboratory]

ii) During a La Niña event, such as experienced during 2010-2011, the easterly winds across the equator strengthen. This leads to even warmer surface ocean temperatures and to higher atmospheric humidity in the western Pacific. In turn, this causes increased atmospheric convection and therefore **heavier than usual rainfall** in the Western Pacific Islands. Because the warm surface water is pushed west, La Niña also leads to colder sea surface temperatures in the Eastern and Central Pacific, around Tuvalu, Kiribati, Tokelau and Samoa. Colder sea surface temperatures lead to lower atmospheric humidity, less convection and therefore **lower rainfall, possibly even drought**. Warmer water in the Western Pacific increases the number of cyclones West of the dateline. This means that countries such as the Solomon Islands, Vanuatu and Fiji are more vulnerable to cyclones during La Niña conditions.



[Source: NOAA Pacific Marine Environmental Laboratory]

iii) During an El Niño event, the easterly winds across the equator weaken. The warm water that usually resides in the western Pacific moves further east, towards the dateline. Depending on the strength of the El Niño, this warm water can travel all the way across the Pacific to the South American coast. This leads to reduced rainfall in the Western Pacific, and sometimes severe drought in Indonesia and Australia. However, there is increased rainfall in the Central and Eastern Pacific [this is expected by the end of 2012). Warmer water in the central Pacific also increases the number of cyclones that occur east of the dateline. **This particularly affects the Cook Islands and French Polynesia.**



[Source: NOAA Pacific Marine Environmental Laboratory]

At a glance:

During La Niña	
Strengthened easterly tradewinds.	
In the Western Pacific	***In the Central and Eastern Pacific***
Warm Sea Surface Temperature, relatively deep warm pool.	Cool Sea Surface Temperature on the equator
Low Atmospheric Pressure	High Atmospheric Pressure
Heavy Rainfall	Low Rainfall
Higher Sea Level	Lower Sea Level
Increased cyclone activity	Decreased cyclone activity

During El Niño	
Weakened easterly tradewinds	
In the Western Pacific	***In the Central and Eastern Pacific***
Shallower warm pool, cooler Sea Surface Temperature	Warmer Sea Surface temperature
High Atmospheric Pressure	Low Atmospheric Pressure
Lower Rainfall	High Rainfall
Lower Sea Level	Higher Sea Level
Decreased cyclone activity	**Increased cyclone activity**

Author's Note: Given that these abiotic factors are quite different it seems likely that sea turtle abundance may be influenced by ENSO events. No data exist for the Cook Islands. **Endnote vi** provides further information on monitoring NSO.

Future global sea turtle research and conservation priorities

Witherington (2003) has noted that problems which were identified as being threats or impacts for loggerhead sea turtles also provided conservation opportunities. Mast *et al.* (2006) discussed the important role of the Marine Turtle Specialist Group (IUCN-MTSG) in deciding research and conservation priorities. A new study by Hamann *et al.* (2010) has provided a comprehensive review and listed the most-important global priorities:

1. Reproductive biology
1.1 What are the factors that underpin nest site selection and behaviour of nesting turtles?
1.2 What are the primary sex ratios being produced and how do these vary within or among populations and species?
1.3 What factors are important for sustained hatchling production?
2. Biogeography
2.1 What are the population boundaries and connections that exist among rookeries and foraging grounds?
2.2 What parameters influence the biogeography of sea turtles in the oceanic realm?
2.3 Where are the key foraging habitats?
3. Population ecology
3.1 Can we develop methods to accurately age individual turtles, determine a population's (or species') mean age-at-maturity, and define age-based demography?
3.2 What are the most reliable methods for estimating demographic parameters?
3.3 How can we develop an understanding of sea turtle metapopulation dynamics and conservation biogeography?
3.4 What are the past and present roles of sea turtles in the ecosystem?
3.5 What constitutes a healthy turtle?
4. Threats
4.1 What will be the impacts from climate change on sea turtles and how can these be mitigated?
4.2 What are the major sources of fisheries bycatch and how can these be mitigated in ways that are ecologically, economically and socially practicable?
4.3 How can we evaluate the effects of anthropogenic factors on sea turtle habitats?
4.4 What are the impacts of pollution on sea turtles and their habitats?
4.5 What are the etiology and epidemiology of fibropapillomatosis (FP), and how can this disease be managed?
5. Conservation strategies
5.1 How can we effectively determine the conservation status of sea turtle populations?
5.2 What are the most viable cultural, legal and socioeconomic frameworks for sea turtle conservation?
5.3 Which conservation strategies are working (have worked) and which have failed?
5.4 Under what conditions (ecological, environmental, social and political) can consumptive use of sea turtles be sustained?

'Bringing it all together'

A WORKABLE APPROACH FOR MANAGING SEA TURTLES IN THE COOK ISLANDS IS TO:

Undertake long-term research
Provide appropriate education
Build capacity and plan relevant conservation measures
Where necessary implement legislation

Research
i) Determine the present status, abundance and distribution of sea turtles throughout the archipelago
ii) Identify critical habitats
iii) Establish ongoing surveys on **Index Beaches** at various atolls to determine trends
iv) Identify and quantify threats and impacts:
- a) fishery bycatch
- b) direct take of meat and eggs***** (see below)
- c) pollution
- d) loss of critical habitats
- e) climate change

Education
i) Deliver environmental and marine education
- a) teach a turtle module in each school, especially at senior student level
- b) give community presentations
- c) teach the *Turtle Rangers* programme ™
- d) provide training courses to science teachers
- c) use Lifeskills and non-academic approaches for student development
- d) identify potential tertiary level students
- e) facilitate post-graduate research

Conservation and capacity-building
i) Build capacity at local grassroots level
- a) initiate a turtle monitoring project on each atoll
- b) advise Island Councils on specific options for their unique environment
- c) assist community efforts towards sustainable resource use

ii) Build capacity at government level
- a) assist MMR and NES to develop sea turtle management options
- b) assist MMR and NES to report relevant findings to regional bodies
- c) design suitable training modules for government workers

Legislation
i) Advise National Government and Island Councils on legislative needs
- a) assist with Parliamentary committees
- b) provide background information for *Rahui* decision-making

*****A realistic approach is to make an assessment of the actual take on each island. This can be done through a community-led turtle project on each atoll, or directly by *Honu Cook Islands*. In either case community education will occur. It is likely that as islanders gain more insight into the particular problems that turtles face (long-lived, late-maturing, and migratory at all life-stages) they will find their own conclusions about what is sustainable or not. It may be that they decide to allow turtle-hunting at certain times or places, but that they restrict the size-classes that may be taken. At some atolls hunting might be sustainable, at Tongareva for instance: it has the largest nesting aggregation in the nation; turtles (and sea birds) are mainly targeted for the New Year celebrations and infrequently during most of the year. The main educational challenge will be to shift hunting away from nesting females on beaches and permitting incidental capture at sea. Given that most of the younger generation do not eat turtles anyway; direct take will probably disappear locally in a few decades. Eating turtle eggs has virtually disappeared already; in less than thirty years. A second aspect is the cultural norm on each atoll. At Pukapuka for instance, seabirds are a much sought-after delicacy: without the strictest protection within *Rahui* ~ all the birds would have been eaten by now[70]. In contrast at *Tukao* the people like having the birds around in their environment, and they don't normally kill them, so legislation or control is not necessary.

Pukapukan feast

[70]On Pukapuka the *Rahui* system is known as *Pule*; each village has another motu for resource-gathering.

Summary of findings and achievements

During this initial research-phase in the Cook Islands (2009-2012) the author identified a number of important aspects concerning sea turtles, their behaviour and use of habitats: some findings are novel, but others are already known from populations elsewhere and, perhaps for the first time, are reported here from the Cook Islands.

i) *Chelonia mydas* and *Eretmochelys imbricata* are confirmed year round in Cook Islands waters for the first time.
ii) All life stages of *C. mydas* have been observed.
iii) *E. imbricata*: mostly juveniles and a few adults were observed, but no hatchlings.
iv) Nesting by *C. mydas* is confirmed for 10 of the 15 islands in the archipelago.
v) Nesting by *E. imbricata* has not been found anywhere in the archipelago so far.
vi) **866 *C. mydas* nests** have been reported to SWOT and TREDS databases.
vii) Tongareva Atoll is the nation's most important nesting site, followed by Palmerston.
viii) Start of the egg-laying period is reported for Palmerston and Rakahanga Atolls.
ix) Non-nesting period on Palmerston in 2012 was 164 days (20th April to 1st October).
x) Tongareva Atoll may have year-round nesting on at least one motu.
xi) Hatching success rates are high (95%, n = 102 nests).
xii) First data for nest incubation period in the Cook Islands (58 days, SD 2.7 days, range 55-60 days, n = 3 nests at Rakahanga).
xiii) ests are laid in the forest or under vegetation at the back of the beaches.
xiv) Nests laid mid-beach are rare (less than 25 altogether).
xv) Most turtles nest successfully at their first attempt.
xvi) U-turns were rare (n = 7).
xvii) On the atolls adult nesting emergences may occur around high water.
xviii) esting may be clustered around small passages (*'ava'*) through the reefs.
xix) No nest predation was found.
xx) One clutch was taken for food at Tongareva; otherwise egg-take was absent.
xxi)) Sea turtles are eaten on most, if not all, atolls; nesting females are preferred.
xxii) The first Index Beach in the Cook Islands was identified at Tongareva; a 3-year DNA-sampling and nesting-census study is now underway there (see below).
xxiii) Two small Index Beaches are being monitored at Rakahanga; as are the five mostimportant sites at Palmerston Atoll.
xxiv) **646** in-water sightings have been reported to the TREDS database.
xxv) Two *C. mydas* and one *E. imbricata* showed short-term site-fidelity (five months) at Papua Passage, Rarotonga. **(White, unpublished data).**
xxvi) Adult Angelfish (*Pomacanthus imperator*) were observed cleaning both *C. mydas* and *E. imbricata*: **this is a new record (White, unpublished data).**
xxvii) On Rarotonga's reefs there is a ratio of just over 2 *C. mydas* to 1 *E. imbricata*.
xxviii) wo juvenile *C. mydas* captured for food were tagged and released at Tongareva.
xxix) Three juvenile *E. imbricata* were observed underwater at Palmerston Atoll.
xxx) juvenile *E. imbricata* was observed underwater at Suwarrow Atoll.
xxxi) i) The author is the Cook Islands National Co-ordinator for the TREDS database.
xxxii) i) Research data are added to the Cook Islands Biodiversity Assessment.

xxxiii) **Nesting Aggregation data (*Chelonia mydas*)**: the author has changed the Cook Islands status from being data-deficient to:
i) Southern Group – 25-100 females (with Palmerston Atoll estimated to have at least 55 nesting green turtle females*****)
ii) Northern Group – 100-500 females (Mangarongaro at Tongareva Atoll is estimated to have at least 139 nesting green turtle females*****)

Author's Notes: * Based on the nesting population-density classes at OBIS-SEAMAP. Not all atolls and islands have been assessed yet, so this is likely to further increase

Educational Activities

1) The author taught sea turtle modules to students and staff from the following schools: Niua (Pukapuka); Tauhunu and Tukao (Manihiki); Omoka and Tetautua (Tongareva); Lucky (Palmerston); Tereora College (Rarotonga)

2) And also at the **LifeSkills** Expo in Manihiki (September 2011)

3) ***'Frontiers Abroad'*** A good relationship has been established with Nan Hauser (Cook Islands Cetacean Research); both of us contributed to a programme for Earth Science graduates '*Frontiers Abroad'* organised by Stanford University (USA) and Auckland (NZ). Hosted by the Whale Research Centre, the author provided some insight into turtle biology, ecology, threats, and research in the Cook Islands during their fieldwork week at Rarotonga.

4) Post-graduate research supervision (University of York)

5) New Zealand School Journal: Sea turtle research at Rakahanga Atoll was described in an article prepared by Gemma Galbraith, assisted by the author ~ this will be used by the Cook Islands Ministry of Education as a teaching resource.

Community Outreach and Capacity-building

1) Community presentations have been given at Palmerston, Rakahanga and Tongareva.

2) The first turtle projects with community-participation have now begun at Palmerston, Rakahanga and Tongareva; in time these will become community-led.

3) The author discusses various options for sustainable resource with the Island Councils: some Council-members have suggested that sea turtles could be managed within *Rahui* (also see Hickey & Johannes 2002).

4) The author collaborates with Regional organisations, including SPREP and NOAA, and participates in the Pacific genetic-sampling programme.

Professional advice: The author provides scientific and professional guidance to several organisations:

National Government and Island Councils in the Cook Islands
The Whale & Wildlife Centre, *Atupa*, Rarotonga
Kerulos Centre, Jacksonville, Oregon
Tirana and Vlore Universities, Albania
Uto ni Yalo, Fiji
James Borrell
(http://www.jamesborrell.co.uk/2012/12/24/fieldwork-sea-turtle-conservation-on-remote-pacific-atolls/)

Roman Catholic Church (16th January 2010): The author met with Bishop O' Connell at Rarotonga; which was followed by an in-depth discussion with Auxiliary-Bishop Julius from Sydney, Australia. He represents the Environment to that Diocese; it became clear that the Roman Church wishes to define its response to global climate change, and to set out its Environmental Policy. Consequently the Church seeks the advice and opinions of professional scientists. Of particular concern for the Pacific region is sea-level rise and its possible impacts upon small islands, such as Tuvalu and the atolls in the Cook Islands, as these may well be submerged; the Roman Catholic Church has congregations throughout the Pacific Region.

This large cetacean was encountered enroute to Palmerston onboard Southern Cross; and several photographs were forwarded to Nan Hauser www.whaleeresearch.org

Data: 1st April 2012 at 09:30. Latitude: 19.59539 South, Longitude: 160.46902 West.

The First "Index Beach"

The author selected the western side of *Mangarongaro motu* (midpoint: 09° 03.30 South; 157° 59.30 West) as the first **Index Beach** in the Cook Islands for ongoing monitoring of nesting sea turtles. The main reasons are that this motu supports substantial nesting[71] and, importantly, this may be year-round; also, it is uninhabited and visited fairly infrequently to harvest resources (see also Newman & Moller 2005; Pike 2008). Some nesting turtles are known to have been killed there for food in 2011 (White *pers. com.*).

Tongareva Atoll. Only two motu are now inhabited: Omoka Village has about 100 people; Tetautua 30. Mangarongaro motu is uninhabited, but occasionally used for resource harvesting; its western beaches (leeward reef) are the primary research site. Two-ended arrow is 1 km. [Map adapted from GoogleEarth].

A 3-year monitoring programme (2012-2015) is now in progress on *Mangarongaro*: the focus is a nesting-census, and to tag and genetically-sample any encountered turtles. This may reveal connectivity between the local stock and other turtle populations (Dethmers *et al*. 2006; Maison *et al.* 2010; NMFS 2010; Wallace *et al.* 2010); and perhaps resolve some of the unknown turtle haplotypes from bycatch mortalities; furthermore there may prove to be unique assemblages of turtles in the South Pacific, as was the case at Hawai'i (Dutton *et al.* 2008; Pilcher 2011).

The ocean-side beach between *Manoro* and *Ahua Manu* (about 8 km) has been included. As monitoring progresses we will be able to define five or six core-nesting areas, where most eggs are laid (Margaritoulis & Rees 2001). Tongareva Island Council is a project partner and

initial research has been funded by NOAA[72]; training for local researchers is

[71]The number of turtle nests was an order of magnitude greater than other Tongarevan sites visited in 2011

[72]National Oceanographic and Atmospheric Administration; US Federal Government

included within the funding-grant. Several of the global priorities in Hamann *et al.* (2010) are being addressed.

Objectives:

- Identify turtle species that are nesting
- Characterise the genetic stocks of sea turtles present in the Cook Islands
- Determine core nesting zones
- Determine nesting and peak-nesting periods
- Determine inter-nesting interval and clutch-frequency
- Determine nesting success (%); conduct nest inventories
- Use incubation period &/or temperature-loggers to show sex ratio bias
- Determine nesting population structure (mean CCL & size range)
- Report previously-tagged turtles and their origin
- Assess general health and note obvious injuries
- Identify threats and impacts, including direct take or egg-collection
- Design and deliver environmental education
- Implement resource-monitoring training for interested islanders
- Develop appropriate conservation measures for Tongareva Atoll (*rahui*)
- Identify any other suitable 'index beaches' for ongoing monitoring
- Establish baseline data to compare population trends over time
- Note fluctuations in nesting abundance & correlation to extreme climatic events
- Contribute data to national and regional biodiversity assessments

Experimental work includes:

i) Determining the incubation temperatures for some nests (miniature data-loggers)*****
ii) Genetic analysis to determine the haplotypes of adult females
iii) Photo-recognition studies
iv) Biodegrading period for eggshells

*****Sand temperature experiments (Fuentes *et al*. 2009a; but also see Limpus *et al*. 1983; Godley *et al*. 2001) will be undertaken to elucidate likely sex ratios of sea turtle embryos: the sex ratio of green turtles in Oceania is unknown and is thus assumed to be 50 percent (NMFS 2010).

However, it is not enough just to monitor nesting beaches for a long period of time, because nesting habitats are unlikely to reflect current changes in the entire population (Crouse *et al*. 1987; Bolten *et al*. 1993; Bowen *et al*. 1993; Grant *et al*. 1997; Chaloupka & Limpus 2001; Chaloupka 2003, 2004; Polovina *et al*. 2000, 2004; Seminoff 2004; Carreras *et al*. 2006; Mansfield & Musick 2006; NMFS &USFWS 2007a, 2007b; Chaloupka *et al*. 2008; Limpus 2009; NMFS 2010); not least because the slow-growth and delayed-maturity inherent in these species means that populations **may already be in decline** by the time changes become apparent from nesting females: e.g. smaller and fewer females nesting, longer intervals between nesting migrations, reduced egg-success, and lower fecundity (Heppell *et al*. 2003; Harvey *et al*. 2005; Limpus 2009; Wallace *et al*. 2010).

Honu Cook Islands gathers comprehensive baseline data on the distribution, status, population structure and trends for sea turtles nationally, by using a combination of: inwater studies, beach-monitoring and genetic-sampling, mark-recapture studies, gathering anecdotal evidence; and assessment of potential threats and impacts: these are contributed to national authorities, regional organisations, and to the sea turtle scientific community globally. Telemetric studies will be undertaken as funds allow.

An important finding would be the inter-annual variability in nesting abundance, which is affected by the behaviour and migratory-patterns of individual turtles (e.g. Limpus *et al.* 1992; Seminoff *et al.* 2002): most turtles do not nest every year and some may migrate thousands of kilometres between their foraging and nesting habitats (also see Randall 1998)[73]. Another insight would be to determine if there is any correlation in nesting abundance with El Niño events (ENSO: El Niño Southern Oscillation). The author does not know if the observations at Tongareva in 2011 were made in an average year, a high density nesting year, or a low abundance year? (*c.f.* Limpus & Nicholls 1988, 2000; Chaloupka & Limpus 2001; Solow *et al*. 2002; Saba *et al*. 2007; Chaloupka *et al*. 2008a; Reina *et al*. 2008).

Tongareva's other beaches will be monitored regularly for nesting evidence; and inwater assessments made, especially on the leeward reef, in order to gain an understanding of marine habitat use; particularly by internesting turtles. (see also Santos *et al.* 2006).

[73]Randall (1998) notes that a decrease in species diversity occurs when moving eastwards from the Indian Ocean into the Pacific Ocean. The Tongan Trench (where two of arth's tectonic plates-Indo-Australian Plate and the Pacific Plate-meet between Fiji and Samoa) also acts as a barrier to the dispersal of species.

Tiki-tiki Tangata ~ The Circle of Humanity

The importance of community involvement in conservation cannot be overstressed: it is essential if any measure of sustainability is to be achieved. By taking responsibility for natural resource use, which already happens on the northern atolls, it is still possible to have well-balanced and abundant ecosystems. In the Cook Islands we already recognise that the environment is our natural heritage and it is within our powers to keep it pristine; and biodiversity is our national treasure. The critical elements are people and population-density. Take Rarotonga as an example: it is naturally beautiful, but has high population-densities; most of the coastal zone is inhabited. Some lagoons and reefs are degraded or polluted; reef fish are avoided because of *ciguatera*; fresh water supplies are limited; road use is high and there are moderate levels of crime. Tourism is the nation's most important industry and is managed well.

At the opposite end of the scale are the Outer Islands. Population-density is low, resource use is mostly sustainable, environments are usually pristine or well-balanced, and food resources are abundant. Crime is usually minimal and tourism limited. Issues include: depopulation and the associated loss of culture and language; the need to have money for supplies, power and phone bills, and material goods. There is also a marked generation gap between older, more-traditional, and the more-interconnected younger age-groups. Life is still essentially subsistence-based and people work very hard within close-knit communities.

Contrasting the two realities: Rarotonga is a westernised, cash-based economy that needs legislation and enforcement; people are mostly involved in the quest for money and must pay for most things; they are generally disconnected from the environment. On the atolls people are an integral part of the environment; this provides most of their food and general needs. Life is hard, but there is always time to sit and talk with friends. Having a sustainable food supply is never far from our thoughts, and mostly we take only what is needed on each occasion. Sharing with one another is common, especially when there is an unexpectedly-large fish catch. The Island Councils think carefully about *Rahui* and the principle is used wisely, based on the particular needs of their own communities: people know which resources need protecting: when the harvest is opened everyone participates, when closed the resource is left to regenerate.

So rather than rush to 'develop' the Outer Islands in order to bring them into a cash-based economy and in the process destroy everything that is unique about them: a much better approach is to use the ***'natural value'*** of the environment itself, and promote that instead (Mooney 2010).

This can still raise revenue, but in a much more sustainable way. A few local jobs that are directly concerned with natural resources and the environment could be created: one such option would be have small groups of local researchers; they would receive scientific training, undertake resource monitoring and collect data; which will be contributed to the national assessment of biodiversity. Many countries have park rangers for example; in the Cook Islands this is already in place for Suwarrow Atoll; plus a local community-project manages Takitumu Conservation Area on Rarotonga. Operating funds may be sourced through international grants and aid; but also by small donations from visitors. A second and complementary approach is to run courses for international participants (including at governmental level) that demonstrate the benefits of having a well-balanced ecosystem, and how to keep it in balance. The two keys for maintaining equilibrium are: i) sustainability ~ how much can you take from the environment without it collapsing; ii) cost/benefit analysis ~ is the effect of any action likely to be beneficial or detrimental to the environment or particular natural resource? These have resulted in the development of Environmental Impact Assessments over the last two decades or so; but ultimately it is about awareness: we choose to consider an issue holistically (i.e. everything is included) or we ignore some aspects because they are inconvenient or cost money.

Whether this point of view is agreed with or not matters very little. The fact is that in large parts of the world natural resources are degraded, have gone, or are on their way to disappearing (Mooney 2010 provides a timely review). Professor Callum Roberts (2007) shows very clearly what has happened with fish and fisheries over the last millennium: we are now in the 'endgame' with many ocean areas devoid of fish, and the major fishing nations rushing to scoop up the last few remaining fish stocks. This directly affects the Cook Islands, because foreign industrialised fisheries are permitted to operate throughout the EEZ (Ponia *pers. com.*). History has already recorded the *'tragedy of the commons'* (Hardin 1968)[74]; but this is worsened when a natural resource has some commercial value (Hamilton 1839)[75]. Roberts and Hawkins (1999) highlight the extinction risk in the sea.

Successive human generations come to regard their current environment as being normal (the 'baseline'; Pauly 1995) and measure any gains or losses relative to that; however, this might only be 5-10% of what existed just a few decades earlier (see the Millennium Ecosystem Assessment 2005). Furthermore, trying to recover a population on the point of collapse is challenging: most of the largest and fittest animals will have already gone; the gene-pool is already extremely limited with little capacity for variation; the distribution and range of a species may have been seriously reduced; and it may be difficult to find a mate if populations are fragmented[76]. Saenz-Arroyo *et al.* (2005) show that this baseline shift can occur remarkably quickly.

A risk with species or habitat management plans and conservation initiative aims is that they might be trying to maintain a resource in its presently-degraded state, rather than at some previous level of abundance (Roberts 2007); which, even if achievable (Hobbs *et al.* 2006), is likely to take some time. However, we can, and need to, do better than that (Verity *et al.* 2002; Roberts 2007; Mooney 2010). The Cook Islands is in a better position than most countries to use its natural resources sustainably: i) the human population is

[74]When people have access to a free, but limited resource that nobody owns or cannot be controlled ~ the tendency is for individuals to take as much as possible before others do so: this inevitably leads to the loss of the resource; whereas if it was only used sustainably everyone would continue to benefit.

[75]Hamilton was talking about fur seals in the South Shetland Islands: in two years (1820-1821) sealers killed every single animal ~ none were left!

[76]White (2007) noted this for Mediterranean monk seals (*Monachus monachus*): only single animals were observed during four years of continuous research in the coastal waters of Kefalonia, Greece. The global population of *M. monachus* consisted of about 400 animals.

very small; ii) the archipelago is very large; iii) much of the environment is in a healthy and abundant condition. By showcasing our *'natural capital'* we have the opportunity to promote environmental sustainability, as well as acting as a species reservoir: both of these would have regional benefits. The Cook Islands can become a world leader in this.

There are concerns about the structure, functioning, and health of the marine ecosystem and its ability to recover from anthropogenic perturbations, especially pollution (Sherman 2000): given that the global ocean is approximately 99% of the biosphere volume (Norse 1994) this is of great importance. The concept of ecosystem integrity provides a route for desirable attributes to be attained in the future, without worrying if impacts were caused or affected by human activities (Hobbs *et al.* 2010). The Cook Islands Government has proposed a Marine Protected Area (MPA) in the southern half of the nation; this will be one of the largest in the world, but industrialised fishing will still be permitted throughout the EEZ; even if, perhaps, some no-take zones are created. The integration of MPAs into fisheries management remains a major challenge (McCay & Jones 2011). Planes *et al.* (2000) noted some of the benefits of protecting large sea areas; and White (2007) noted the need for regional co-operation in the Mediterranean; where three continents, Africa, Asia and Europe converge.

Conclusions

"Many people are oblivious to how, as the desirable species are stripped out of the oceans, we will be left with the hardiest, most undesirable species – most likely jellyfish and bacteria, the rats and cockroaches of the sea". Professor Callum Roberts, University of York, 2005.

The absence of a previous systematic survey in the Cook Islands means that it is very difficult to determine how the current populations of sea turtles compare with their past distribution and abundance. Nevertheless, the author has shown that both *Chelonia mydas* and *Eretmochelys imbricata* are present throughout the year in the archipelago. All life stages of *C. mydas* were encountered, whereas most *E. imbricata* were juveniles. Nesting is confirmed for *C. mydas* from Aitutaki, Manihiki, Manuae, Mauke, Nassau, Palmerston, Pukapuka, Rakahanga, Suwarrow and Tongareva. Rarotonga is quite unlikely to support nesting because of coastal zone development, substantial human presence, and several Type C beaches; four other Southern Group islands (Atiu, Mangaia, Mitiaro and Takutea) were not visited.

The most important nesting site in the Cook Islands is Tongareva Atoll (a conservative estimate is 500 nests per annum), followed by Palmerston Atoll (conservative estimate is 100 nests per annum): on both of these atolls the majority of egg-laying occurs on the uninhabited and seldom-visited motu. Working with local community participation *Honu Cook Islands* now has ongoing small-scale research programmes in place on both atolls, and a better understanding of nesting abundance should be possible in the coming years. A third community-project has been established at Rakahanga Atoll, where the Senior students are monitoring nesting events as a science project under the author's guidance; some of the island's adults are also involved.

So far no *E. imbricata* have been found nesting anywhere in the archipelago; six tracks at Tongareva might possibly have been made by hawksbills, as the pattern of locomotion appeared to be asymmetrical rather than the more-usual symmetry associated with green turtles; this is unconfirmed as neither nesting adults nor hawksbill hatchlings were seen. One adult-sized female hawksbill was encountered in the lagoon at Tongareva. Dr Cécile Gaspar has similar concerns for French Polynesia: turtles arriving at her clinic on Moorea are mostly smaller than 50 cm CCL; and adult hawksbills are rarely seen at sea either (Priac *et al*. 2010). Encounters with juvenile *E. imbricata* on the reefs at Palmerston, Rarotonga, Suwarrow and Tongareva suggest that nesting by this rare species could occur in the Cook Islands archipelago at some point in the future; which presumably happened in the past, even though there are no data. The identification of nesting sites in Oceania that are used by hawksbill turtles is therefore a high priority.

An important finding from the Northern Cook Islands is that the Mean incubation period for three of the four green turtle nests laid at Rakahanga (between late-September and early-November 2011) was 58 days[77]; these may be the first such data reported from the Cook Islands. Another observation is that most *C. mydas* nests are laid in the vegetation

[77](SD ± 2.7 days; range 55-60 days; n = 3).

and thus may be important as sources of male hatchlings; nest success rates are also high (95%) and nest predation minimal.

One possible reason for optimism is that the plight of endangered species is now a global issue: in the last 30 or so years international legislation has been put in place and many of the threats have been considered, even if not yet resolved: e.g. fishery bycatch has now been recognised as an economic problem by that industry (i.e. fish-catch is reduced if bycatch occupies the hooks); loss of turtle nesting beaches, especially from unplanned and often illegal development (e.g. White 2007), has been challenged, and the more environmentally-aware countries now require EIAs[78]; international trade in endangered species has been substantially reduced, including for the Japanese *'bekko'* tradition (see Groombridge & Luxmore 1989). Furthermore, some severely-depleted turtle populations are now recovering as a result of thoughtful long-term management endeavours (see Balazs 1980; Balazs & Chaloupka 2004; Nel *et al*. 2011; Pilcher 2011; Pritchard 2011). National and international outreach efforts have raised public awareness of environmental activities in the Cook Islands. The Government should be commended for its efforts to establish a very large Marine Protected Area in the southern half of the archipelago; its proposed ban on shark-finning throughout the EEZ; and also its measures to reduce fishery bycatch.

The approach adopted by the author and by extension *'Honu Cook Islands'* has proven to be remarkably successful. As many atolls in Oceania are very isolated, it makes perfect sense once you do reach them to undertake research, deliver education and build capacity simultaneously. Sharing research findings with local communities and also explaining the implications has been very well received by Cook Islanders throughout the nation. By integrating into each community, rather than being on the outside looking in, our research group has become well-placed to make a significant contribution towards creating a sustainable future, living in an abundant, well-balanced and healthy ecosystem.

The atolls in the Northern Cook Islands are perfectly able to maintain their environments in good condition, and use natural resources sustainably. This also places responsibility onto national government to enhance and not destroy this fragile balance of Nature. Any development proposals should, therefore, be in harmony with the environment and not detrimental to it: this is commonly stated in Cook Islands legislative Acts. One obvious example concerns the international fisheries that are an increasingly-important source of revenue for the nation. It would be possible in the northern atolls to excavate several small ponds on the uninhabited motu to rear *'ava'* (milkfish; *Chanos chanos*) that could then be sold to commercial long-liners as bait (Mokoroa *pers. com.*). Such ponds already exist; they are small shallow channels cut into the sand, flushed by seawater, and with little discernible environmental impact. In stark contrast would be a fish-processing plant (envisaged in the Longline Regulations 2008): this would first have to be built, which is an environmental impact, and then operated, which is a severe environmental impact (e.g. the fish-cannery at Levuka, Ovalau, Fiji); it is highly-likely that the workers would also have to be imported. The only practical sites for such a development are Rarotonga and

[78]Environmental Impact Assessment.

perhaps Aitutaki, as these have frequent transport links and worker availability; rigorous and transparent Environmental Impact Assessments are essential during the planning and construction phases, and should be ongoing throughout its operational life[79].

Legislation

The question of legislation for sea turtles and their habitats does need to be addressed. Having reviewed many aspects of life and law, both parliamentary and customary, in the nation: the author considers that the following points would benefit from investigation by a select committee:

i) The traditional subsistence-based way of life, and the industrialised economic market – based models are effectively opposites. Traditional customary use recognises that natural resources are finite, and must have closed periods to allow each resource to regenerate; this ensures its sustainability (Johannes 2007 and references therein). In contrast the cash based market economies require perpetual growth and infinite resources: neither of which are true (Roberts 2007 and references therein). In the Cook Islands the divide between the two realities is essentially the Northern Atolls, including Palmerston, and the Southern Group islands.

ii) Sea turtles spend more than 99% of their lives in the marine environment. In the Cook Islands, because fishing takes place throughout the EEZ, these marine habitats are under the jurisdiction of the Ministry of Marine Resources and/or Island Councils. The Marine Resources Act (2005 and its predecessors) applies to all areas seawards of the MHW mark (Mean High Water). However, the National Environment Service has responsibility for biodiversity and its protection throughout the EEZ. The Environment Act (2003) specifically includes marine and migratory animals; and makes special mention of the ‘foreshore’ ~ the area from the MHW and inland for 30 metres. What this means is that when a sea turtle comes ashore to nest, and invariably moves inland of the High Water mark, she changes jurisdiction. Furthermore, because the Environment Act only applies to five islands, none of which hosts significant nesting, most sea turtle reproduction in the Cook Islands falls outside of any legal protection; as the Marine Resources Act does not apply in the nesting zone.

iii) Is direct take of sea turtles and their eggs allowed or prohibited? If legally allowed how will it be monitored? If prohibited how will it be enforced? The pragmatic approach is to discuss this with communities nationwide. If this varies island-by-island then so be it ~ at least it will be clear.

Ecosystem changes occur independent of human activities, such as fishing (Mann 1993): in other words, the background processes, including physical and chemical structures; biodiversity abundance and health; species replacement and changes to trophic levels will continue due to complex interactions between biotic and abiotic factors: anthropogenic interference tends to worsen any impacts, particularly the rate of change (many examples have been reviewed by Roberts & Hawkins 1999; Verity *et al.* 2002; Hobbs *et al.* 2006;

[79] This was a lesson learned from the nuclear fuel-reprocessing plant at Sellafield, Northern Britain.

Roberts 2007; Poloczanska *et al.* 2008; Mooney 2010 - and the extensive references therein). New technologies are capable of overcoming biogeographical and biophysical barriers to species dispersal (Hobbs *et al.* 2006).

There are also additional impacts that are a direct consequence of human lifestyles and industry. The advent of the 'consumer *throw-away* society' and the manufacture of plastics occurred in the 20th Century; perhaps each being dependent upon the other. Despite the remoteness of many atolls in Oceania the outside world, unfortunately, still has a negative impact upon these fragile ecosystems: the most obvious one being marine debris, notably plastic waste. Not only does rubbish spoil our beautiful islands, but it is very hard work for us to collect it all, and then our only option is to burn it, because there is insufficient soil depth for a land-fill site; this adds to greenhouse-gas emissions (White *pers. com.* 2012). The global dispersion of persistent waste can only become worse, given that more plastics have been manufactured in the first decade of the 3rd Millennium C.E.[80] than since their invention nearly 100 years earlier (e.g. Ryan *et al.* 2009). The longevity of plastics is estimated to be hundreds to thousands of years (Barnes *et al.* 2009). The problem of persistent waste in the Outer Islands was brought to the Government's attention by the author in 2011, and practical solutions are still urgently required to resolve it: particularly for the safe disposal of lead-acid batteries; butane lighters; non-rechargeable batteries; disposable nappies; aluminium cans; and broken plastic water-tanks.

The true extent of changing global weather patterns is not yet understood. Proponents of Restoration Ecology raise three highly relevant points: i) Given that changes have already been identified in other species (e.g. Parmesan & Yohe 2003) it is unlikely that humans will not be similarly affected; ii) Some of these shifts occur remarkably quickly (<5 years); iii) Even if decisive action is taken immediately: dramatic and significant effects are inevitable in the next 20-30 years (Harris *et al.* 2006).

The willingness of local communities to participate in the author's work in the atolls has been inspirational. Not only is traditional and sustainable resource-use widespread, but the need to have islanders educated at advanced levels was clearly understood. The risk facing many small communities is the loss of their culture, knowledge, and language; these are exacerbated by depopulation. There is a need for people to have money, even in these subsistence lifestyles, because such things as electricity and telephones have to be paid for. A further concern in the Outer Islands is that national government is perceived as selling the nation's natural resources, especially fish, with little recompense going to the atoll-communities. In other words patrimony and sustainable food supplies are being sacrificed for short-term revenue. At present there is no national funding for biodiversity research or conservation. Small-scale, low-budget, locally-managed projects are likely to provide greater benefits than larger, heavily-managed, high-cost programmes. However, local-scale efforts do require small financial inputs over a lengthy period: i.e. continuous basic level funding (Horwich & Lyon 2007). The Cook Islands NBSAP (2002) notes that the benefits from and responsibility for biodiversity are shared equitably by all Cook Islanders. The Environment Act (2003) defines the Environment Protection Fund (Part 9;

[80] Common Era.

section 61) and states that *monies held therein shall be expended on the protection, conservation and management of the natural environment etc.* All people leaving the Cook Islands pay a Departure Tax (currently $55 pp.), part of which should support the Environment Protection Fund81.

The author will continue to advise and guide Island Communities in their sustainable use of resources; facilitate higher education in the Outer Islands working closely with the Ministry of Education; and assist in the formation and operation of locally-managed environmental monitoring projects on each atoll: not least in order to preserve Traditional Knowledge and Practices and the role of ethnobiodiversity in ensuring subsistence-level food security (Thaman *et al.* 2010).

As a nation the Cook Islands has a remarkable opportunity to conserve marine turtles and their habitats. This would benefit our future generations, the wider Pacific region and perhaps ensure the continuance of these ancient species globally. Whether this happens or not depends on every one of us: the choice is ours!

Meitaki Poria e Kia Manuia

Michael

Mangarongaro
31st December 2012.

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Endnotes

Dethmers *et al*. (2006) & NMFS (2010) provide the following details for the Cook Islands Nesting Aggregations (NAs) and those other NAs that are nearby.

Northern Cook Islands NA. The Northern Cook Islands NA consists of green turtles that nest in the northern Cook Islands, except for Pukapuka Atoll, which is included as part of the West Polynesia NA. The Cook Islands consist of 15 volcanic islands and atolls. In this NA, green turtles nest at Tongareva (aka Penrhyn), Rakahanga and Manihiki Atolls. Reports from the 1960s and 1970s indicate the presence of green turtle nesting activity at these locations but no further details on nesting female abundance or trends are available (Balazs 1995). Woodrom-Rudrud (2010) additionally lists green turtle nesting activity at Suwarrow atoll and Nassau island, although information regarding number of nesting females is not included for these sites. Based on limited available information, it is assumed that 1-25 green turtles nest annually in this NA.

Southern Cook Islands NA. The Southern Cook Islands NA consists of green turtles that nest in the southern Cook Islands. In this NA, green turtles nest primarily at Palmerston Island, which hosts the majority of green turtle nesting within the Cook Islands. According to a review provided by Balazs (1995), reports from the 1960s and 1970s refer to Palmerston as an important nesting location for green turtles in the Pacific, although no indications of numbers of nesting females were provided. From 1972 to 1977 a decline in the number of nesting turtles was observed by inhabitants (Balazs 1995). Annual nesting numbers declined from 30-40 to <10 in under ten years (Helfrich 1974). Additional sites in the southern Cook Islands identified by Woodrom-Rudrud (2010) include Mangaia, Atiu, Mauke, and Rarotonga islands, although no further information on nesting abundance is available. Based on the limited available information, it is assumed that 1-25 green turtles nest annually in this NA.

West Polynesia NA. The West Polynesia NA consists of green turtles that nest in American Samoa, Tokelau, Pukapuka Atoll in the northern Cook Islands, and the Phoenix Islands in central Kiribati. In this NA, green turtles nest at Swains Island, Rose Atoll and Tutuila in American Samoa, all eight Phoenix Islands in Kiribati, all three atolls in Tokelau, and Pukapuka Atoll in the Northern Cook Islands.

In American Samoa, sub-adult and adult green turtles occur in low abundance in nearshore waters around Tutuila, Ofu, Olosega, Ta'u and Swains Islands. Up to several dozen green turtles nest on Rose Atoll annually (review provided by Balazs 2009). No nesting trend data are available, but anecdotal information suggests major declines in the last 50 years (Tuato'o-Bartley *et al* 1993, Utzurrum 2002). Since 1971, 42 individual nesting green turtles have been flipper tagged on Rose Atoll (Grant *et al.* 1997) during various trips.

No green turtle nesting occurs in Independent Samoa, though 36 adult females and 14 adult males were opportunistically examined during a hawksbill research programme conducted by the Western Samoa Fisheries Division during October 1970 to May 1973 (Witzell 1982). While adult greens were observed near reefs year-round, during December-February they were observed gathering near reef passages connecting large lagoonal foraging areas near Upolu Island. Witzell (1982) surmised that these adults may be part of the group that nests on Rose Atoll during August-September.

The Phoenix Islands are under the jurisdiction of Kiribati and consist of eight low coral islands and atolls. Green turtle nesting has been observed at all eight locations including Canton, Nikumaroro, Enderbury (aka Rawaki), Phoenix, Birnie, Hull (aka Orona), Sydney (aka Manra), and McKean Islands. Canton and Enderbury Islands reportedly host the largest numbers of nesting green turtles of these eight sites. Observations in the early 1970s suggested that several hundred nesting females occurred on Canton Island (Balazs 1975), and a survey done in the summer of 2002 recorded at least 160 old nests on Enderbury Island (Obura & Stone 2002). A combined total of 60-80 nests were recorded annually (possibly representing ~ 20-30 females) at the other six islands in the Phoenix group during surveys in the summers of 2000 (Stone *et al*. 2001) and 2002 although this is likely to be an underestimate of nesting activity because the peak nesting season regionally is October–November (Balazs 1995). Combining available information, it is estimated that 100-300 green turtles may nest in the Phoenix group annually. Little to no trend information is available for the Phoenix group.

Tokelau consists of three coral atolls, Atafu, Nukunonu, and Fakaofu, all of which are known to have green turtle nesting. Balazs (1983) estimated 120 total nesting females annually in Tokelau. Sea turtle capturerates declined from the early-1900s to the 1980s despite more sophisticated hunting methods, indicating a likely decline in resident or nesting turtles (Balazs 1983). Updated information regarding abundance and trends of nesting green turtles in Tokelau was not available to the authors at the time of writing.

Pukapuka is a coral atoll in the northern Cook Islands. Green turtles nest on one of the uninhabited islets and there is some directed harvest of turtles and eggs (Balazs 1995). No further information on abundance or trends of nesting green turtles at this site was available to the authors at the time of writing.

Based on the available information, it is assumed that a mean annual total of approximately 101-500 females nest in this NA. There is little to no information on the trend of nesting green turtles in this NA, although the available information suggests there may be a decline in recent times.

Northern Line Islands NA. The Northern Line Island NA consists of green turtles that nest in the northern Line Islands. The Line Islands consist of eleven atolls and coral islands in the central Pacific south of Hawaii, eight of which belong to Kiribati and three of which are the U.S. possessions of Palmyra Atoll, Kingman Reef, and Jarvis Island. In this NA, green turtles have been documented nesting at Palmyra Atoll, Jarvis Island, and Kritimati and Tabuaeran (aka Fanning) Islands in Kiribati. Information on abundance of nesting females in recent years is not available for this NA as no surveys have been conducted. Low-level nesting at Palmyra was observed in 1987 and along the west coast of Jarvis Island in the 1930s (NMFS & FWS 1998) but more recent information is not available. Turtles appear to have declined considerably at both Fanning and Kritimati Islands between the early-1800s when human habitation began and the 1990s (Balazs 1995). Based on the limited available information, it is assumed that 1-25 green turtles nest annually in this NA.

Southern Line Islands NA. The Southern Line Islands NA consists of green turtles that nest in the southern Line Islands of Kiribati. In this NA, green turtles have been reported nesting at Vostok and Caroline (aka Millennium) Islands although details regarding numbers of nesting females were not provided (Balazs 1995). Further information is not available for green turtle nesting abundance or trends in this NA. Based on the limited available information, it is assumed that 1-25 green turtles nest annually in this NA.

West French Polynesia NA. The West French Polynesia NA consists of green turtles that nest in western and central French Polynesia. French Polynesia consists of 130 islands and atolls spread over a large geographic area in the central south Pacific. In this NA, green turtles have historically been observed nesting at Tupai, Bellingshausen, Mopelia, Manihi Atoll, Tetiaroa Atoll and Scilly Atoll. Based on the available information, approximately 101-500 green turtles nest annually in this NA.

Nesting is concentrated at Scilly Atoll (aka Manuae) in the Leeward Islands, and observations in the late-1970s, early-1980s, and early-1990s suggested 300-400 nesting females occurred there annually (Lebeau 1985; Balazs *et al*. 1995). These observations, in conjunction with information from local residents, indicate a decline in nesting numbers between the 1950s and early-1970s, although numbers may have stabilised between 1972 and 1991 (SPC 1979b; Balazs *et al*. 1995; Pritchard 1995). Nesting females and adult males tagged at Scilly Atoll have been recovered in Tonga, New Caledonia, Vanuatu, the Cook Islands, and Fiji; this tag return information reveals some of the longest range migrations recorded for green turtles (SPC 1979b).

Nesting occurred on Manihi Atoll in 1971 (Hirth 1971, cited in Pritchard 1995) but no more recent information is available. Sporadic nesting surveys at Tetiaroa Atoll have been conducted since 2004 (Te Mana o te Moana 2008) although 2008-2009 was the first nesting season with an organised, sustained survey effort which revealed 81 crawls and 33 nests (Te Mana O Te Moana 2009). Low level nesting has also been observed at Tikehau Atoll (Te Honu Tea 2008).

ii Bell *et al*. (2005) recently put the entire rationale for tagging turtles into perspective. Out of some 30,000 green turtles *Chelonia mydas* released from the Cayman Turtle Farm (1980-2001) during a headstarting programme (captive-raised hatchlings and yearlings were released in order to, hopefully, restock depleted wild populations), a total of 392 individuals were recaptured in the region. Approximately 80% of all turtles released during the programme had been tagged in some way (flipper tags, living tags and scute notching). Another long term study, at Tongaland, South Africa, has notched over 310,000 loggerhead hatchlings since 1971; of these, 101 have been encountered as nesting adults since 1988 (Hughes, 1974a, 1974b, Baldwin *et al*. 2003; see also Nel *et al*. SWOT 2011). This not only highlights that turtle-tagging studies should be conducted over a long period of time, but also indicates that any returns are likely to be very small (White 2007).

iii NMFS (2010) reported that 11 of the 13 green turtles caught as bycatch in the American Samoa longline fishery (which, incidentally, encompasses the entire Cook Islands EEZ; White *pers. com*. 2011) from April 2006-August 2010 were sampled for genetic analysis in an effort to identify the stock origin of sea turtle interactions. Results of mitochondrial DNA sequencing were available for nine of the sampled animals (the most recent two were still to be analysed) and revealed the following: (1) one individual with a haplotype (CmP80) representing nesting aggregations of the Great Barrier Reef area, the Coral Sea, and New Caledonia; (2) two individuals with a haplotype (CmP22) representing nesting aggregations of the Marshall Islands, Yap and American Samoa; (3) two individuals with a rare haplotype (CmP65) only found so far in the nesting aggregation in the Marshall Islands, (4) two individuals with haplotypes (CmP31 & CmP33) of unknown nesting stock only found so far in foraging green turtles around Fiji , (5) one individual with a haplotype (CmP20) commonly found in nesting aggregations in Guam, Palau, Marshall Islands, Yap, Northern Mariana Islands, Taiwan and Papua New Guinea, and (6) one individual (CmP47) with a haplotype found in nesting aggregations in Yap, northern and southern GBR, New Caledonia, Coral Sea, Timor Sea, and east Indian Ocean (Peter Dutton, NMFS, *pers. com.*). Work is ongoing to sufficiently characterise all the Pacific green turtle nesting stocks with informative genetic markers in order to improve the ability to assign stock origin of individual animals (NMFS 2010).

To date, four genetic samples from stranded or foraging turtles around Tutuila have been analysed. Two samples from stranded green turtles in PagoPago harbour had a haplotype known from nesting green turtles in American Samoa, Yap, and the Marshall Islands. However, since many green turtle nesting aggregations in the Pacific still have not been sampled, it is possible that this haplotype occurs at more than these three sites. In addition, two samples have been analysed from foraging green turtles at Fagaalu, but the haplotype is of unknown nesting origin (Peter Dutton, *pers. com.* 2010).

iv Sea turtle legislation from some countries in Oceania (Maison *et al.* 2010):

Australia Marine turtles in Australia are protected under the Environment Protection and Biodiversity Conservation Act of 1999 (EPBC Act), which implements several international agreements/conventions to which Australia is a signatory. Traditional Owners, as recognized under the Australian Government's Native Title Act of 1993, are able to assert their rights to gain customary authority for shared resources such as marine turtles which includes traditional hunting rights. On a regional level, the Torres Strait Treaty between Australia and PNG outlines the boundaries between the two countries and how the sea area may be used. The Treaty includes provisions for traditional fisheries in the area, including turtle harvest by indigenous groups. Australia is a participant in the Convention for the Protection of the World Cultural and Natural Heritage (World Heritage Convention), as well as CMS and CITES (both of which list sea turtles in Appendix I: species threatened with extinction).

Fiji

Sea turtles and their eggs are managed under Fisheries Regulations in Fiji. The Fisheries Act, as amended in 1979 and 1991, outlines gear requirements when spearing a turtle and also states that "No person shall at any time dig up, use, take, sell, offer or expose for sale, or destroy turtle eggs of any species or in any way molest, take, sell, offer or expose for sale, or kill any turtle the shell of which is less than 455 mm [18 inches] in length. No person during the months of January, February, November or December in any year shall in any way molest, take, sell, offer or expose for sale, or kill any turtle of any size". The possession, sale or export of any turtle shell less than 18 inches in length and the export of turtle flesh and turtle shell unless it is worked into jewellery or otherwise processed into a form approved by the Permanent Secretary for Primary Industries and Cooperatives are all prohibited acts (Government of Fiji 1992). A National Moratorium prohibiting the killing, harming or molesting of any marine turtles including their meat, eggs or shell was first enforced in 2004 by the Fijian Government. It was recently extended for a further ten years by the Fijian Cabinet until 2019. Indigenous Fijians are still able to legally harvest marine turtles if they obtain prior approval from the Fisheries Department. There is some disagreement, however, regarding the effectiveness of Fiji's moratorium mostly due to lack of compliance and enforcement (Laveti & Mackay 2009). Fiji is a participating party to CITES.

French Polynesia

French Polynesia is an overseas territory of France and sea turtles have been completely protected since 1990 by the Polynesian government (DELIBERATION No. 90-83 AT *du 13 Juillet 1990 relative à la protection des tortues marines en Polynésie Française*). Prior to this date, traditional harvest with seasonal and size restrictions was permitted. Under the revised statutes, turtles are fully protected and it is strictly forbidden to harm, own or hunt sea turtles or engage in commerce of any kind pertaining to the sale of shell, meat and eggs. Scilly Atoll has been protected as a marine reserve for sea turtles since 1971 by the local government (Vu l'arrêté No. 2559 DOM *du 28 Juillet 1971 portant classement du lagon de l'île Manuae ou Scilly*). French Polynesia is not a participating party to CITES (although France is a participating party).

Japan

In Japan, there are eight laws and ordinances that regulate (allow via permit) or prohibit actions harmful to sea turtles, such as taking, buying, and selling turtles, their eggs, and any derivative products, or restrict access to nesting beaches. In general, harvest is prohibited but exemptions may be obtained for subsistence use. The Law for the Conservation of Endangered Species of Wild Fauna and Flora is the primary law in Japan that intends to conserve endangered species. It prohibits the capture of sea turtles and eggs for sale for all seven species and prohibits domestic assignment or transfer of endangered species listed in CITES (*Umigame Hogo no tameno* 2006). This law was established in accordance with CITES and is enforced by the Japan Ministry of Environment.

Kingdom of Tonga

Fisheries Conservation and Management Regulations (1994) prohibit the possession, disturbance, take, sale, purchase, or export of turtle eggs; sale, purchase, or export of hawksbills or their shells; and use of a spear gun to take a turtle; and establish closed seasons for leatherback turtles between January 1st - December 31st (Bell *et al*. 1994; Folumoetui'i, 2006). Hawksbills are the only sea turtle species fully protected via Tongan legislation and harvest of other turtle species is permitted seasonally (November-February) with a minimum size specified (shell length of <45cm may not be taken) (Folumoetui'i 2006).
Tonga is not a participating party to CITES (Maison *et al*. 2010). In the market at Nuku'alofa there were several hawksbill carapaces for sale (White *pers. obs.* 2009); these were all smaller than the legal permitted minimum size, thus it seems that enforcement of environmental law is lacking. Directed take of green turtles for consumption and sale still occurs in Tonga and laws are generally not adhered to or enforced (Havea & MacKay 2009).

Kiribati
Kiribati is an island nation that consists of 32 atolls and one raised coral island that are separated into three distinct chains, the Gilbert Islands, Phoenix Islands, and Line Islands, dispersed over 3.5 million square kilometres. In Kiribati, the Wildlife Conservation Ordinance (Laws of the Gilbert Islands 1977) prohibits hunting, killing or capturing any wild turtle on land and fully protects the green turtle in the following places: Birnie Island, Caroline Island, Christmas Island, Flint Island, Gardner Island (*Nikumaroro*), Hull Island (*Orona*), Malden Island, McKean Island, Phoenix Island, Starbuck Island, Sydney Island (*Manra*), and Vostock Island. Kiribati is not a participating party to CITES.

Nauru
Nauru is the world's smallest island nation and consists of one small island, approximately 21 square kilometres in area, located in the southwestern Pacific Ocean. Maison *et al*. (2010) found no reports of green turtle nesting activity on Nauru; and the nation is not a participating party to CITES.

New Caledonia
Regulations related to sea turtle management in New Caledonia vary within the country. In the Loyalty Islands province (as per fishery regulations of 1985) the take of marine turtles and their eggs is prohibited from November 1st to March 31st. As of January 2008, the 1985 regulations have been amended for the EEZ, the Main Island (Northern & Southern provinces), and remote islands such that it is not permitted to capture, sell, purchase, or disturb any marine turtle species or nest at any time. Additionally, the compulsory use of handling equipment (de-hooker, line-cutter, etc.) in commercial fisheries is required for incidental catch of turtles. Regulations prohibit the export or import of marine turtles (alive or dead) or any turtle parts or products, and exceptions may be granted for customary celebrations or scientific purposes. New Caledonia is not a participating party to CITES (although France is a participating party).

Niue
Niue is an island nation in free association with New Zealand. It consists of a single island approximately 256 square kilometres in area located east of Tonga. Green and hawksbill turtles occur in Niue waters (Government of Niue 2001), but Maison *et al.* (2010) were unaware of any reports of green turtle nesting activity on Niue. Domestic Fishing Regulations (1996) prohibit the harvest or take of all turtle species unless approval is received from the cabinet. Niue is not a participating party to CITES.

Papua New Guinea
In PNG, marine resources and lands are owned by a large number of clan and sub-clan groups whose tenure rights are recognized in the national Constitution. With respect to sea turtles, the 1976 Fauna (Protection & Control) Act restricts the harvesting of protected wildlife, the devices and methods by which fauna may be taken, and the establishment of localized protective regimes on land and waters under customary tenure (Kinch 2006). Additionally the 1979 International Trade Act regulates and restricts the export of CITES listed species. In PNG, only leatherback turtles are protected under the Fauna (Protection and Control) Act that makes killing of leatherbacks or taking of leatherback turtle eggs illegal with fines of 500-1000 kina (100 to 300 US$). Any person who buys or sells or offers for sale, or has in possession leatherback turtle eggs or meat can also be fined 500 kina. The Act does not formally protect green turtles and makes provisions for persons with customary rights to take or kill turtles, but states that turtles cannot be taken, killed, or sold between the months of May and July. Furthermore, the Act stipulates payments for turtles:
(a) K20.00 for a turtle less than 60 cm in length; and (b) K30.00 for a turtle of 60 cm or more in length. The PNG government Department of Environment and Conservation has the authority and responsibility to enforce laws and environmental Acts. The Torres Strait Treaty between Australia and PNG outlines the boundaries between the two countries and how the sea area may be used. The Treaty includes provisions for traditional fisheries in the area, including turtle harvest. PNG is a participating party to CITES.

Pitcairn Islands
Green turtles nest at Henderson Island with an estimated total of 10 females annually (Brooke 1995). No nesting was recorded at Pitcairn, Ducie, or Oeno Islands during the 1991-1992 nesting season. Pitcairn and

Ducie were deemed to have unsuitable substrate for nesting while Oeno had suitable substrate but no activity was observed (Brooke 1995). This small nesting assemblage does not appear to be threatened by direct harvest or other major anthropogenic sources of impact. As per the Local Government Ordinance of 2001, no person may harass, hunt, kill or capture any sea turtle (*Cheloniidae and D. coriacea*), and exception may be granted under permit for scientific purpose or for traditional subsistence use (Laws of Pitcairn, Henderson, Ducie, and Oeno Islands, 2001). The Pitcairn Islands are a territory of the UK which is a participating party to CITES.

Republic of Marshall Islands

The harvest of sea turtles in the RMI is regulated by the Marine Resources Act (RMI 1997) which sets minimum size limits for greens (34 inches carapace length) and hawksbills (27 inches carapace length) and closed seasons from June 1st to August 31st and December 1st to January 31st . Egg collecting and take of turtles while they are onshore is prohibited at all times. The Marshall Islands Marine Resources Authority is the entity with the responsibility of managing marine resources in the RMI. RMI is not a participating party to CITES.

Republic of Palau

Palau domestic fishing laws specify minimum size limits for green turtles (34 inches carapace length) and hawksbills (27 inches carapace length) and closed seasons from June 1st to August 31st, and December 1st to January 31st (SPC & BMR Palau, 2007). Taking of eggs or female turtles while onshore is prohibited at all times. Palau is a participating party to CITES.

Samoa

Local Fisheries Regulations in Samoa prohibit fishing for, possession, or sale of greens and hawksbills under 70 cm (27.6 inches) CCL, as well as the disturbance or take of nests or eggs. The Ministry of Agriculture and Fisheries (formerly the Department of Agriculture, Forests, and Fisheries) is the responsible authority to manage fishery resources, including sea turtles, and enforce local fisheries regulations in Samoa. Additionally, the Marine Wildlife Protection Regulations (2009), under the Ministry of Natural Resources and Environment, make exemptions for subsistence take of turtles, prohibit captivity of turtles (unless permitted), prohibit the commercial capture and sale of turtles, protect turtles and eggs during the nesting season (November to February), prohibit the sale, purchase and possession of eggs, and require that any turtle caught during fishing activities be released and reported. Samoa is a participating party to CITES.

Solomon Islands

The Solomon Islands Fisheries Act (1993) regulations prohibit the sale, purchase, or export of sea turtle species or their parts, protect nesting turtles and eggs during the breeding season (June to August & November to January), and contain specific protection for leatherback turtles (SPREP 2007). The Solomon Islands is a participating party to CITES and the Wildlife Protection and Management Act (1998) prohibits the export of five turtle species or their derivative products (greens, hawksbills, loggerheads, olive ridleys, and leatherbacks).

Tokelau

Tokelau consists of three coral atolls, *Atafu*, *Nukunonu*, and *Fakaofu*, all of which are known to have green turtle nesting. Balazs (1983b) estimated 120 total nesting females annually in Tokelau. Sea turtle capture rates declined from the early 1900s to the 1980s, despite more sophisticated hunting methods, indicating a likely population decline (Balazs 1983b). Updated information regarding abundance and trends of nesting green turtles in Tokelau was not available to Maison *et a*l. (2010) at the time of printing.

According to a 1998 marine resources survey at Fakaofu, the local council of elders has established village rules stating that when a turtle is caught, it must be shared among the village using a traditional system or resource sharing called *Inati* (Passfield 1998). Local village rules also protect sea turtles while they are nesting. Ono & Addison (2009) claim that today turtle fishing is officially prohibited throughout Tokelau, however the Project Global country profile for Tokelau (Project Global, accessed online 10/2010 by

Maison *et al*.) states that there are currently no formal regulations by the Fisheries Department to protect sea turtles or their eggs in Tokelau; therefore the actual protective status of sea turtles remains unclear. Tokelau is not a participating party to CITES.

Tuvalu

In Tuvalu, the Wildlife Conservation Ordinance (1975) prohibits hunting, killing or capturing any wild turtle on land, except under and in accordance with the terms of a valid written license granted to that person by the Minister (Government of Tuvalu 1975). Tuvalu is not a participating party to CITES.

Vanuatu

Fisheries Regulations under the new Vanuatu Fisheries Act (2009) prohibit the take, harm, capture, disturbance, possession, sale, purchase of or interference with any turtle nest (or any turtle in the process of nesting), and the import, or export of green, hawksbill, and leatherback turtles or their products (shell, eggs, or hatchlings). The Act also prohibits the possession of turtles in captivity. A person may apply in writing to the Director of Fisheries for an exemption from all or any of these provisions for the purposes of carrying out customary practices, education, and/or research. Vanuatu is a participating party to CITES.

United States and Possessions

Endangered Species Act (ESA) of 1973 (16 U.S.C. § 1531 *et seq.*)

American Samoa

In addition to protection under the federal ESA (1973), sea turtles in American Samoa are protected by the Fishing and Hunting Regulations for American Samoa (DMWR 1995) which prohibit the import, export, sale, possession, transport, or trade of sea turtles or their parts and take (as defined by the ESA) and carry additional penalties for violations at the local government level. The Department of Marine and Wildlife Resources (DMWR) is the agency with vested authority and responsibility for conservation of protected species and enforcement of protected species regulations in American Samoa.

The SA prohibits unauthorised 'take' of listed species which is defined as to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (16 U.S.C. § 1532(18)). Under the SA, exceptions to 'take' prohibitions are permitted for scientific research or when take is incidental to an otherwise lawful activity, as long as the level of take will not jeopardise the existence of the species in the wild or appreciably reduce the likelihood of recovery in the wild. Both NOAA Fisheries Service and USFWS have dedicated enforcement divisions to handle violations of the ESA. The U.S. is a party to several international agreements related to sea turtles including the Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC) and the Convention on International Trade in Endangered Species (CITES) which prohibits international trade of marine turtles and marine turtle derived products. While the U.S. is not a party to the Convention on Migratory Species (CMS), they are a signatory to the Convention on Biological Diversity (CBD). Local state and territory governments may have additional protections in place for sea turtles.

Pacific Remote Island Areas

Pacific Remote Island Areas (PRIAs) are U.S. areas that are widely spread throughout the Pacific and include Wake, Johnston and Palmyra Atolls, Kingman Reef, and Jarvis, Howland, and Baker Islands. Following a 28-day assessment in 1983 it was concluded that green turtles do not nest at Johnston Atoll, but occur foraging within the atoll (Balazs & Forsyth 1986). Low-level nesting was observed at Palmyra in 1987 and along the west coast of Jarvis Island in the 1930s (NMFS & FWS 1998) but no recent surveys have been conducted. Both Jarvis and Palmyra are geographically part of the Line Islands chain of coral atolls and islands in the central Pacific and are uninhabited remote National Wildlife Refuges administered by the USFWS. Jarvis is visited infrequently by refuge staff for one to two days at a time every two years. There is a research station on Cooper Island at Palmyra Atoll operated by The Nature Conservancy (TNC) that houses a small maintenance staff year-round and various research groups for shorter time periods. Anecdotally, no evidence of sea turtle nesting has been observed at Palmyra in recent years (USFWS, *pers. com.*). In 2007, an in-water sea turtle research project was initiated at Palmyra by the American Museum of

Natural History and Columbia University. While nesting beach monitoring is not a focus of the project, any nesting activities will be documented by either the project or by TNC staff that currently reside at the Atoll.

The PRIAs do not support resident human populations and do not have local governments. Therefore, all sea turtle species that occur in the PRIAs are protected by the federal ESA as described previously.

v White 2007 includes the following: "A widespread impact on turtles in the marine environment results from their interaction with fishing operations (Henwood and Stuntz, 1987). A useful consideration of the bycatch problem is a division between fishing with nets or baited hooks. The extent and duration of a fishing operation makes a difference to the level of impact on a non-target species (e.g. Hall, 1996, 1998; Hall *et al*. 2000; Lewison *et al*. 2004). For instance, a fleet of commercial long-liners trailing 100 km mainlines for several days is likely to cause far greater damage than a single fisherman with a few hundred metres of line deployed overnight (White 2007). Aguilar *et al.* (1995) noted that a large number of loggerheads, perhaps 20,000 annually, were being caught on longlines of the Spanish tuna fishery; some of the turtles used the bait as a food resource (Tomas *et al*. 2001; Lewison *et al*. 2004) and were re-captured on several occasions. White (2004) confirmed that loggerheads do eat discarded fish. Weidner *et al.* (1999) indicated that bycatch levels can reach 3 turtles per 1000 hooks deployed; Lewison *et al*. (2004) estimated that 3.8 million hooks per day are deployed globally. Lewison *et al*. (2004) also estimated that the global turtle capture for pelagic longlines was 200,000 loggerheads (& 50,000 leatherbacks) in the year 2000 alone, which means that tens of thousands of turtles die each year from fisheries encounters (Lewison *et al*. 2004). NFMS (2001a) estimated that 17-42% of loggerheads captured on longlines would die, either immediately or subsequently, as a result of their fishery encounter. Spotila *et al*. (1996, 2000) suggested that, for leatherbacks *Dermochelys coriacea*, an adult mortality level greater than 1% in fisheries would lead to population collapse. Lewison *et al*. (2004) indicate it is likely that this mortality threshold level is being exceeded for both loggerheads and leatherbacks in the Pacific Ocean."

vi El Niño and La Niña have far reaching effects beyond the borders or the tropical Pacific Ocean. The warm waters in the Western Pacific during a La Niña trickle through the narrow passages north of Australia and south of Indonesia into the Indian Ocean. This affects weather patterns in places like Thailand and Western Australia. Warm waters during strong El Niños reach up the coast of North America and down the coast of South America to cause heavy rainfall on the west coast of the United States of America, & in the usually dry deserts of Chile.

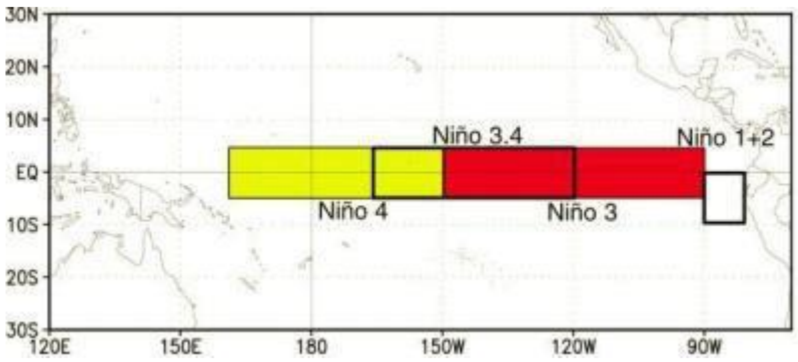
Fast winds in the **jet-streams** that encircle the earth at high altitudes are redirected by the atmospheric component of El Niño and La Niña. This means that these tropical Pacific Ocean processes have an impact on such distant processes as snowfall in the Himalayas and rainfall in Madagascar.

The Pacific Ocean soaks up a vast amount of heat during a La Niña event, and dumps this back into the global atmosphere during an El Niño. This can cause global surface average temperatures to decrease by up to 0.5°C during a La Niña, and we can expect to see global temperatures increase in the near future after the recent event (for late 2012).

Indices of La Niña and El Niño.

To easily see what the state of the Pacific Ocean is in, some simple indices have been developed: The **ENSO** (El Niño Southern Oscillation) **index** compares the air pressure in Tahiti (in the Eastern Pacific) to the air pressure in Darwin (Western Pacific). These two values are easy to observe, and give a quick measure on the strength of the easterly winds across the equator. To find the most recent ENSO values, have a look at http://www.cgd.ucar.edu/cas/catalog/climind/soi.html

The difference in ocean temperature from usual across the equatorial pacific is used as another index of El Niño and La Niña. The **Niño 3** index monitors the temperature across a box in the Eastern Pacific, while the **Niño 4** index uses a box in the central-western Pacific. The **Niño 3.4** index uses a box that overlaps these.



The areas of the Pacific ocean used to define the Nino indices. [Source: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/nino_regions.shtml]

There are also more complicated methods which look at the way both the ocean and the atmosphere are behaving to describe what state the Pacific ocean is in. These include the **Multi-variate ENSO Index (MEI)**, see http://www.esrl.noaa.gov/psd/enso/mei/ and the **Coupled ENSO Index (CEI).**

What State is the Pacific Ocean in Now? (late-2012)
A lot of effort has gone into observing the ocean and atmosphere around the Pacific. This is done with moored buoys (the TAO / TRITON array across the equator), satellites (to look at sea surface temperature, sea surface height and winds) and the Argo array (for a wider view of subsurface ocean temperature and salinity).

Here are some links to see what the current data is suggesting.

http://www.esrl.noaa.gov/psd/enso/enso.current.html
http://www.esrl.noaa.gov/psd/enso/mei/
http://www.esrl.noaa.gov/psd/map/images/sst/sst.anom.gif

What is Forecast to happen in the next few months? (for late-2012)
Predicting what the rainfall and temperature will be like in a few months is crucial for effectively managing our resources. Some examples are;

- What crops should we plant?
- Will a colder ocean bring more fish?
- Should we top up our water reservoirs so we have water to drink?
- Should we empty our reservoirs so they can cope with heavy rain?
- Will forest fires be more likely this summer?
- Will cyclones be more likely this summer?
- etc.

The *Island Climate Update* gives an idea of what is expected in the Pacific. This information is based on many sophisticated computer models that simulate what the earth's atmosphere and ocean will do in the next few months.

[i] http://oceanworld.tamu.edu/resources/ocng_textbook/chapter14/chapter14_03.htm