Honu

Tongareva Henua

Dr Michael White
2016

Sea Turtles in the Cook Islands: Volume Two (2013-2015)

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In fondest memory of Papa Rongo Taia of Te Tautua who passed away on Sunday 29th November 2015. A wise and very good man, and a Keeper of Nature.

Papa Rongo Taia: 50th Anniversary of Cook Islands Independence, *Te Tautua, August 4th 2015*. Photo by Dr Michael White.

Sea Turtles in the Cook Islands: Volume Two (2013-2015)

Tongareva Henua

This journal mostly describes the research and conservation efforts that are ongoing on Tongareva Atoll in the Northern Cook Islands. The atoll is shown to be the most important sea turtle habitat in the nation and increasingly it appears to have considerable prominence in the central South Pacific, perhaps even being the most important in this part of the world. Tongareva has the paramount nesting beach for green turtles in the Cook Islands; the lagoon is a developmental habitat for juvenile green and hawksbill turtles; and mating occurs on reefs and in the lagoon, thus making this atoll a critical habitat for chelonians.

There are several reasons underpinning the atoll's importance: the foremost being the low number of people present and minimal impacts from any building development. It is also clear that our conservation approach is correct. Our intention is to maintain an abundant, healthy and diverse ecosystem; and, most importantly, to pass this on to future generations so that they will have even more than we do. Looking from an animal's perspective it seems likely that a clean environment, and an absence of light pollution, noise, and intrusive human activities would all add to the attractiveness of Tongareva's habitats, particularly for egg-laying when a female *honu* (sea turtle) seeks a quiet, dark, undisturbed place in order to procreate.

In stark contrast Rarotonga in the Southern Cook Islands, which should support honu nesting, does not. Its entire coastal zone is developed, mostly for the tourist industry, which provides the country's primary source of income. Roads are adjacent to the beaches, light pollution is ubiquitous, people wander around the shoreline for much of the night, so that quiet and dark habitats do not exist. Lagoons are degraded by human activities, including terrestrial run-off, but the worst impact is building development on most of the sandy beaches: leaving few, if any, places available for honu nesting. Rarotonga's nearshore waters do support foraging sea turtles, but even these can suffer from noise pollution or human pressure. A recent example in 2012 was the dredging and extension of Avatiu harbour that caused massive siltation on the northern reefs, forcing the seemingly-resident honu to leave (White *pers. obs.*).

Kuki Airani (Cook Islands) has two very distinct realities: a westernised cash-based society on Rarotonga that is largely disconnected from Nature; and the Outer Islands, which are mostly subistence-based, living closely entwined with the natural world, which provides most of their needs. These two realities do not sit well together, nor do their underlying philosophies. Rarotonga's national government views things from a financial perspective; while the *Konisara* (Island Councils) are more concerned with food-security and the well-being of their communities. Nowadays people in remote atolls do need money to pay power and phone bills, or purchase additional supplies (e.g. rice, flour & oil), but having a pristine, healthy and abundant ecosystem is far more important. The pragmatic view is to accept the environmental degradation of Rarotonga, which drives the national economy; whilst taking great care to conserve and enhance biodiversity in the Outer Islands to ensure the safety and food sovereignty of our future generations. However, it is not quite as simple as this, because our planet is also under severe threat from numerous far-reaching problems.

These pressures include human population growth; global climate change and more frequent extreme weather events; increasing biodiversity loss and habitat destruction; increased ocean acidification; pollution (the oceans are full of plastics); overfishing and its associated bycatch; unsustainable use of natural resources; and potential sea level rise. There is clear evidence that the ice-sheets, glaciers and permafrost around the world are melting, which is bound to affect the global ocean. Although some of Rarotonga and the makatea islands might continue, a sea-level rise of 1-2 metres would overwash the atolls and and put pressure on people to leave. So that readers truly understand: at the end of the last Ice Age, about 11,000 years ago, the Irish Sea rose by 140 metres; and the Strait of Gibraltar was formed.

Kuki Airani and other similar small nations are well placed to lead the world in a new direction. The business-as-usual model ~ destroying our planet for financial profit ~ is a road to nowhere. We cannot eat money. Nature takes time to grow and reproduce, so if we wish to survive then we must put more effort into activities and practices that are beneficial to our planet, such as tree planting and sustainable land-usage; and we must avoid ecologically harmful ones, including any pressures that result in biodiversity reduction or loss, and habitat degradation or destruction. Our situation at present is that many different global threats are combining to make life on Earth very challenging. It is no longer just a case of addressing one factor or another: it is time for us to completely review how we co-exist with our planet and all of the other life forms in our Biosphere. This will not be an easy task, as our present ways-of-life are based upon gross carbon usage, unsustainable resource use and complete uncaring towards the natural world. Furthermore these impacts are not equitable, the poorest people suffer greatly trying to find their daily food and water; the greediest few take far more resources than they need, but they also waste a considerable proportion of these: effectively denying resource-availability to those in greatest need. Great Britain for example is a wealthy state, but with millions living in poverty (many having to use charity food banks to survive): it is a very unequal nation, USA has similar patterns of inequality. So is there any hope?

The Cook Islands Biodiversity Strategy and Action Plan (NBSAP 2002) begins with the following:

"Kia akaaiteiteia te raveraveanga akonoanga, taporoporoanga e te tua'anga o te au puapinga te ka rauka mai no roto i te au apinga natura."

"To equitably share the responsibility to conserve and use biodiversity sustainably, and to equitably share the benefits."

Thus it is self-evident that, in the Cook Islands at least, one part of a nation ~ whether individuals or government ~ should not degrade or deny the natural world and its abundant resources to others. Biodiversity is our national treasure and our patrimony. **Our Gift to the Future.**

So let us begin our journey by voyaging to the far North near the Equator … *open your eyes and follow the stars!*

2012: Background and project launch

When NOAA (National Oceanic and Atmospheric Administration) offered a research grant[1], the Principal Investigator (PI), Dr Michael White, was completing a 2-month expedition assessing sea turtle habitats on Rakahanga Atoll, Northern Cook Islands; this atoll had been unsurveyed for 40 years (White & Galbraith 2013). A Honolulu-based trading ship (S/V Kwai) came by at the end of August 2012, and so the PI decided to take passage across to Tongareva Atoll. This was the first ship to visit the Northern Group atolls in five months, and, as it turned out, there was not another for a further seven months. Logistic arrangements were at an early stage and so the start of fieldwork would be somewhat limited, especially without boat fuel, but it was more important to get to Tongareva.

Sea turtles in Oceania

Sea turtles (*honu*) 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; Cadena & Parham 2015). 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: *Chelonia mydas* (Linnaeus 1758); *Eretmochelys imbricata* (Linnaeus 1766); *Lepidochelys olivacea* (Eschscholtz 1829); *Caretta caretta* (Linnaeus 1758); *Natator depressus* (Garman 1880); *Dermochelys coriacea* (Vandelli 1761); a seventh species *Lepidochelys kempii* (Garman 1880) has not been reported from the region. The status of sea turtles in the Pacific Islands region remains incomplete 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, carving, songs, dances, tattoos, as well as in traditional navigation. They are also an important, and often highly regarded, source of food for many coastal or atoll dwellers (see Allen 2007 and Woodrom Rudrud 2010 for reviews).

[1] Grant # NA12NMF4540263 Nesting census and genetic sampling of an unstudied sea turtle population at Tongareva Atoll, Northern Cook Islands.

The Cook Islands

The Cook Islands (08° to 23° South, 156° to 167° West) form a *Large Ocean State* spread across almost two million km^2 of the central South Pacific. The archipelago is divided: **Northern Group:** the atolls of Manihiki, Pukapuka, Rakahanga, Suwarrow and Tongareva; with Nassau being a sandy cay on a coral base; **Southern Group:** atolls of Manuae and Palmerston, near-atoll of Aitutaki, volcanic and makatea islands of Atiu, Mauke, Mitiaro and Mangaia, Rarotonga is a high volcanic island with a fringing reef, Takutea is a sandy cay (Spalding et al. 2001). The total land area is 241 km^2. Manuae, Suwarrow and Takutea are uninhabited.

There are two different realities: most of the Outer Islands lead a subsistence way of life gathering their resources from nature. Rarotonga, with the national capital Avarua, is a westernised cash-based economy deriving most of its revenue from international tourism, especially stop-overs, and selling permits for offshore industrial fisheries in the EEZ (Exclusive Economic Zone). Aitutaki falls between the two with several large resorts catering for tourists who want to visit a second island besides Rarotonga, but some of the villages are subsistence-based. In the Northern Group only Manihiki has a partially-developed cash culture: supplying black pearls from artisanal farms to the Rarotongan tourist trade; it has a fortnightly flight to the Southern Group. Otherwise, transportation links to the Northern Atolls are generally poor, typically 3-4 ships a year. Outer Islands are sparsely populated, with about 85% of the national population living on Rarotonga; there is a large diaspora in New Zealand and Australia. People are very religious, especially on the atolls. Land cannot be sold in the Cook Islands, so customary tenure by extended families is the norm (about 95% of land is traditionally owned).

Cook Islands are in the cyclone belt, and each island has been devasted at least once. The cylone season is from 1st November until May each year. The PI was on Aitutaki when *Cyclone Pat* hit in February 2010, this caused structural damage to 95% of the buildings and 63 houses disappeared (White 2012).

Sea turtles in the Cook Islands

In common with much of Oceania sea turtle research in the Cook Islands was lacking. Largely due to an absence of resources, including scientific expertise, and transportation difficulties within the archipelago. White (2012) reviewed the state of knowledge for sea turtles in the Cook Islands: scientific records for turtles in the Cook Islands were sparse and fell 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 1960s and 1970s (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 a poster (McCormack 1995) and a very general pamphlet on sea turtles (WWF undated). Prior to White's study (2012), 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 2011). 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* (islets). The absence of systematic surveys in the Cook Islands means that it is very difficult to determine how present populations of sea turtles compare with their past distribution and abundance. Also there was no clear indication of when or where nesting actually occurs.

Balazs (1995) and Pritchard (1995a) visited the Cook Islands within Pacific-wide surveys during the late-1960s and early-1970s to investigate the distribution of sea turtles. Balazs (1995) concluded that Palmerston Atoll was the most important nesting site in the Cook Islands for green turtles, based on data from around 1970; and subsequent authors have cited this accordingly (Dethmers et al 2006; Maison et al 2010, NMFS 2010; Wallace et al 2010; Woodrom Rudrud 2010). The present author found this not to be true, but it is still an important nesting site nationally (White 2012, 2014).

Four sea turtle species: green *Chelonia mydas*; hawksbill *Eretmochelys imbricata*; leatherback *Dermochelys coriacea*; and loggerhead *Caretta caretta* are now confirmed as using Cook Islands territorial waters; the first two species are present throughout the year (White 2012, 2013, 2014). *D. coriacea* is 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 2012, 2014; White & Galbraith 2013). Nesting emergences were first reported from Mauke, Southern Cooks, in February 2012 (June and Andrew Hosking *pers. com.*; Cathy Siota *pers. com.* 2012)[2].

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 2012, 2013, 2014). 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 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.

[2] 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.*).

Egg-laying period

Little had been written about when sea turtle nesting occurs in the Cook Islands (White 2012) and so the exact period for egg-laying in the archipelago, and neighbouring Tonga and Samoa, was 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: egg-laying periods for green and hawksbill turtles (if they nest) could be co-incidental, overlapping, or separate. Nesting might also occur year-round at certain locations; *Mangarongaro*[3] for instance (White 2012, 2014). Balazs (1975) had 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 for 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)[4].

[3] A motu at Tongareva Atoll.

[4] 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.

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 2012) and some of the other Polynesian nations (e.g. Marquez 1990; Meylan & Donnelly 1999; SPREP 2007; NMFS 2010; and data citations in SWOT 2011; Dutton et al. 2014), 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).

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[5]. The following NAs are of direct relevance to us in the Cook Islands:

i) Western Polynesia: Pukapuka is 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.

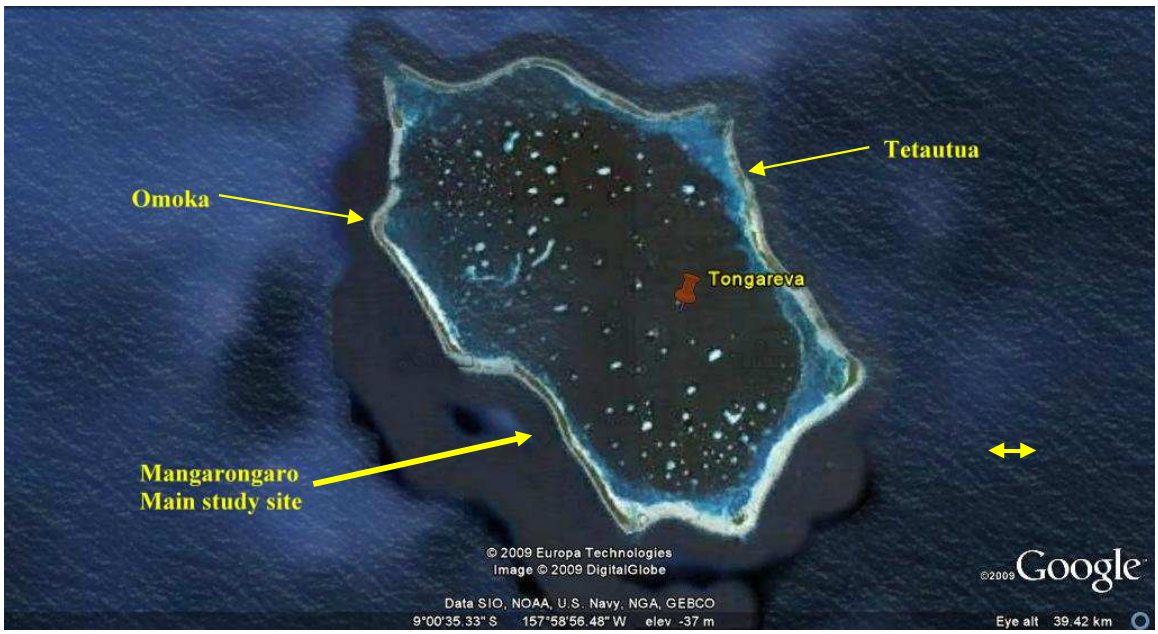
For places where few sea turtle data exist a conservative approach has been adopted when defining the NAs; these geographical locations are categorised in the lowest group: *1-25 nesting females per annum* (based on 4.5 nests per female per annum; Van Buskirk & Crowder 1994). The Cook Islands are data-deficient (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; White 2012, 2013, 2014).

[5] 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).

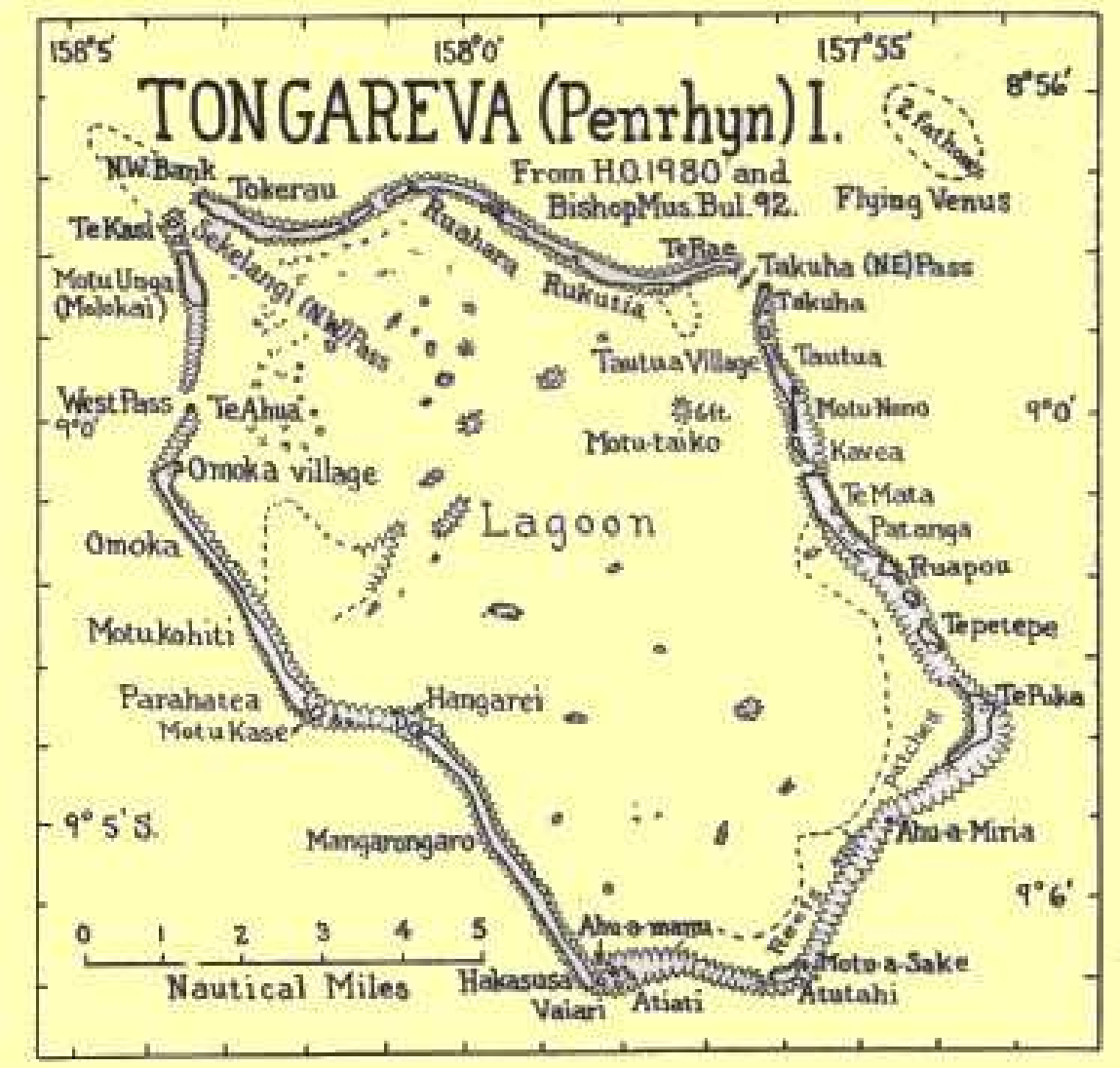
Tongareva Atoll: The research site

Tongareva Atoll is the northeasternmost atoll in the Cook Islands, and the most remote in the archipelago (09° South, 158° West). This is the largest atoll and lagoon in the Cook Islands, with an area of 233 km^2. The coral reef has a circumference of 77 km. The atoll is divided into numerous motu (islets) with a total land area of 9.8 km^2. There are two inhabited villages: *Omoka* is on the western motu of *Moananui* (about 130 people) and *Te Tautua* in the east on *Pokerekere* (about 45 people); all other motu are uninhabited.

The main sea turtle nesting site is *Mangarongaro* motu; a journey of 10-20 km from Omoka depending where we are surveying. This motu was selected by the PI as the first **index beach** nationally, but there were no data for turtle abundance or population trends (White 2012). Mangarongaro is 9.5 km long and 150-200 m wide; all nesting emergences are across the leeward (western) reef; none from the lagoon side, where beaches are unsuitable for egg-laying. The northernmost 1 km and the southernmost 0.5 km are unsuitable for nesting (coralline rock or boulders): the western nestable zone is about 8 km long and a few metres wide. This has been divided into three sections that are separated by small areas of boulders. **Mahera** is the northern section, length 3 km, (mid-point 09°02.27 South, 157°59.25 West); the central section is **Tetoto**, length 2 km (mid-point 09°03.18 South, 157°59.06 West); the southern sector is called **Akasusa**, length 3 km, (mid-point 09°04.37 South, 157°58.21 West).



Tongareva Atoll. Only two motu are now inhabited: *Omoka* has about 130 people; *Te Tautua* 45. Mangarongaro motu is uninhabited, but occasionally used to harvest resources; its western beaches (leeward reef) are the main research site. Two-ended arrow is 1 km. [Map adapted from GoogleEarth].



Map of Tongareva Atoll from 1980 (Bishop Museum) showing names for various motu, however, islanders also use different names for many places. [The name 'Penrhyn' derived from a British slave and transportation ship *'Lady Penrhyn'*].

Beach morphology

Mangarongaro's western beach is narrow, steeply-sloping and a dynamic habitat. Sand overlays coralline pavement or boulders, and extends along most of the western shore. Sand coverage can be deep, but may also be stripped away completely by strong wave action. Sand grains are coarse, making nest construction easy. *Kirikiri* (coral rubble) comes and goes. Someimes there are large areas with kirikiri, then it all gets washed away again. It seems the substrata is not so important for nesting honu. Ease of access from ocean on to shore appears to be the determining factor: whether sand or kirikiri is present the female will try and nest; both substrata types allow successful hatching.

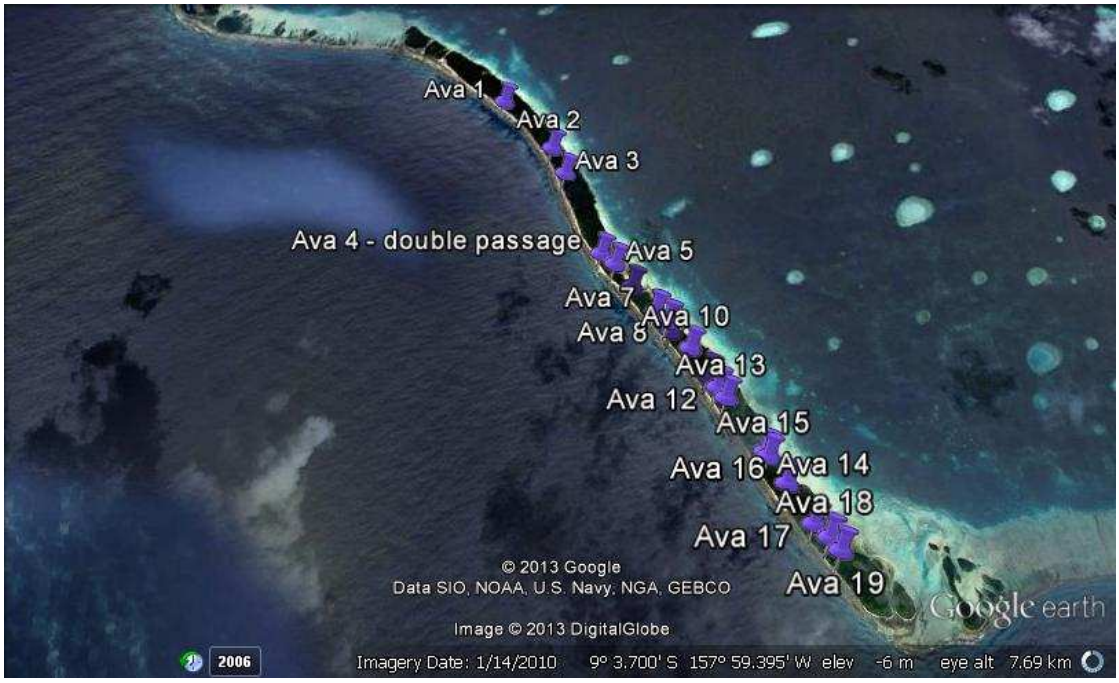
Substrata categories are:

Nestable: i) sand; ii) kirikiri
Non-nestable: iii) pavement; iv) boulders; v) coralline rock

Non-nestable areas can shift. Although pavement remains, the sand or kirikiri can be removed and subsequently replaced through ocean dynamics. Boulder sections are fairly stable, and provide recognisable boundaries between nesting sectors, but fierce wave action will carry these boulders off to sea. Coralline rock sections are barren, the surfaces very sharp, and would be extremely difficult for a honu to cross.

The leeward reef

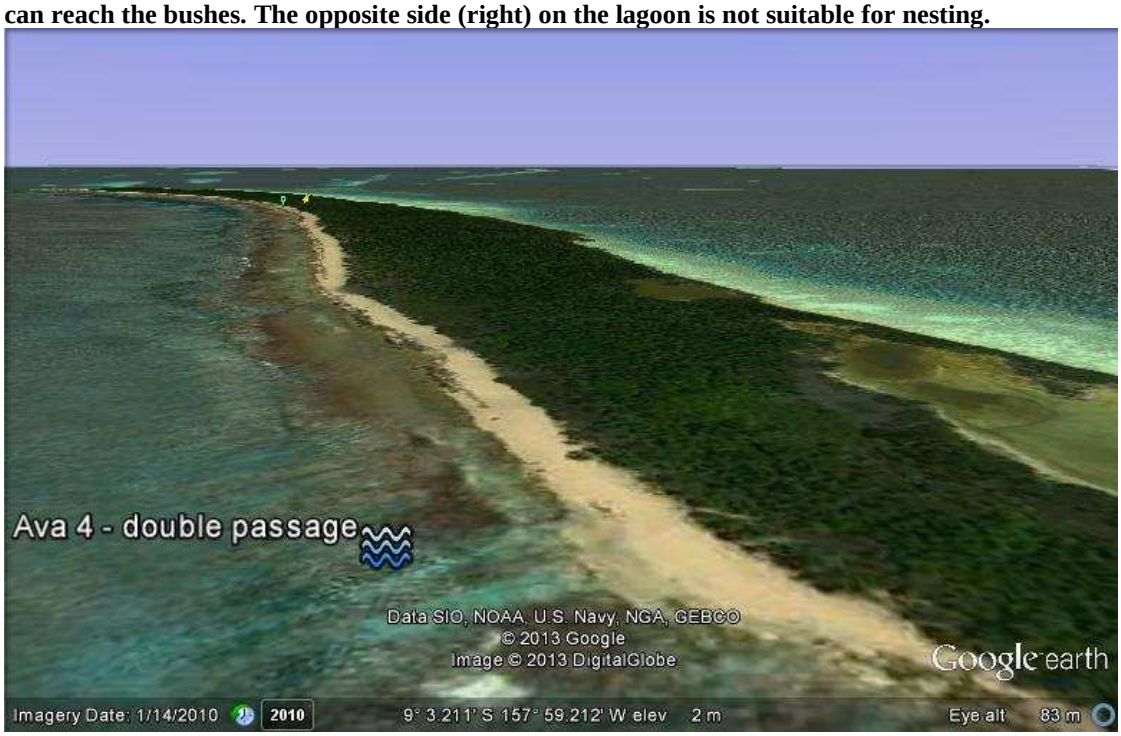
The reef drop-off is mainly about 20-50 m from shore and several sections have a raised coral wall adjacent to the beach. At numerous places there are small breaches through the reef (‘*ava’*): nesting occurs near these ava. GPS waypoints were fixed for 19 ava (numbered sequentially from the north; a few tiny ava were not marked). Nests were way-marked, and nest clustering shows significance relative to the ava, in other words most adult emergences occur via these ava. Adult emergences do occur at other spots where it is possible to crawl over the reef-top, or swim through a partial lagoon.



Nineteen ava through the leeward reef were waymarked (GPS); numbered from the north. Ava 4 marks the border between Mahera (north) and Tetoto (centre); Ava 10 is the border between Tetoto and Akasusa (south).

Above: Perspective view of *'ava'* (small passages) through western reef of Mangarongaro motu.

Below: *Ava 4* ~ double passage. Border between Mahera & Tetoto. These narrow sandy beaches are good nest sites; egg-laying is mostly in the vegetation at the back of the beach, but high water can reach the bushes. The opposite side (right) on the lagoon is not suitable for nesting.



Above: Perspective view of nearshore coral barriers at low water; waves indicate the reef drop-off.

Below: Rising tide shows the barrier can be traversed around high water; and also that the crawl to the nesting zone can be very short (1-2 metres).

Both photos show turtle tracks adjacent to ava; over time we could show a significant pattern for nesting clusters near to these passages.

Nest placement

Most nesting occurs at the back of the beach in the vegetation (coconut, pandanus, and low bushes; see White 2012 for detailed descriptions); only 3 nests were laid mid-beach. U-turns (n = 2) and non-nesting emergences are rare (n = 3): in other words it seems that if a turtle comes ashore she usually nests. If a honu hit rocks under the sand while digging the nest, she dug a second body-pit nearby; if hard substratum was encountered again then maybe the animal would return to the ocean without laying eggs, only to re-emerge later.

Nests are often laid underneath *'hara'* (pandanus) leaves.

Green turtle nests are usually laid under vegetation or by the forest margin.

These nests were laid the night before: the sand has not had time to dry out, and the snapped-off plant material was still fresh.

It seems likely that many turtles would strand on a rising tide (high water period), making it easy to cross the nearshore barrier and access the beach, then return to sea well before low water. At spring tides (Full Moon and New Moon) turtles may only have to crawl 1-2 metres to reach the vegetation line and lay their eggs. This makes it difficult to patrol at night without scaring the honu back to sea before laying their eggs. Traversing the jungle at night is also difficult, and although it was tried as an alternative to walking along the upper beach, it proved impractical because there were too few places to get from the forest onto the beach, so large sections were missed. Beach slope is obviously sufficient for adequate drainage of substrata at egg-chamber depth, but has not been scientifically assessed; at times the high water strandline is in the bushes. This was a regular occurrence during 2015 with flotsam indicating the overwash extent.

Up and down tracks suggest that emergence occurred on a rising tide when the coral barrier could be traversed. The nest had been laid a few hours earlier.

Research notes from 4th September 2012 to 28th February 2013

How logistic challenges affected the early surveys

Because of the need to reach Tongareva in order to conduct the present research, the PI had no choice but to voyage across from Rakahanga onboard S/V Kwai (early-September 2012), even though this meant there were no supplies to start the project. Some surveys were undertaken nonetheless, bringing in some encouraging results.

Mangarongaro: An initial survey was conducted at the **Mahera** and **Tetoto** sections on 21st September 2012. There were no tracks or nests at **Mahera**; this had been a hot-spot for nesting during preliminary surveys in 2011 (White 2012). At **Tetoto** there were recent tracks and **38 nests.** Some of these nests had hatched in the preceding 1-2 months (based on the desiccation of various egg-shells found at the beach-surface): this fact alone means that **nesting must have occurred between May and July 2012**, as it takes about two months for the eggs to incubate. [Nesting clusters were near *avas*: 3, 5, & 7-9].

Akasusa was surveyed a week later (28th September 2012) to waymark the *ava*: this was the PI's first survey here, as during preliminary investigations in 2011 we had no boat or gasoline (a small kayak was used, but being rammed by sharks was a big problem). There were new tracks and **60 nests** (13 recent; 47 more than one month old): **nesting** was definitely underway **during September 2012.** Because of time constraints (daylight hours) nests were not waymarked on this occasion. The tracks were in 3 main clusters at the back of steeply-sloping beaches near to avas 16-18. Several older tracks were still visible beneath the more-recent ones (see photo above), perhaps made by the same females whilst laying their previous nests, as sea turtles do show strong nesting-site fidelity.

The third survey (17th October 2012) investigated the atoll's eastern side: **Pokerekere, Kavea, Temata, Tepetepe, Patanga** and **Tepuka motu,** but found no evidence of nesting. Many of these sites are unsuitable for egg-laying: the shoreline by the windward reef tends to be rocky, with little or no access from the ocean; sand is rare and there are large sections of rocky pavement, as well as very jagged rocks. The reef abuts the land for much of this eastern shoreline (i.e. no reef-top lagoon). The southeastern corner has a shallow lagoon between the reef and motu, with many isolated coral heads (*toka*), so this would be a suitable foraging or resting habitat. The inner lagoon-side beaches of all these motu are very narrow (1-2 metres), mostly water-logged, and often with dense vegetation reaching to the water's edge. In one or two places nesting could occur, but probably in sandy patches inside the forest, rather than on the beaches themselves.

During this survey the PI met a useful contact at Te Tautua, who said that he had anecdotal knowledge for turtles, such as seeing numerous small hawksbills in the lagoon; tragically, the man had a stroke next day and passed away (so that knowledge was also lost; RIP).

We also found significant *'green tides'* in the lagoon near to Tepuka. [There were two similar occurrences in mid-2012 before the PI returned home; fishery officers sent

photographs and water-samples of the earlier events for analysis in Rarotonga, but the findings were inconclusive. There had been substantial fish kills: mostly reef-grazers, such as convict surgeonfish *Acanthurus triostegus*].

After the eastern surveys mentioned above logistical difficulties kicked in. The PI did not own a boat and had to try and persuade people to take their craft out. Grant funding had not been finalised so the PI used the last of his savings to buy gasoline locally; then there was no more fuel available for outboard-motors. It must be stressed that these atolls are subsistence-based cultures and not cash-economies, so islanders themselves have very little money or resources and the highest priority is gathering food. All cargo arrives by sea and shipping is rare, so supplies are often unavailable anyway.

Lady Moana bringing cargo to Omoka, it tends to come about 3 times per year.

Above: Temata; Below: Tepuka looking north. These are both on the atoll's eastern side and generally unsuitable for nesting (the pale yellow colour is actually coral).

Top shows the atoll's windward reef: this is unsuitable for nesting. Left shows *'green tide'* found in the lagoon to the west of Tepuka (October 2012)

Limitations of weather

Weather conditions also affected our survey opportunities. The lagoon is so large that it acts like an inland sea: large waves and heavy swells; the wind *'fetch'* can be over 10 km. This re-suspends sediment so that underwater visibility is often zero: again making passage amongst the *toka* quite difficult. The PI plotted several safe routes using GPS, but this does take time; there are also local waymarkers. The cyclone season is from 1st November until May; we never know when we will get hit. Every atoll has been devastated at least once in recent years [the last time at Tongareva was in 2010 when Cyclone Pat destroyed the school and numerous houses; and then continued southwards to destroy most of Aitutaki (White 2012)]. In 2013 Cyclone Garry came past and there was a Tropical Depression at French Polynesia in late-January. There was an earthquake in the Solomon Islands (4th February 2013) and a tsunami alert, but it came to nothing; a predicted 2013 El Niño did not happen. 2014 was a quiet year for cyclonic activity locally. Fiji's Meterorological Service (Nadi) calculates an increased risk for 2015-2016 with 10-14 cyclones predicted. The first was Cyclone Tuni (Category 1), which mostly affected Niue (28th -29th November 2015) before collapsing. Cyclone Ula was near to Niue (31st December 2015).

Between 26th & 30th August 2011 we had tsunami-like waves for five days on the leeward reefs, following almost simultaneous earthquakes near Vanuatu and Chile.

2015: a changing world

We are now living in changing weather conditions. Global climate-change is not some hypothetical future event to be discussed endlessly by politicians, arguing who should do what and when. Our weather has already changed. Apart from one year (1998) all the hottest years globally have occurred since 2000. The warmest year since records began in 1880 was 2014, but then every month in 2015 set new temperature records, so it is likely to be recorded as the hottest year (see below).

Rainfall patterns at Tongareva have changed too. In 2010 (before the PI arrived) there was a 6-month drought: water was severely limited and the school was closed. When continuous research began in September 2012 rainfall was 11-16 days per month until year-end. However, 2013 was a very wet year with rain falling on 254 days. Showers tended to be heavy, so flooding was widespread. Then 2014 was a drier year (rain on 131 days). The pattern in 2015 is more variable: January-March had rain on 18 days per month (range 17-19 days), but this reduced in April (6 days with rain). In total rain fell on 157 days, but some months were very dry; rain soaks immediately into the porous coral sand. Mangarongaro motu had no rain for almost 6 months. [Table 1 below]

The latter half of 2015 provided an opportunity to record impacts of El Niño in the Northern Cook Islands. The oscillation (ENSO) was confirmed as being in place on 12th May 2015 by Australian, Japanese and NOAA meteorology services. The previous major ENSO event was 1997-1998, when many coral reef systems globally suffered damage; about 16% died. Tongareva had normal seawater temperatures (about 29-30ºC) in 2015. Prevailing easterly winds shifted slightly southwards (East, East-southeast, Southeast, South-southeast); rainfall was limited.

The weather in December 2015 was noticeably hotter; increased solar radiation made afternoons challenging, and several times it was difficult to complete nesting beach track-counts. Overnight winds collapsed and the lagoon was hot for weeks (33-35ºC). Brief showers occurred every few days keeping water tanks topped-up. The ocean by the leeward reef was also warm (32ºC) in the latter part of December.

The author found the **first coral bleaching**[6] at Tongareva on 21st December 2015 in the northern part of the lagoon near Tokerau motu. Bleaching seems to have happened within seven weeks, as it was not apparent on a previous survey (28/10/2015); but it could even have been during the very hot three weeks of December (photos below).

Atoni Williams (*pers. com.*) reported that the ocean reef at Molokai was bleached on 28th December (northwest of atoll). The author found several bleached *toka* (isolated coral heads) at Mahera (southwest of lagoon): these were OK when visited two weeks earlier [12th December OK, 30th December bleached]. See APPENDIX TWO.

Several green tides were seen in the lagoon during November 2015, but no fish kills. It is unclear what may occur this summer with hot dry weather and ENSO interlinked.

[6] Higher water temperatures stress the corals causing them to expel symbiotic zooxanthellae, which means that photosynthetic nutrients from these dinoflagellates are also lost to the coral colony.

Table 1. Monthly rainfall at Omoka, Tongareva. Records indicate any days that had some rainfall. Squalls are common, showers often brief but heavy. It is very rare to have a day with no sunshine (2-3 per year). 2013 was a wet year, 2014 a much drier one. El Niño was confirmed on 12th May 2015. The weather patterns in 2015 showed greater variability than normal.

Monthly tally of days with rainfall			
Month	**2013**	**2014**	**2015**
January	21	16	19
February	11	15	17
March	13	5	17
April	21	9	6
May	23	14	10
June	24	7	11
July	23	10	12
August	24	8	6
September	28	8	9
October	23	15	15
November	17	12	21
December	26	12	14
Totals	**254**	**131**	**157**

NOTES:

El Niño and La Niña have far reaching effects beyond the borders of 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, and 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 influence distant events such as snowfall in the Himalayas and rainfall in Madagascar.

The Pacific Ocean absorbs a vast amount of heat during a La Niña event, and releases 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. 2015 was likely to be the hottest year on record, even without ENSO.

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 (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, see http://www.cgd.ucar.edu/cas/catalog/climind/soi.html

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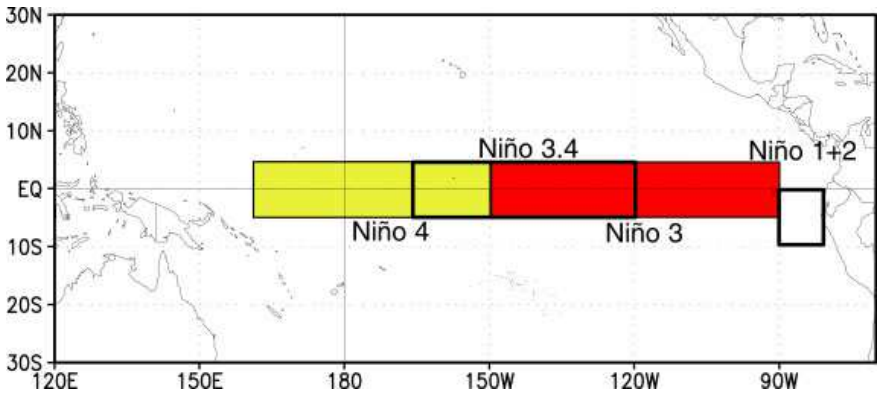
The difference in ocean temperature from usual across the equatorial pacific is used as another index of El Niño and La Niña. The **Niño 3** index monitors the temperature across a box in the Eastern Pacific, while the **Niño 4** index uses a box in the central-western Pacific. The **Niño 3.4** index uses a box that overlaps these, and is relevant for Tongareva.



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).**

First coral bleaching found at Tokerau motu 21st December 2015. [Next page shows a close-up of this coral; then two more images from Mahera on 30th December; five toka were viewed: all had bleaching]. ***Wider surveys began after New Year 2016.***

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Project funding and then some supplies arrive

After negotiating all the complex financial and registration arrangements required by NOAA and complying with the procedures for inward payment of funds to the Cook Islands (anti-money-laundering) a grant in late-November 2012 enabled gasoline to be ordered from Rarotonga. A new line (PDL Shipping) intended to make a monthly cargo-run to the atolls! *Tiare Moana* arrived in December 2012 for a few hours, offloaded cargo and left. Other than a brief stop (in April 2013) it didn't return. This story is repeated for each new shipping venture: they assume they can make a profit, but it is not possible (this would be known as a 'loss-leader' in commercial airlines). There are few people, with little money, and voyages are long because the atolls are extremely remote.

Extending the project time-frame

These complications meant fieldwork got off to a slow start so, following advice from NOAA's Programme Officer, the PI requested a 12-month *'no cost extension'* via GOL-website. Fieldwork was extended until September 2014, but the grant remained unchanged. Five project progress reports (PPRs) would then be required.

***

Research notes from early-2013

4th February 2013: A day-time survey of the northern half of Mangarongaro was conducted, finding recent tracks and **22 nests** at Mahera. Another **38 nests** were found in the **Tetoto** sector (this central sector seemed to be the more used in this year). We noticed egg-shells at the surface and excavated one hatched nest near to ava 6 (81 eggs; 100% hatch success).

Mataora Marsters - Director of Tongareva Marine Resources Centre agreed to make a boat available for surveys (**Ben Ponia**, Secretary of Marine Resources, supported this idea). A reconditioned outboard-motor first had to be freighted from Aitutaki in the Southern Cook Islands. We surveyed **Akasusa** on 27th February: finding **60 nests.** There were recent tracks (6 near to ava 7; 3 near ava 16). Four nests had already hatched near to ava 19, and 1 more near ava 14 (excavations would be done at another time). A local MMR staff-member came on this survey: building local capacity.

Note: Unfortunately a few days later the water-pump impeller on the outboard-motor broke, so again we had no boat ~ for almost five months. Work shifted to educational activities and local foot-patrols instead.

Moananui: western beaches along the main inhabited motu (Village of Omoka) were walked regularly; but nesting is infrequent. *Mataora Marsters said nesting was all along this shore in 2007.* On the **19th January 2013** nesting activity was found at the southern tip (nesting occurs here mostly along a 2-km section by the runway; photo above): this was the first nest here since May 2011 (about 20 months). Possibly six nests had been laid or attempted, but signs in the sand were confusing, numerous human footprints and perhaps a honu had been killed! A recent firepit was nearby. The PI continued to walk these beaches regularly, but nothing else was found. In late-February 2013 the PI learnt that a honu, which had been eaten at Thanksgiving Feast (14th January 2013) was the female laying this nest. The people involved had watched and videoed her laying eggs, and then killed and cooked it. Their idea of conservation was to let the honu nest first before eating it. A widespread belief is that turtles **only nest twice.** Traditional knowledge has a way of estimating when a female will return to lay her second nest: if a developing egg is held up to the light a dark patch indicates number of days (folk know inter-nesting is about a fortnight); so killing during the second event was more likely.

People then decided they wanted to hand-feed any hatchlings for several weeks before releasing them to sea (to stop them being eaten by fishes and birds). The PI visited the airport nest on 4th March, but it hadn't hatched; two days later 142 hatchlings emerged (100% egg success). A small pen was constructed in the lagoon at Omoka, however, families wanted to take hatchlings home; so most houses on the atoll had a few honu. Not a perfect situation, but it was a good opportunity for education over time. The PI addressed all of these aspects in a 60-hour **Honu & Life-skills course** at Omoka school; which should then filter upwards to the adults.

We gained advantage from these events: students measured the CCL (curved carapace length) on their animals; and also learned how behaviour changes when migratory animals are confined in a group **~ they attack each other ~** most had rear flippers partially-eaten. Before release we collected genetic material from two animals, the students learned how to sample; multiple paternity was discussed. Hatchling DNA is not a regional priority, but because the mother had been eaten, some haplotype information was thought better than nothing: there being no DNA records for the Cook Islands (Dutton et al. 2014), and so this might assist with unidentified fishery bycatch. These are the first known genetic samples from live sea turtles in the Cook Islands. Hatchlings were also used to demonstrate photo-recognition techniques (scute & scale counts; facial patterns etc; White 2006).

Two small juvenile green turtles were measured and DNA-sampled. They were too small to tag, but photo-recognition data were collected. The bottom right image shows that one turtle has an additional vertebral scute between V4 & V5 scutes. (September 2013).

Nesting effort by sea turtles in 2013

Please note that the Y-Axis scale changes in the next 3 graphs

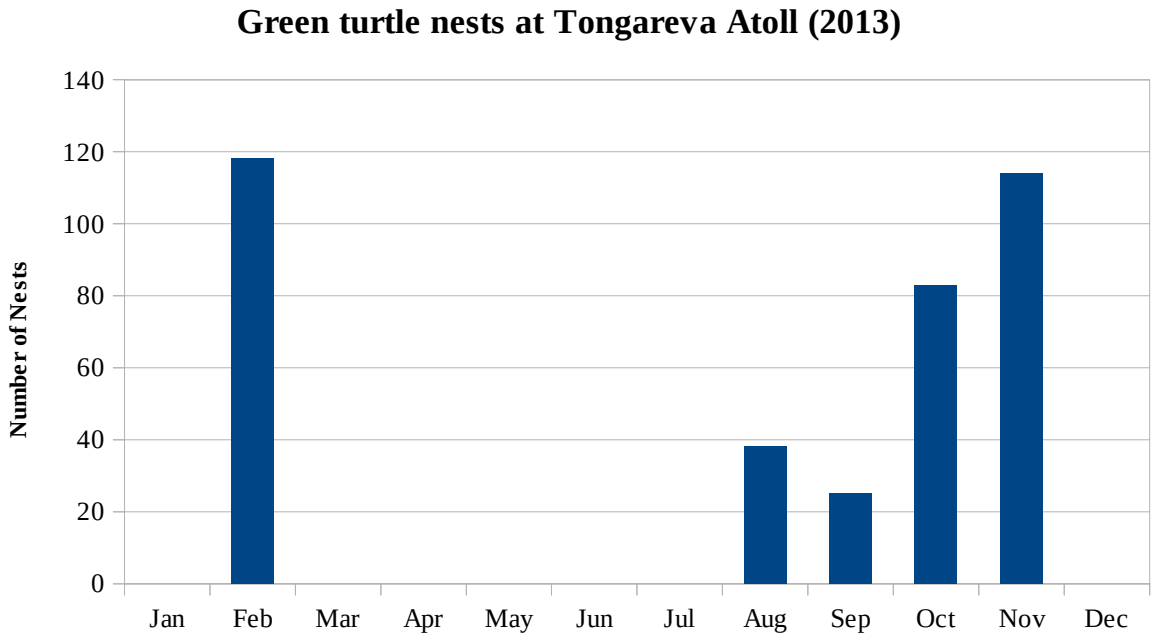


Figure 1. A total of 378 nests were identified at Tongareva during 2013; these are all assumed to be laid by green turtles *Chelonia mydas*. In January and December there were extensive community religious commitments and weather was poor, so surveys did not occur. The outboard-motor failed in early-March and spares were unavailable until July, so Mangarongaro was unsurveyed for five months. June & July are usually the quietest months anyway. February had 118 nests and November 114 nests.

Nesting effort by sea turtles in 2014

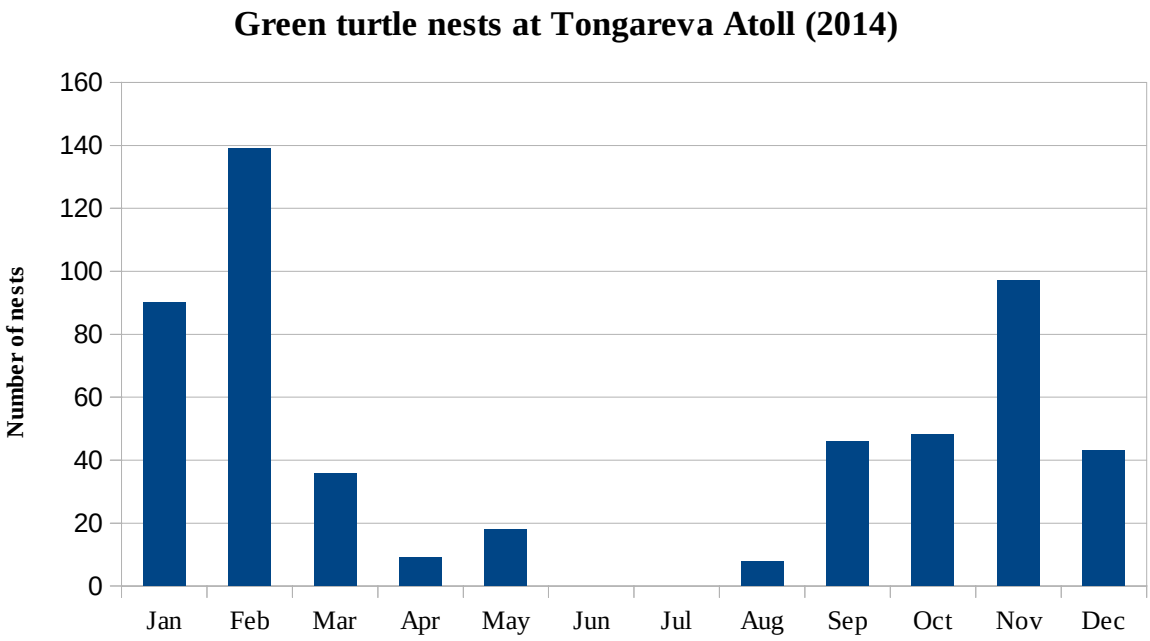


Figure 2. A total of 534 nests were identified at Tongareva during 2014; these are all assumed to be laid by green turtles *Chelonia mydas*. **This was the first year in which surveys were conducted in every month.** There were no nests in June and July. Peak nesting effort was in February with 139 nests, followed by November with 97 nests. In August there were eight nests: four at the northern end of Mahera and four at the southernmost part of Akasusa ~ nothing in the intervening 8 km.

A survey of all the southern half of Mangarongaro on 2nd September found 6 new nests, and nothing new in the northern half. Another survey of the northern half (10th September) found 33 new nests; at least 3 were laid the previous night (Full Moon 9th September 2014).

Almost unbelievably, a survey on 13th September found that very high tides had removed all track evidence from the previous survey: it was good luck that the weather had been conducive for fieldwork that week. *"I can say with confidence that nesting picked-up at the end of the 1st week of September 2014"* (White *pers. com.*).

At the end of November 2014 there were 4, possibly 6, nests laid at Hangarei (northern point of Mangarongaro) ~ this is **the first activity** of any kind at this site. Sand accreted allowing easy access from the lagoon and reef approaches. It is a very dynamic habitat and the honu only crawled a short distance before laying their eggs under fallen coconuts.

Nesting effort by sea turtles in 2015

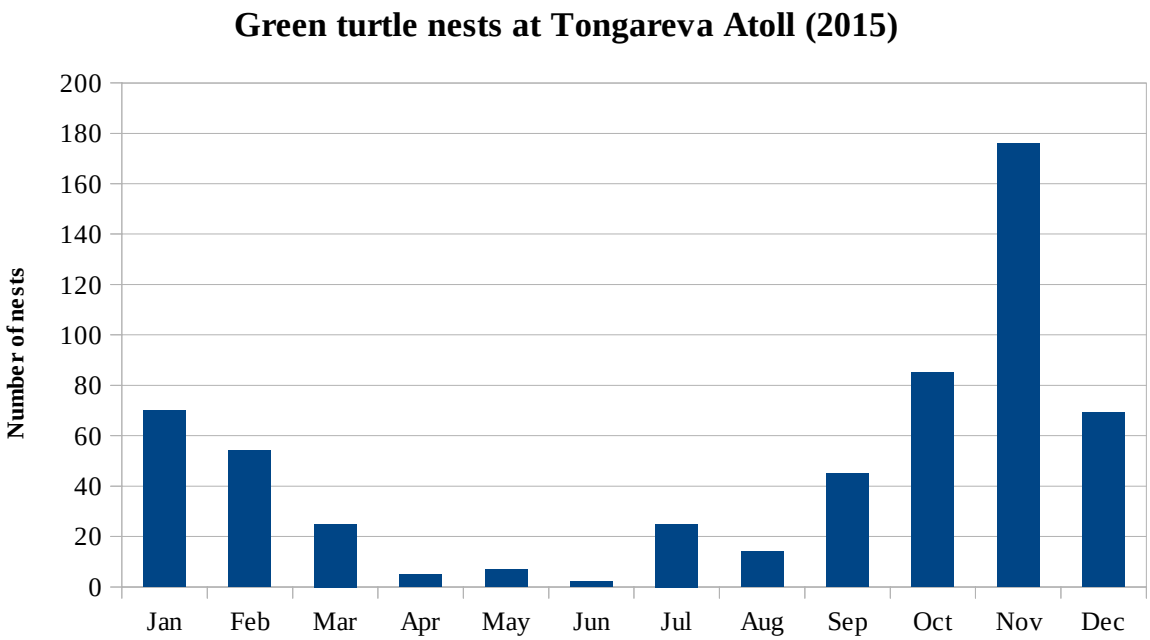


Figure 3. A total of 577 nests were identified at Tongareva during 2015; these are all assumed to be laid by green turtles *Chelonia mydas*. S**urveys were conducted in all months.** In late-January (24th & 25th) parts of the atoll were overwashed across the western reef. Cyclone Pam was over by Niue and then went on to devastate Vanuatu.

After the overwash in late-January 2015 nesting on Mangarongaro declined sharply: there were 54 nests in February 2015. In contrast the previous February (2014) was peak-nesting (139 nests). February 2013 also had 113 nests, but a lack of data before that meant peak-nesting could not be determined reliably. Coincidental with a collapse in nesting few foraging honu were seen in the lagoon for weeks. Possibly the turtles headed out into deeper water, but we have no proof.

Comparable data from January to May (2014 & 2015) show there were fewer nests in all months of that five-month period in 2015 than in 2014 (292 nests in 2014; and 161 in 2015). The author wondered if animals might return mid-year to complete their reproductive cycle? Data here suggest this may have happened. June and July were always two months with few or no nests, yet in July 2015 we find 25 nests at Mahera. **November had 175 nests**: the greatest monthly tally since research began five years ago. Perhaps some of the February animals did return, joining the 2015-2016 nesters. This should become clearer with a long-term dataset.

El Niño was confirmed on 12th May 2015: it is unclear if this has an impact on current nesting activity; because honu tend to be migratory animals their reproductive voyage may have started a year or more ago. Perhaps some effect will occur in another year.

Important New Findings from Tongareva Atoll

1. Egg-laying period:

The importance of Tongareva Atoll is enhanced by extensive green turtle egg-laying. There is no doubt that **Mangarongaro motu is the paramount nesting site** in the Cook Islands (White 2012, 2014). Nesting on Mangarongaro appears to be year-round, but with a peak during the austral spring and summer (Table 2 & White 2014); the other motu are less predictable.

Note: year-round nesting contrasts with the findings from Palmerston Atoll (Rufford Trust Expedition, April 2012), where nesting appears to be seasonal. That expedition found 187 nests, but some were several years old. There was a **164-day non-nesting interval** (from 20th April to 1st October; White 2012). For many years Palmerston Atoll was believed to be, and cited as, the most important green turtle nesting habitat in the Cook Islands, based on data from about 1970 (Balazs 1995; Pritchard 1995a). Palmerston Atoll is the second most important, with nests mainly being laid on Cook's motu, Tom's motu, and Primrose motu (White 2012, 2014).

2. There is a strong association between nest clusters and small passages through the reef at Mangarongaro:

Nesting emergences are definitely occurring by the *ava* (small breaches in the reef). There is one section between Avas 9 and 13 where almost nothing occurs. From a human perspective there seems no obvious difference between this and other areas where nesting occurs; perhaps turtles see something else. Scuba surveys on these reefs are being done in 2016, subject to weather.

3. Nesting so far appears to be stable:

Reproductive effort over five years suggests nesting at Tongareva is stable (White 2014). This was not previously known for the Cook Islands or similar nations in Oceania (NMFS 2010). It is recognised that it probably needs two or three decades before a true picture emerges. The absence of long-term data means it is unclear what level should be considered a high or medium density nesting year. The weather in 2013 was also unusual with rainfall on 254 days (there had been a 6-month drought in 2010), but again, any significance or correlation between weather patterns and nesting is unclear (Limpus & Nicholls 1988; Brooke 1995; Solow et al. 2002).

Table 2. Annual nesting effort by sector at Mangarongaro. There were differences across the three sectors over the months, sometimes little happened in one area, but another section had numerous nests. Presumbly this reflects nesting site preferences of individual honu. The central sector Tetoto had the most consistent effort. As explained above we lacked a boat in early 2013, so no surveys were undertaken for five months. That may have been of little consequence as nesting eases off in March to May, whilst June and July usually have few or no nests. In 2014 and 2015 surveys were conducted in all months making those data reliable. Akasusa can have substantial nesting or very little. August 2014 had 4 nests at the northern end and 4 at the southern tip ~ nothing in the intervening 8 km. 2013 was a very wet year with some rainfall on 254 days. 2014 was much drier with rain on 131 days. In 2015 several important things happened: i) on 24th-25th January the atoll was overwashed from the west, then nesting decreased [few turtles were seen in the lagoon either so they may have moved offshore into deeper water]; ii) El Niño was confirmed on 12th May; iii) egg-laying increased in July; iv) November had the largest monthy tally of nests (n = 175) in five year's research.

	2015				2014				2013			
Month	**Mahera**	**Tetoto**	**Akasusa**	**Tally**	**Mahera**	**Tetoto**	**Akasusa**	**Tally**	**Mahera**	**Tetoto**	**Akasusa**	**Tally**
January	60	7	3	**70**	62	28	0	**90**	N/S	N/S	N/S	**N/S**
February	23	10	21	**54**	22	37	80	**139**	31	29	58	**118**
March	5	2	18	**25**	20	10	6	**36**	No	Boat		
April	4	0	1	**5**	9	0	0	**9**				
May	5	2	0	**7**	8	9	1	**18**				
June	2	0	0	**2**	0	0	0	**0**				
July	25	0	0	**25**	0	0	0	**0**				
August	5	9	0	**14**	4	0	4	**8**	0	31	7	**38**
September	5	35	5	**45**	27	11	8	**46**	21	4	0	**25**
October	24	37	3	**64**	41	7	0	**48**	42	19	22	**83**
November	44	77	54	**175**	76	16	5	**97**	32	51	31	**114**
December	46	17	6	**69**	24	17	2	**43**	N/S	N/S	N/S	**N/S**
Totals	**248**	**196**	**111**	**555**	**293**	**135**	**106**	**534**	**126**	**134**	**118**	**378**

***October 2015 had 20 nests at Tokerau motu, and 1 nest at Te Tautua (the 1st recorded); and another nest there in November. 2015 total is 577 nests.**

Some excavations to determine egg success

Top: Ru Taime excavating a nest near Ava 5 (March 2014).
Bottom: Egg tally to determine clutch hatching success.

Top: Jacob Taime and friend learning to excavate and tally eggs (April 2014).
Bottom: Some undeveloped eggs.

Top: Recently hatched nest showing egg-shells at surface and emergence hole.
Bottom: Tally ~ 118 eggs, 3 undeveloped (98% success).

Nest success:

Egg success was determined by conducting an inventory of already-hatched nests. The process is time consuming, so only a few can be done on a particular day. On Tongareva the only practical time to undertake excavations is during the morning: after about noon the full strength of the sun falls on the western beach until sunset, there is rarely any wind, and humidity is high. Researchers were given a practical demonstration, and then everybody excavated their first nest guided by the author. Two points were stressed: **hatching success** is the number of eggs that reached full term and the babies emerged from the shell; **clutch success** (nest success) has a different meaning.

Clutch success was the total number of empty eggshells, minus any dead neonates found in the nest. This would equate to the number of hatchlings that emerged from the nest onto the beach; although they might be predated later. Any unhatched eggs were examined to identify possible reasons for failure (White 2012).

Table 3. Inventories of hatched nests were conducted when survey logistics allowed. A total of 1703 eggs were assessed; 1626 had hatched successfully (96%). Of the 77 unhatched eggs: 66 were unfertilised; 1had an eye-spot; 1 died at an early stage; three died at mid-development; and four at a late stage. Two died emerging from eggs *'pipped'*.

Eggs	Hatched	Infertile	Eye-spot	Early	Middle	Late	Pipped
1703	1626	66	1	1	3	4	2

Hatching success of eggs at Tongareva is high, typically over 95%. One example is an analysis of 17 clutches found the **Mean = 97% hatched eggs** (SE 1.5; range 77-100%). In fact 7 clutches were 100% successful; 3 were 99%; 2 were 98%; 2 were 97%; 1 was 95%; and two nests less successful (85% & 77%). When coupled with a general lack of terrestrial predators (there are wild pigs but no nests have been rooted up) this nesting rookery can be regarded as successful and probably sustainable; although we have no trend data yet (White 2014, 2015; and unpublished data from 2010-2015).

The PI also found similarly high clutch success rates at Palmerston and Rakahanga Atolls (White 2012, White & Galbraith 2013).

Nesting at other sites around the atoll

Tokerau motu: the westernmost of the northern string of islets; on 5th Nov 2013 three nests were discovered near its eastern end. The ocean coastline is poorly-suited for nesting. There are sandy and kirikiri areas and nests were in both substrata. Access to land is across a nearshore coral barrier, so probably occurs nearer to high water (White 2012). The lagoon side mostly has poor access.

Tokerau Motu.

Even more interesting was that in October & November 2015 several nests were laid nearer the western end of Tokerau on a small sandy section; access from the ocean is challenging ~ over a jagged reef. The first tracks were found on 09/10/2015 (Pakaiere Isaaka *pers. com.*); the author surveyed on 13/10/2015 and tallied nine nests. The subsequent survey (28/10/2015) found 11 more nests. The sand was very confused as numerous honu had nested there, and perhaps had overlaid previous clutches. Rather than disturb developing eggs, the PI decided to leave any excavations until hatching is complete. A survey on 21/12/2015 found no new nesting.

Tokerau Motu: ocean shoreline had some nesting.

Ruahara: this northern motu is east of Tokerau and Paniko. Nesting was previously unknown: 31 nests were found on 28th Nov 2013. Unlike neighbouring Tokerau: most of Ruahara's northern shore may be suitable for nesting and some of its south coast is accessible from the lagoon; the western end is not suitable. A cluster of seven nests was found at a sandy inter-tidal area along the central southern section. The north shore comprises steeply-sloping sand and kirikiri with some boulder sections. Access is over the reef top; again most probably nearer to high water. The nearshore coral barrier varies in height (maximum 1 metre) along its length; there are small breaks through the barrier in a couple of places that would allow honu to pass through. Other sections are lower and smoother, so honu could cross around mid-water. Four sectors had clusters of nesting (in both kirikiri and sand), and these were monitored through the months. Egg-laying does not occur here every year. Nesting was not made public to avoid a sudden increase in direct take of nesting females; this site is near to both villages, whereas Mangarongaro is much more distant and requires more fuel to get there.

Ruahara north shore; nests can be seen in the right-hand photo.

Exciting News!

Te Tautua Village: the eastern motu of Pokerekere. Two nests were laid here in 2015 (27th October & 6th November). None of the younger people have ever known nesting to occur in their village. Presumably nesting did occur some decades ago; and perhaps we are now seeing those cohorts reach maturity (demonstrating natal fidelity).

One of the grandfathers took the first clutch to eat (egg-take has virtually disappeared in the Cook Islands; only one other nest was taken at Tongareva, in August 2011).

Te Tautua has a long tradition of eating honu. Whilst the CICC Church was preparing for its opening ceremony in 1904 a huge green turtle was found to have fallen into a hole on the reef-top. This was a Blessing and became the feast of inauguration. The massive carapace was held against the wall and its outline sketched there.

Te Tautua nest is beneath the red saw handle in the foreground.

Tongareva Atoll green turtle population:

From the results in White (2014) and nesting graphs 1-3 above it is evident that turtles (probably predominantly *C. mydas*) lay around 500 nests per year. It is possible to make a rough estimate of how big the nesting adult population is. Female green turtles lay 3-6 clutches per nesting season at intervals of about 2 weeks, so 500 nests represent the reproductive output of some 80-170 individuals. However, female green turtles do not nest every year. Instead they need 3-4 years to build up reserves between breeding seasons, so the population nesting at Tongareva is probably in the region of 240-680 females. Male numbers are unknown. The in-water observations of juveniles, sub adults and mating pairs indicate strongly that the whole life-cycle of *Chelonia mydas* takes place within the Cook Islands and their EEZ. This means that external threats are limited and that local conservation measures are crucial. Although hawksbill turtles are seen occasionally, the data are too limited to make estimates (White 2012, 2014).

Cultural practices, sea turtles, sustainable direct take (from White 2014):

Honu are a delicacy in Polynesia and occasional hunting occurs; usually nesting females are targeted, being easy to kill. Previously honu were killed every Saturday to provide the feast after Sunday church (Papa Saitu *pers. com.*). Over the last five years at Tongareva (2010-2015) four females were taken while nesting, two juveniles and one adult female by net, one sub-adult speared, and four sub-adults (3 female, 1 male) were taken at sea by hand. During the same period only one egg-clutch had been harvested (13th August 2011). A turtle was killed for the official opening of Te Tautua solar power array by Rarotonga's government (25th June 2015). One other turtle was killed for a 21st Birthday party in early-November 2015. For the second year running Omoka did not kill turtles for its Thanksgiving Feast (11th January 2016). By adopting a non-judgemental approach the author learns of most captures. These were the first reported findings for direct take locally. White & Galbraith (2013) noted turtles were occasionally speared underwater at Rakahanga Atoll. In the context of likely turtle numbers mentioned above, this level of mortality is quite low, although hopefully our educational approaches will decrease it still further.

Living on a remote atoll is not like living in a city e.g. our nearest supermarket is 1400 kilometres away. Whatever nature provides is used (Webb 1997; Cincolta et al. 2000). Conservation measures have to be culturally acceptable. External enforcement is unlikely to succeed, not least because outside authorities are rarely trusted. Threatened species awareness is growing and, recently, people suggested only taking honu when other food is unavailable, which happens occasionally. Egg-take is now rare in the Cook Islands; 30 years ago most clutches were eaten (White 2012). Many of the younger people do not eat turtles, and by including women and girls as project researchers this awareness is more easily carried forwards to future generations.

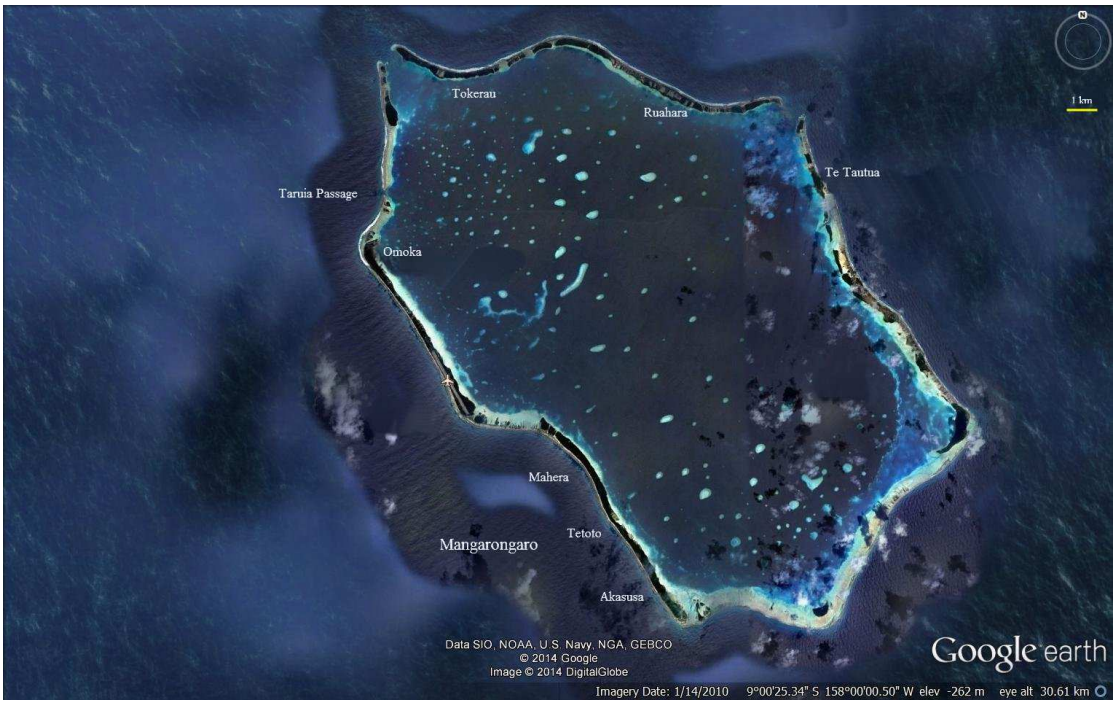
Limited turtle take may be sustainable at Tongareva because:
i) The sizeable turtle nesting population so far appears to be stable (see above).
ii) The main rookery is on a remote, uninhabited motu, so direct take is further limited by fuel availability (Allen 2007).
iii) Seabirds, crabs and large fish will prey on hatchlings, but nest predation has not been observed, even though rats and feral pigs are present on motu.
iv) Nesting is not confined to one site, so local extirpation is less likely to occur (Avise & Bowen 1994).
v) Usually one or two turtles are hunted in January for Thanksgiving, to conclude the seven-week celebration of Christmas and New Year. Occasionally other turtles are captured incidentally.
vi) The human population is small and causes few environmental impacts. Power was turned off overnight, resulting in little light or noise pollution. White et al. (2013) noted that this might enhance a habitat's attractiveness for sea turtles.
vii) An important awareness is to live in balance with nature and that species take time to grow. Our conservation approach emphasises **sustainable use of resources**, rather than the profit-driven unsustainable practices favoured in much of the world (White 2014).

Juvenile green turtle dna-sampled, tagged and released (school beach, August 2014).

In-water sightings

It is about 20 km from Omoka to Akasusa and honu are seen surfacing to breathe or swimming in the lagoon. Data are recorded using the methodology in White (2012). Incidental encounter reports from islanders are also noted. Most people use small aluminium boats and it is challenging to capture big honu for DNA-sampling. Mainly it comes down to safe sea and weather conditions; the large size of the lagoon means that waves are often substantial; the wind 'fetch' is over 10 km.

We have already shown that Tongareva Atoll is a mating habitat, and also a year-round juvenile developmental area (White 2012, 2014). The entire green turtle life-cycle (*Orahanga*) can occur in the Cook Islands sea areas EEZ (White 2014). Juvenile hawksbills were seen occasionally; only 1 adult-sized *E. imbricata* was observed.



Tongareva Atoll. All the land in the Cook Islands could fit in this lagoon. It is frequently very choppy as the winds are predominantly from the East. [Map adapted from GoogleEarth].

Marine data (2013-2015)

Between 1st January 2013 and 31st December 2015 there were 97 confirmed species records for green turtles that included eight mating pairs; and two juvenile hawksbills.

In 2013: there were 18 records *C. mydas* (we had boat problems for several months); in 2014: 57 *C. mydas* & 1 *E. imbricata.* Between 1st January and 31st December 2015 only 23 honu (22 green, 1 hawksbill) were encountered, which reinforces the author's contention that honu could have left for deeper water following the overwash and the nearby Cyclone Pam (see above). A large honu was seen entering via Taruia Passage (sex not determined as it was very deep) on 30th May 2015: this was the first sighting in several weeks. Mating was observed in January 2016. No hawksbills were seen in a 5-week survey by MMR Rarotonga (they left Omoka on 12th September 2015).

Potential habitat degradation due to infrastructural developments

It is an unfortunate fact of life that in the Cook Islands most habitat impacts and their subsequent pressure on associated species are caused by building infrastructure (e.g. White 2012, 2013, 2014, 2015). In economic terms this is often referred to as *'development'*. From a biological perspective it is clearly an environmental impact. The term *'sustainable'* also has opposite meanings: economically it implies perpetual profit-making, whereas biologically it means that a habitat or species can continue to function indefinitely. Many businesses utilise natural resources to make a profit, and those resources might be finite or take time to grow, so this will not be sustainable unless nature has the time needed to reproduce and remain abundant. Globally the loss of biodiversity is a major concern, with many species facing the threat of extinction, largely because of human activities: habitat loss is the greatest cause of such impacts.

Cook Islands Marine Park (CIMP)

Prime Minister Henry Puna proclaimed a marine park in the southern half of the Cook Islands EEZ (2013); this would cover around one million km^2. On paper this might appear to be a good idea, but there are some obvious detriments.

i) The CIMP's purpose seemed unclear. Recently a team from the Prime Minister's Office toured the Outer Islands giving short presentations to Communities explaining the Marine Park. The video was well made and would promote CIMP as a tourism asset, whilst supposedly honouring the customary needs and traditions of islanders in the affected area.

ii) Would foreign commercial fishing still occur in the CIMP? The PM's team was unable to answer this. Foreign fishery licences are the 2nd largest source of Cook Islands' revenue; tourism is the primary national income generator (largely limited to Rarotonga, and Aitutaki to a lesser extent).

There is much discontent in the Outer Islands, which are predominantly artisanal or subsistence ways-of-life, concerning Rarotonga's selling off the country's fish stocks to foreign companies. Income from fishery licences fails to be distributed to Outer Islands, but is kept by the Treasury instead. Many resources are, or should be, under customary ownership, including the fish (and see NBSAP 2002).

iii) Will zoning be delineated in the CIMP? Again, the presentation team was unable to answer. Islanders want to know if they can fish and gather traditional marine resources; whether additional impacts will occur in their customary tenure sea areas; and what Rights they will maintain or lose.

Discussions in the Outer Islands show renewed support for Traditional Management of natural resources i.e. Locally Managed Marine Areas (LMMAs). This is a wise choice, because a local Community and its Council can respond **immediately** to any threat: for instance closing the harvest for a species that is seen to be reducing in abundance, size or quality. The resource can be monitored by the Community until it feels safe to re-open the take (i.e. scientific assessment of the biological evidence). In contrast if resource-management is left to a remote national government it is likely to

be prioritised according to present or future economic needs, consulted upon, or ignored altogether.

Islanders might support zoning for scientific study only (no-take areas); local fishing only; tourism-related activities (whale-watching, rod & line fishing charters etc.); and commercial fishing, subject to agreement.

A major concern, especially at Palmerston Atoll and in the Northern Atolls, is that if CIMP prohibits commercial fishing in the southern half of the EEZ, then all the foreign fisheries will relocate into northern waters, thus increasing the pressure on our already-reducing fish stocks (White *pers. obs.*) and fragile environment. One of the reasons that NMFS-PIRO supported the present research is because the US fishing fleet based at Pagopago has permission to fish throughout Cook Island's waters, as well as adjoining sea areas, and they wanted to understand honu bycatch better.

For sea turtles, whales and other protected species an increase in fishing pressure in the northern region is likely to cause greater impacts or habitat degradation. Islanders are currently discussing what needs to be done to ensure their present and future needs, and long-term food sovereignty.

Seafloor nodules

The presence of manganese nodules on the seafloor of the Cook Islands presents an economic opportunity and a potential marine disaster. This also has relevance to the previous section (CIMP).

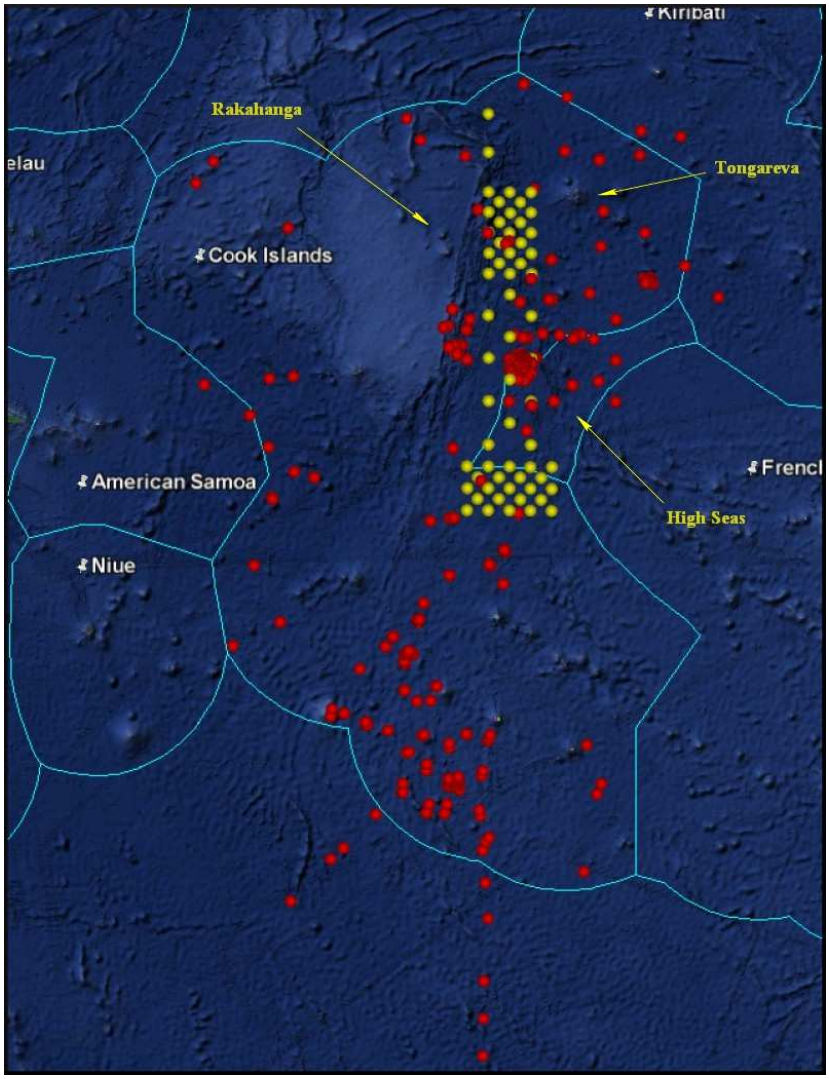
Nodules in the Cook Islands are particularly high in cobalt. The nodules are formed by precipitaing minerals out of the seawater, accreting at a rate of about *1mm per million years*, and thus can be regarded as a non-renewable resource. The distribution of nodules on the seafloor follows current movements from Antarctica to the Equator; with a particularly dense pattern to the south of Tongareva. The nodules are at depths of around 5 km, so mining them will not be easy.

Various ideas for nodule-mining have been suggested, but none are proven. Seabed-trawling would destroy the fragile balance of benthic life, as witnessed in shallower depth bottom-trawls. A major concern is that the deep ocean ecosystems are poorly understood http://www.eu-midas.net/science. A second idea is to to send down a large suction hose and suck the nodules off the seafloor, and also likely to suck up the soft sediment as well. When mining proponents were questioned, their answer was the 'tailings' would be pumped back overboard from a surface barge at some depth or other; thus impacting the water column as well as the seafloor.
Www.seabedmineralsauthority.gov.ck

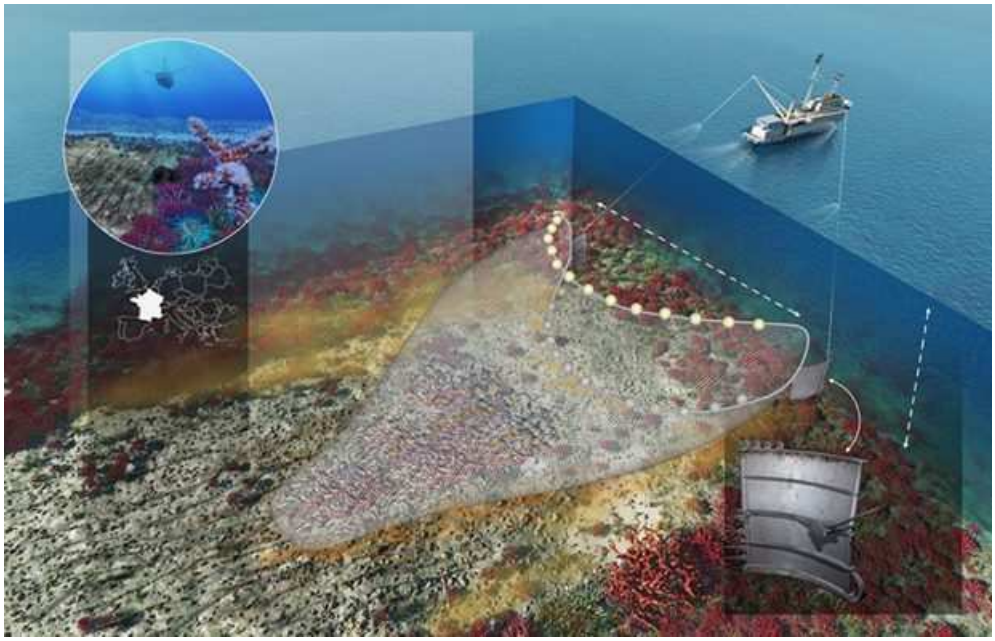
The most environmentally-friendly option would be to deploy a robotic vehicle, similar to the moon-landers, that has video cameras and mechanical grabs. It collects nodules individually, leaving the benthos almost unharmed. After a period of training the computer would be virtually autonomous, but with an over-ride control from the surface. This technology already exists http://www.mbari.org/mars/science/rover.html Vehicle buoyancy can also be adjusted to have virtually no impact.

During the Marine Park presentations mentioned above, seafloor mining was also discussed. A general feeling was people didn't want yet another impact on our oceanic ecosystem. Discussions in the Outer Islands centre on prohibiting activities within 200 km of any island. This is still to be resolved. Once again it can be seen that decisions from the southern Cook Islands, e.g. whether to allow or prohibit industrial activities in the Marine Park, are likely to impact on the northern group atolls and oceanic ecosystem. The Seabed Minerals Authority is urged to proceed with utmost caution.

Industrial activity in the northern sea areas, including noise or light pollution, or ecosystem damage through increased fishing or marine mining is likely to have an adverse impact on sea turtles, cetaceans, manta rays and pelagic sharks that use these areas. The southwestern corner of Tongareva is the most important sea turtle nesting site in the Cook Islands (White 2012 & 2014); Rakahanga Atoll also has a little nesting, but adult green turtles forage on their reefs year round (White 2012; White & Galbraith 2013). **The precautionary principle must always apply.**



Google Earth image shows Cook Islands EEZ. The yellow & red dots indicate seafloor nodules. Arrows indicate Tongareva & Rakahanga Atolls, both important sea turtle habitats; a pocket of High Seas between Kiribati, Cook Islands & French Polynesia makes ocean management difficult.



Typical trawl impact on the benthic environment. (Photo www.constantinealexander.net).

Tongareva: Taruia Boat Passage and Omoka wharf

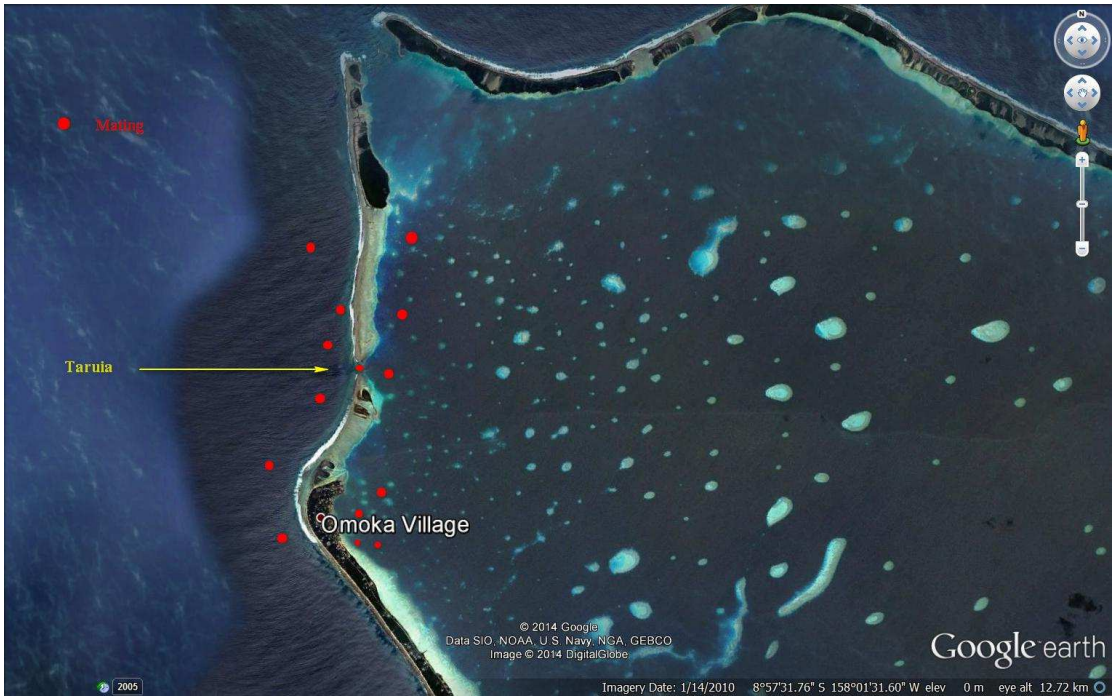
In September 2014 NZ Army surveyors visited Tongareva to measure a few depths in the lagoon and Taruia Passage. This formed part of a South Pacific assessment as an adaptive response to climate change. Tongareva is the only haven in Northern Cooks.

Taruia breaches the western reef and has a cleared depth of 6 metres. Two other passages exist (*Siki Rangi*, northwest, depth 3 m; and *Takuua*, northeast, depth 5 m), both are only suitable for small craft.

An infrastructure development proposal via NZ High Commission/NZAID suggested deepening Taruia Passage (which the Atoll Council has concerns with) and repairing wharves at Omoka, which would be acceptable if impacts were minimal. All parties are agreed that **an oil spill in Tongareva's lagoon would be an ecological disaster.**[7]

Why might this proposal be an issue? Many of our records for mating sea turtles have occurred in Taruia, or in the ocean or lagoon nearby (see map below). Mating is seen near Omoka wharf (White 2014). Our data show Tongareva is a **critical habitat** for endangered species and therefore must be taken into account. If this plan proceeds an EnvironmentaI Impact Assessment (EIA) should include local people, as we have extensive year-round knowledge of the atoll; making findings direct evidence rather than just anecdotal.

[7] This was also the view of Adam Greenland, New Zealand's Hydrographer.



Map shows honu mating records (red dots) near to Taruia Passage and Omoka Village.

Two vital points must be considered: i) in-water construction work at Omoka wharf should be done between 1st June & 20th July (about 7 weeks): this is the quietest period for nesting, and just before mating is known to occur. Construction work on land could be outside that. ii) if clearance work does proceed in Taruia, especially if explosive blasting is planned, then the passage, adjacent lagoon and outer-reef must be checked for sea turtles before EVERY detonation (White *pers. com.* 2014).

Tropic Twilight

In fact the above section changed slightly and Omoka wharf was progressed within an annual exercise by the New Zealand Defence Forces (NZDF) ~ ***Tropic Twilight*** ~ in September 2015. NZDF tries to do Local Engineering Tasks that benefit communities. At the eastern end of the wharf were four old fuel tanks belonging to *Te Kukupa*, the police patrol-boat. New Zealand's Ministry of Foreign Affairs and Trade (MFAT) was to move the fuel depot slightly inland and then return the decrepit tanks to Rarotonga. An Auckland firm (GHD Ltd. PO Box 6543, Wellesley Street, Auckland, Aotearoa) prepared the ESIA (GHD 51/33421), which included NZDF's work-programme; this plan was agreed to by Konisara. It stated clearly that no vegetation would be disturbed and no mature trees destroyed; also that aggregates would be shipped from Rarotonga by barge with the rest of the major equipment. [*This becomes important below].

The Project Manager from GHD Ltd introduced himself to Dr White and asked for feedback about the ESIA. The project was generally good and very well-planned; and GHD/NZ High Commission had responded to our original concerns regarding coastal zone light pollution in this most important sea turtle habitat in the Cook Islands; and the proximity of the new fuel tanks to the school (*Hapi Omoka*). **Meitaki Poria.**

Omoka wharf: yellow arrows show seawalls to be repaired; red arrow indicates old fuel tanks; green ellipse is the new fuel-tank location.

One issue was the ESIA's section on **Biodiversity** which said there were no online biodiversity databases. This is not true. A simple web-search (Cook Islands biodiversity) leads to 'Cook Islands Cultural and Natural Heritage', in other words *Natural Heritage Trust* (Gerald McCormack), which has formed part of government for years. The Project Manager said GHD had asked National Environment Service for information, as well as the Ministry of Marine Resources. It is curious that neither Department knows of the Natural Heritage Trust, not least beause the Environment Act (2003) emerged from the work of that Trust.

2015: An unforeseen trail of destruction!

Several events during this year had significant environmental impacts, some had been planned, but others had not.

Overwash

In late-January 2015 (24th - 25th) the northern part of Omoka village was overwashed. Three factors contributed: spring tides, a super-moon, and, unusually, winds came from the west. Water poured over the leeward reef, around the church and graveyard, and flowed across to the lagoon; the current flow was very strong. Several houses were flooded, but there were no injuries. The community cleaned up debris from the entire area and helped to restore the houses.

Top: Overwash impact; Below: a honu was washed into Omoka village; tagged & released.

The dynamics of the flooding were that large breakers came across the leeward reef, flowing between the small *ahua* and Omoka village towards the lagoon. The water tried to recede back to the leeward reef, but subsequent waves prevented this, so a small wall of water (about 1 metre high) built up and then rushed towards the lagoon. It was obviously a similar effect, but worse, that caused the initial overwash on the Friday night. Such overwash has occurred in the past (Wilkie Rasmussen *pers. com.*). Also a small green turtle was washed ashore on the Friday evening (we tagged, dna-sampled and released into the lagoon).

Further pressure came from *Cyclone Pam* in mid-March 2015. Its nearest approach to us was Nuie, but it then devastated Vanuatu and other Western Pacific nations. Salt-laden winds caused considerable damage to trees along Mangarongaro's nesting zone; some fell down. Tides were higher, reaching to the bushes at times. Honu nests were also found further up in the forest than usual.

Uira Natura ko i Tokerau

Construction of the solar-power grid is described below, but numerous mature trees, including a large *tamanu* (Pacific Mahogany *Calophyllum inophyllum*), were removed because of restrictions on tree height to avoid shadow falling onto the photovoltaic panels. This was a planned impact.

A rogue Executive Officer

A major cause of environmental damage was, unfortunately, the arrival of a new financial administrator (EO) who arrived in mid-2015 from Rarotonga, having briefly visited Tongareva before. The EO said she wanted to strengthen community resilience to mitigate the effects of climate change, but it quickly became clear her personal business interests took precedence over all else. Every decision she then made had an environmental impact; some disastrous.

These impacts initially went unchecked because most of Tongareva's people travelled South: participating in *Te Maeva Nui* 50th anniversary of Cook Islands independence. A few people remained on the atoll looking after everything. Some of the travellers would not return for many months. Our local government was a *caretaker situation*; the EO became a part of that arrangement. Very quickly she overturned all normal rules of Community life and elevated herself, in her mind at least, to head of the island. The reason the following impacts occurred was because she approved her own actions, instead of seeking permission from the Deputy Mayor: *de facto* Head of the Atoll and last remaining resident member of Konisara at the time.

The EO's main misdemeanours were:

1. Sand and coral rubble was removed from Omoka's northwestern beach. Sand-mining occurred without permission and materials were used to form a raised base for the fuel-tank relocation at Omoka wharf. This was not in the project construction plan agreed to by Konisara; who expected that all construction materials would be shipped from Rarotonga. Most sand-mining occurred between 24th-29th August 2015, although more was removed the following week. The author visited the impact site, took GPS waypoints and numerous photographs to show the extent. The Deputy Mayor was informed and he immediately went to see the site for himself, before raising the issue with the EO. It is unclear how much sand was removed from the northwestern beach,

but a minimum and likely conservative guess is 1200 m^3 (refer to Hakono Hararanga Case Study #2). Removing sand from the ocean shoreline was not a wise idea and of all the possible extraction sites this was the worst option: being the area overwashed in January 2015. There is a high probability that future tidal incursions will impact a wider area of the village, including the Church. The graveyard is also at risk of collapsing into the sea as wave action erodes the beach.[8]

Top: the sand-mining site includes January's overwashed area, church is in white rectangle.
Below: sand used as the foundation for the relocated fuel-tanks.

[8] See the first paragraph under **Tropic Twilight** above for GHD workplan details.

Above: Looking North at the sand-mined site, graveyard is immediately to the right.

Below: Towering waves on the western reef.

2. Removing boulders from the breakwater near the hospital. The hospital is the highest-located building on Tongareva and doubles as our cyclone shelter. Adjacent buildings at the Marine Resources Centre are raised on tall stilts, providing additional accommodation. Telecom's satellite station is nearby: a perfect emergency facility. Immediately west of these buildings on the leeward shore is a breakwater made of large coral boulders (this design absorbs wave energy as seawater flows between the rocks). Several tractor-loads of these boulders were removed without permission to be used in the fuel-tank resiting project at the wharf. Degrading the breakwater makes us **more vulnerable** to tsunami or cyclone surge overwash. It was not in the agreed plan.

Hospital and MMR buildings: the highest points on Tongareva

3. Destroying several mature trees behind the hospital. As in point 2 above: removing these trees next to the breakwater increases the risk of overwash from heavy seas and worsens coastal erosion. It was not agreed, nor necessary.

4. Destroying mature trees at Omoka wharf. This also deviated from the fuel tank workplan mentioned above. Several mature trees were pushed down, including a *Tou* (Pacific Rosewood *Cordia subcordata*).

5. Destroying vegetation at the runway's northern end. Removing all shrubs and small trees and then compacting the substratum led to the property of Air Rarotonga's agent being seriously flooded numerous times by run-off from heavy rain; this didn't happen in the past. The airport's weather-station was also damaged by the machine operators (Warwick Latham *pers. com.*).

6. Widespread damage to the forest margin near the main road. Many mature trees were pointlessly bulldozed and rubbish dumped on new saplings. Home-owners were not consulted ~ debris was just dumped on their sections. Phone cables were dug up, disrupting some services. The border between two habitats is always important. It is a transition zone where species shifts occur. Several important bird species occupy this zone, including the **Bristle-thighed curlew** *Numenius tahitiensis* (Seriously Nationally Endangered).

The arrowed trees were all supposed to remain untouched (GHD fuel-tank workplan). The derelict building is the old Omoka hospital, which was demolished in August 2015.

Top: all vegetation removed north of runway ~ run-off then flooded properties to the right.

Below: airport weather station was damaged by machine operators.

Top: shows healthy forest margin with mixed trees & ferns.
Middle: mature trees along roadway pushed down
Bottom: phone cables dug up and then suffered from flooding.

Top: main road in September 2013, cool, shady, no soil erosion.
Bottom: main road in September 2015, hot, dry, bleak, no shade, soil lost to rain.

7. Dumping building rubbish into Omoka lagoon. Another serious and unnecessary impact: cement-blocks, paint, old metal, plastics and building rubble were dumped into the lagoon at the school beach. This is the exact area children use for swimming, water-sports and science. The School Principal was not consulted. Machine operators were told not to despoil the lagoon by the Chairman of the School Association; the Director of TMRC; and the author. The impacted area is fished for food[9], and is used year-round by juvenile green turtles.

Building rubbish, plastics and paint were dumped into Omoka lagoon, which is used for food fishing, recreation, school lessons & water-sports; and as a year-round honu habitat. Sharp, rusty, exposed metal is a public safety hazard: Environmental Health was notified.

[9] Marine Resources Act (2005), Part 3, articles 34 (1), (2 a & b), (3) show this as an offence.

Learning how a honu digs its nest ~ science on the school beach.

On top of these deliberate, unwanted and unnecessary environmental impacts other factors worsened our local situation. High levels of wind-borne salt were problematic throughout 2015 with many trees struggling to cope; lack of rain meant it was hard for trees to eradicate excess salt. Rama (*Ximena americana*) for instance, lost all fruit in February, leaves turned black and were shed, then when the leaves regrew the same thing happened again, so they had no viable fruit all year.

An unidentified insect parasite was, and still is, killing coconut trees alongside the runway. On discovery (by Papa Andrew Vaeau) the author reported it to Rarotonga's Ministry of Agriculture: samples and photos were sent down, but results inconclusive. Damage appears to have been a biosecurity impact introduced by one or more aircraft.

El Niño has already been mentioned and that further affected rainfall patterns in the middle of the year. December 2015 was a particularly hot month.

Tetoto and Akasusa on Mangarongaro suffered substantial tree loss from combined natural impacts. Because that habitat is very important for honu nesting it is dealt with in more detail below, but our habitat restoration effort is proving successful.

The terrible problem of plastic

We are quantifying other threats to species and their habitats. One serious problem is the presence of plastics in the ocean; this will worsen, as more plastics were produced in the first decade of this millennium than in the entire 20th Century (Derraik 2002; Moore 2008; Barnes et al. 2009; Gregory 2009; Ryan et al. 2009; Thompson et al. 2009). Sea turtles are known to ingest plastics, often with fatal consequences (Balazs 1985; Schulman & Lutz 1995; Witherington & Hirama 2006).

We did three beach cleans in both 2013 and 2014 (see Ryan et al. 2009; White & Galbraith 2013), but our only practical option is to burn the rubbish, even though this contributes to air pollution. Over 90% of the debris was plastic; little was local.



It would be very helpful if the Cook Islands and other Polynesian nations made a serious declaration to the world, saying that we really do not want rubbish from the consumer and industrial world on our pristine islands.

Plastics are now known to be present in the global food-web: ongoing genetic research at Plymouth Marine Lab (Great Britain) and CSIRO (Australia) is investigating how far this has moved through the food-web. Fish eat animals that have ingested plastics, and then we eat the fish, so it is likely we already have plastic molecules in our bodies. A study by Woodall et al. (2014) shows plastic filaments have heavily impacted the deep ocean benthos. A further point is that many marine animals ingest or become entangled in plastic debris; this serious impact is largely ignored by the world. Business interests and material wealth seem to be far more important globally than environmental health.


Chris Jordan: Albatross at Midway Island


5-Gyres

Dr Michael White 2016

Some images from colleagues around the world: Uruguay charts a steep increase in recent numbers of dead turtles containing plastic. The next three photos show plastics removed from dead turtles during necropsies. The last picture shows our present day ocean. This is neither healthy nor sustainable.

Dr Michael White 2016

Beach clean along Omoka lagoon: new school is to the right of the fork in the road.

Below: cleaning the school beach.

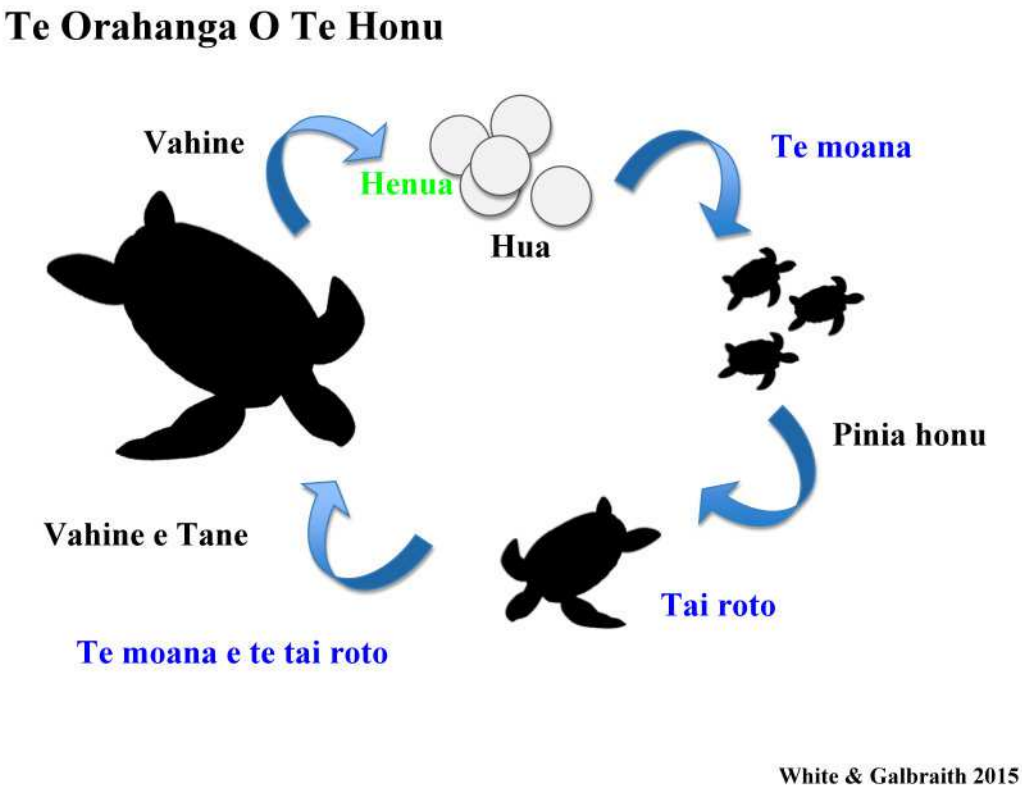
Top: cleaning main road on the way back. Bottom: tallying plastic categories (2014).

Community Participation and Education

Tongareva is a close-knit community with religion at its heart. Leading a subsistence way-of-life means that nature is very important too. Islanders have a great desire to provide their descendants with a healthy, sustainable and abundant ecosystem to meet most of their needs. Now students come on surveys occasionally (weather dependent), environmental awareness is starting to filter upwards to parents. So in time we hope to have most people involved in some way.

Women and girls are an integral part of this project, which has several benefits. Women play an important role in educating their children; many girls will be future mothers and can carry sustainable use of natural resources into our future generations. It extends their role in public-life, but it is not detrimental to existing community tasks, for instance men will continue to fish, and so this project should be seen as widening our resource management skills-base. Women are acknowledged as being affected disproportionately by climate-change, therefore, anything we do to enhance food sovereignty will improve our lives locally. The girls are much better students than the boys.

A project goal was to produce resources in the local language. The photo below is the first scientific information in *Reo Tongareva*.



"Life cycle of honu" is based on a drawing by Gemma Galbraith, prepared for White & Galbraith (2013).

Some other posters are being progressed for birds, crabs, *pipi*, habitats, Environmental Impact Assessments, biodiversity, habitat restoration, and coral bleaching.

OMOKA SCHOOL

TONGAREVA, COOK ISLANDS.

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OMOKA SCHOOL SCIENCE FAIR – A FIRST FOR TONGAREVA, PENRHYN

"This has been a year of many "firsts" for Omoka School in Penrhyn, the northern-most atoll of the Cooks group. A Science Fair was held on Monday the 8th of December 2014, addressing real life and real time issues about the biodiversity of the Tongareva Atoll.

Principal Anna Roumanu, staff, students of Omoka School alongside Dr Michael White, a marine biologist who resides in Tongareva studying honu (turtles), worked collaboratively on the idea of holding a Science Fair at Omoka School. For a whole term, plans were put together to hold the fair and on Monday the 8th this idea finally became a reality.

Omoka school is divided into multi-levelled classes, those being, pre-school; grades 1, 2 & 3; grades 4, 5 & 6; Years 7 & 8; and our senior students who are currently part of the TKU online learning programme with the Ministry of Education, Rarotonga.

Each class was asked to decide on a science issue which would eventually become the focus of a science project. The idea was to come up with a science question, offer a hypothesis and then go out into the community to collect information and data to support a possible answer. A recommendation for how to sustain a healthy environment should also be suggested. The topic had to be relevant to a biodiversity issue currently affecting Tongareva Atoll.

Each class would present their findings to support their project. Dr Michael White and Chairman of the Omoka School Committee acted as judges for the day and would decide on winning classes for best display as well as best presentation of facts.

The class projects were as follows:
1) Pre-school and Grade 1, 2 and 3: Describe 3 common animals that live on Tongareva and their natural habitat. This group studied *Tupa* (crab), *Honu* (turtle) and *Kiore* (Rat). The children worked hard making posters and diorama to show and explain about the animals they studied. Each animal representing a different type, that being crustacean, reptile and mammal. The children learnt about the anatomy and habitat of each animal. They incorporated local knowledge into their presentation and really created some wonderful displays.

2) Grades 4, 5 and 6: Addressed the issue of pipi poe collection. They studied the processes of pipi poe collection and measured quantity of take.

This group worked really hard on finding information about this current issue, even having taken a field trip out onto the coral rock or *toka* as we call it to measure and count pipi shell numbers. For those who don't know, the *pipi* shell is a small scallop shaped mollusc that can develop a natural pearl inside. Since the time of our ancestors, this pipi pearl has been collected and used by the Penrhyn people for both economic and sentimental reasons. It is a real unique and beautiful asset of Tongareva Atoll. Only now has it become a main source of income for the people and so with this new economic drive, people have started to notice the mass taking of the pipi shell, and so thoughts and discussions about conservation have come to the forefront.

3) Years 7 and 8: Studied the impact that pipi shell discards are having on the lagoon.

This environmental issue looked at the growth of algae when the pipi shell discards are thrown into the shallow waters of the lagoon. It also analysed effects such as water quality. They measured algal growth using photo-quadrats and transects.

4) Omoka TKU students: Based their project on rubbish assessment and the impact that improper rubbish disposal is having on our environment.

The *Fair* turned out very well, and parents who attended were keen to ask questions about each class's presentation. The students presented their findings and opened the doors to further discussion in regards to these environmental issues. The Mayor, Papa Tini Ford was very happy with the turn out of the day and has gained a new motivation to help address issues such as the quality of the atoll's rubbish dump after listening to the young people of Omoka express their views about how we are managing our rubbish ... rather badly!

We also listened to an in-depth presentation on Honu by Dr Michael White which helped to inform both teaching staff, students and parents about Honu in Tongareva and also about his research and current scientific work.

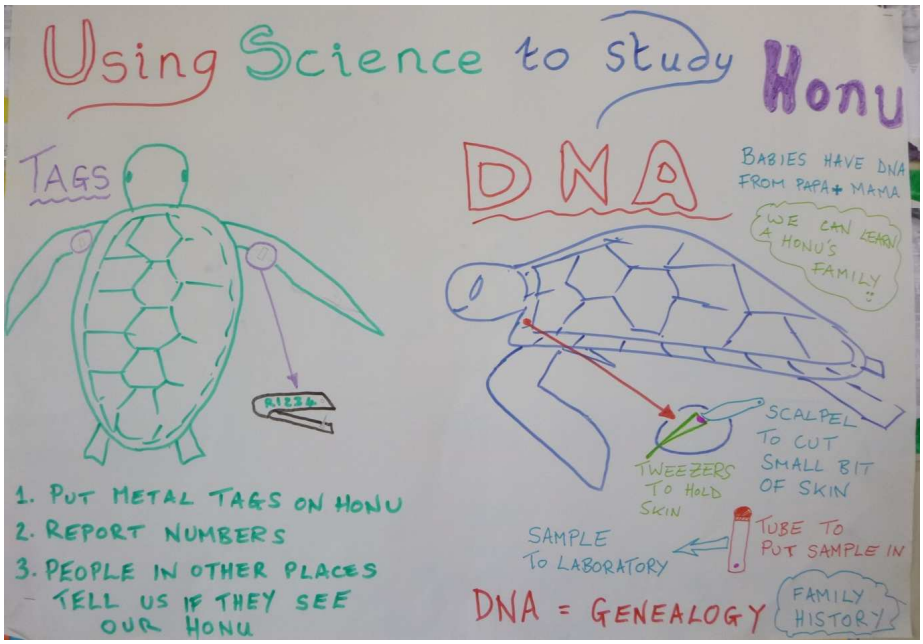
We are very happy with what we achieved today and although we didn't find all the answers, what has happened today is that we have through our children addressed issues that are real for us. We do want to protect what we have and through informing ourselves and our community about such issues, we feel that this is one significant step towards figuring out ways of conserving our environment for the future generations of Tongareva to come."

So this was a very good result for the PI's community-building efforts over four years 2010-2014. To take this a step further Dr White has offered an annual Science Prize ($100) and 'Scientists of the Year' award, so with luck this will become an annual event.

The previous two pages form a press release by Omoka Principal Anna Roumanu.

On Prize-giving Day (10th December) Dr White awarded some Certificates of Merit to outstanding students, and gave the 3rd Prize to the young ones in Grades 1-3 ~ their dioramas were excellent. The 2nd Prize went to the seniors for their assessement of rubbish. This class did have internet time and included a PowerPoint presentation. However, by far the best were Grades 4-6: their research was excellent. Not only did they interview everyone on the island to find out how many *pipi* they took daily & weekly, but they then converted the various collecting bags, baskets and tubs into a single unit of measurement *'kete'* so that all the results were comparable. Another experiment counted the number of shells in a *kete*, revealing that we took 117,180 on the interview day, and 616,590 shells that week. In other words over *half a million* shells a week. This group had a hypothesis, which they answered ~ **the only group to do so** ~ and guided us clearly thorough each stage of their research (materials & methods, resources, community questionnaire in Maori, results, analyses, and overall conclusions). So it was an easy choice to award them **1st Prize, and Scientists of the Year.** ***Bravo.***

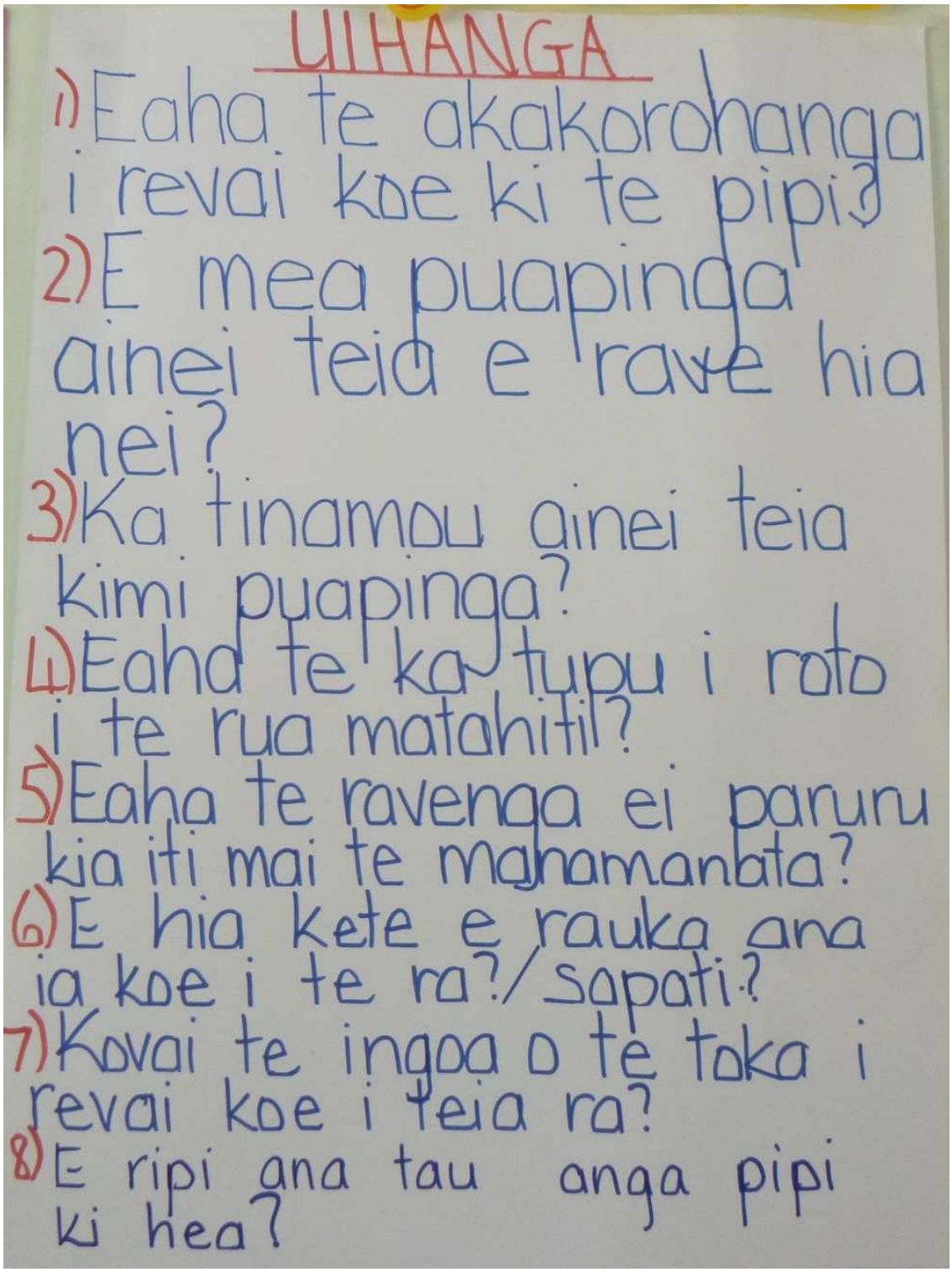
Above: Scientists of the Year 2014 ~ Excellent research and presentation.



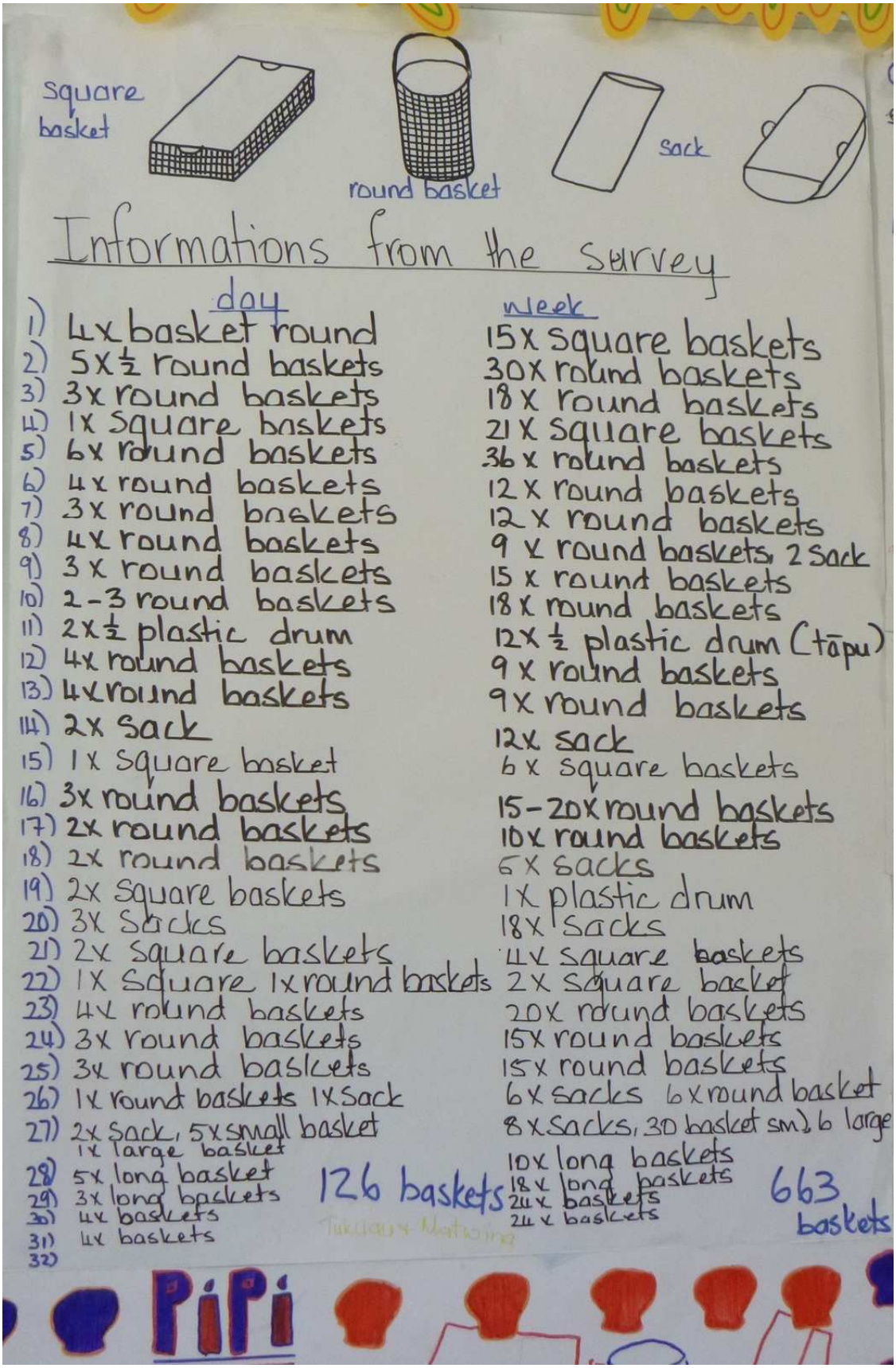
Dr Michael White 2016

Youngsters gained 3rd Prize at the Science Fair. Note Polynesian names on the honu model, and the beautiful toka habitat diorama below.

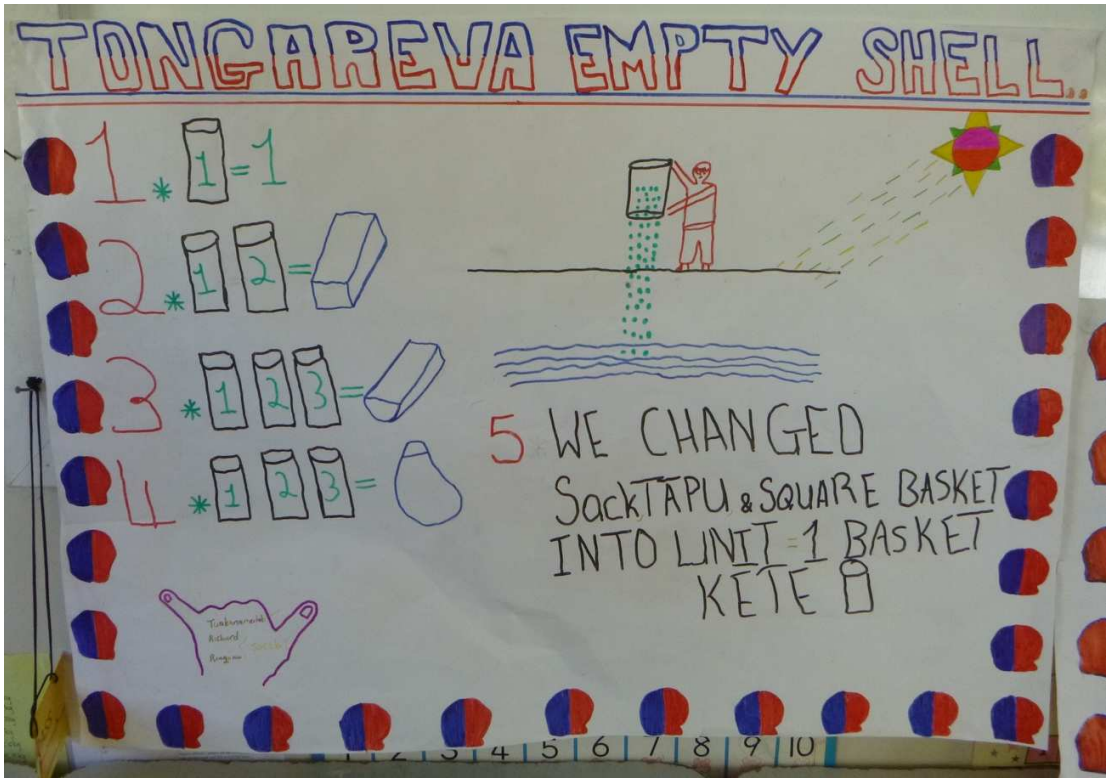
Scientists of the Year Project: Collecting pipi



Survey questions asking community members how often they go collecting and how many shells they take. Also the type of containers they use and the toka harvested.



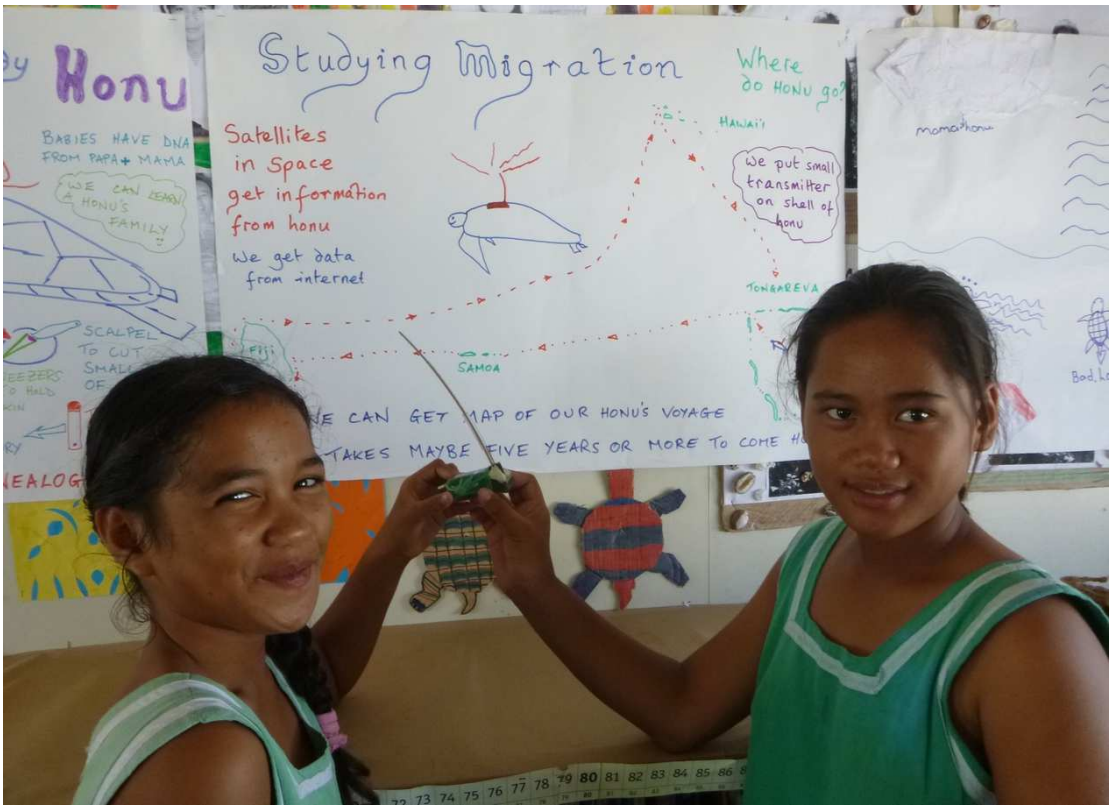
All the community survey data assembled as a poster.

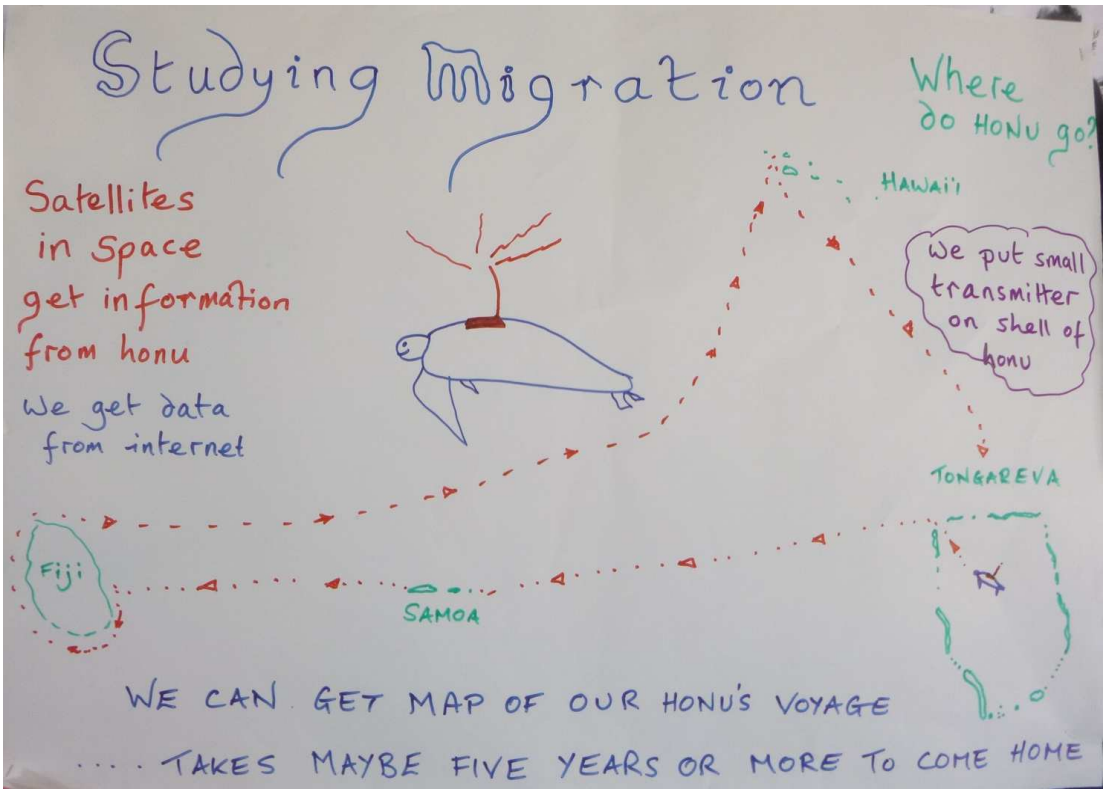


Two really neat experiments were conducted to enable data comparisons. Top: converting all units to kete. Below: 1 kete held 930 pipi shells.

These wonderful students produced the <u>first ever data</u> on how many *pipi* shells were being collected. In the survey week it was **616,590 shells** ~ over *half a million* shells. We reckoned that could not be sustainable.

Satellite Telemetry: we would like to give a huge and *very special thanks* to **George Balazs** in Honolulu for sending us transmitters. We planned and taught, but sadly had to return the units to Hawai'i as our honu disappeared and the batteries slowly deplete. They now have been deployed in China (PRC). ***"Another time George, Mahalo."***





Dr Michael White 2016

Hakono Hararanga (Incorporated)

After slow and steady awareness-raising on Tongareva over the last five years, we have now created our community-based environmental society ***Hakono Hararanga***. Our aims are broad, centred on living carefully and using our natural resources sustainably: so that we leave a healthy, abundant and diverse ecosystem to our future generations.

"We would not want our descendants to think that we did not care enough to leave them anything to eat or live their lives. This is our gift to the future". (statement from Omoka community)

On 26th May 2015 the Society held its first Annual General Meeting: all 18 members were present and voted unanimously to register Hakono Hararanga as an Incorporated Society. Documents were prepared and signed so the Ministry of Justice at Rarotonga could issue a Certificate of Incorporation as *a not-for-pecuniary-gain organisation* (Incorporated Societies Act 1994). Other people now want to join. Hakono Hararanga (Inc.) is included on the latest Scientific Research Permit [**Permit: 21/2015**].

As an Incorporated Society [Certificate 469/2015] we are able to apply for funding in support of climate change mitigation, food security, monitoring and preservation of biodiversity, recording and then teaching Traditional Knowledge, cultural skills (e.g. basket-making, weaving, shell-carving), vocational skills (e.g. boat repairs, mending fishing-nets, and welding). Workshops are to include scientific monitoring and data recording, leadership and project management skills; also practical fieldwork. The PI has shown that it is possible to gain funding for looking after our environment, rather than destroying it for short-term financial profit. [Rufford Trust: RSG # 13924-1].

We have been given some tools by the **Climate Change Group** (Office of the Prime Minister; SRIC-CC) enabling us to clear dead trees in the worst damaged habitats (see story below). SRIC-CC[10] is arranging building supplies to construct a tree nursery at Omoka to rear saplings for transplanting. We are also planning a water catchment and small observation post at Akasusa to help our reforesting and biodiversity efforts. The nursery component includes growing saplings of local tree species to transplant at our habitat restoration sites; we are collaborating with the Agriculture Officer and staff of Tongareva Marine Resources Centre.

We submitted a grant request to the New Zealand High Commissioner's Fund to aid this conservation effort, which is now in review. The rationale for our forestry project and habitat restoration is: **"To restore a badly degraded habitat behind the main sea turtle nesting beach in the Cook Islands. The sex of turtle embryos is determined by the nest incubation temperature: more females are produced fron warmer nests and more males from cooler ones. Increasing global temperatures make it more difficult for males to be produced. The loss of the forest in parts of Mangarongaro skews nests towards feminisation".**

[10] Strengthening Resilience in Island Communities & Climate Change mitigation are funded by GEF.

Ava Rima Restoration Area

Our first project is restoring a degraded area: *Ava Rima* at Akasusa on Mangarongaro motu. Some years ago it looked like a wildfire occurred and was worsened by extreme weather events, many trees are dead. The area supports regular honu nesting. The lack of shade worsens the feminising[11] effect of increasing temperatures: the western side of the atoll is very hot with full sunshine from early afternoon until sunset, and rarely gets any wind (leeward coast). As the months passed by it became apparent we were losing many trees in 2015: every survey found newly fallen trees. Various factors are involved: increased airborne salt levels, no rain, and higher seawater levels. When strong winds collapse trees along the margins, other trees that were sheltered become more vulnerable ~ *losing the protection of the forest*.

We began replanting on 1st May 2015 and have 58 new trees still growing, **despite no rain at that site for six months.**

Ava Rima is off to the left, but this forest habitat has practically failed. In 2015 there was no rain for over six months.

[11] Sea turtles use a process called 'temperature-related sex determination' during egg development.

Senior students on our first field trip clearing the debris. Creeping plants also died by October .

Top: moving dead trees; Bottom: honu nest by *Ava Rima*.

End of the first day ~ 12 new trees planted and a lot of rubbish cleared away. We have to cut the dead trees down so they don't crash onto the new saplings.

Dr Michael White 2016

Senior students and honu research

During these trips we found time to excavate and inventory some hatched honu nests; students all reckoned these were *"the best school days ever"*. In one nest we found a late-term dead embryo, so we collected a DNA sample too.

Dr Michael White 2016




Images above show various stages of nest excavation, and the dead embryo.

On 28th November 2015 an unusual nest was excavated at Akasusa. The bottom of the egg chamber was rocky pavement with about 1 metre of good quality sand above it. During the excavation a live green hatchling was found: the first seen at Tongareva (2010-2016). It was placed on the beach and crawled rapidly to the ocean and swam off aross the reef top. There were several unhatched eggs, each of which contained a dead embryo in various stages of development. Athough a very minor, but significant thermal regime occurs within a clutch: the upper eggs will be slightly warmer than those at the bottom, because they are nearer the warmer surface of the beach and the metabolic heat of developing eggs beneath them rises; also the eggs in the centre of the clutch will be warmer than those at the periphery, the latter being in contact with, perhaps, cooler sand ~ nests often discharge their neonates *en masse*. This suggests that, apart from the minor differences mentioned above, egg development will be at a similar rate for the whole clutch. In this nest death occurred at different stages from eye-spot, to early, mid, and almost full-term. Two eggs were *'pipped'* ~ babies died while emerging from the shell. A likely explanation is that on one or more occasions the higher tides in 2015 overwashed the developing eggs; waves and flotsam were observed in the bushes during several surveys. Excavating a nest is a disruptive process, so the position of eggs within the clutch is not known, but perhaps the bottom eggs suffered the most.

The nest was 88% successful, with 83 of 94 eggs hatching. Unhatched eggs:1unfertilised, 1 eye-spot, 1early-stage, 2 mid-stage, 4 late-stage; 2 pipped.

Top: Nest contents: the live hatchling has already been released; two *pipped* eggs are in the foreground; the unhatched eggs at the rear.

Below: Mortalities at different developmental stages.

Above: early and mid-to-late stages
Below: near full-term

Konisara and Rahui

The Atoll Council (*Konisara Henua*) is the governing body of our island. Amongst other tasks they decide if, when, and for how long to close any particular resource. Mayor Tini Ford is proactive in our traditional system of managing natural resources *Rahui* by closing a harvest to ensure its sustainability. *Rahui* allows us both to protect and use our natural resources sustainably. Issues or concerns are brought to public debate so that all questions can be addressed, and then *Konisara* proclaims *rahui* for a period of time. It is based on **wise decision-making**, adhered to by common consent, needs no enforcement, and works well. Monitoring the resource to understand how it is doing forms an important part of *rahui*, so the prohibition on take can be extended if necessary or re-opened for harvesting. It is based on scientific assessment of data. We seek to increase some of the important food resources: e.g. *manu e hua* (seabirds and eggs); *kaveu* (coconut crabs): the aim is to enhance our long-term food security. Sea turtles were not included within *rahui*, but this still may happen in time. One reason could have been because turtles are a mobile species, whereas a clam bed or bird nesting site is easier to protect. In olden times honu were restricted in some cultures as a *'chiefly food'* (Woodrom Rudrud 2010).

Tongareva's MP ~ Wilkie Rasmussen (left); Head of the atoll ~ Mayor Tini Ford (right); and retired Island Secretary ~ Andrew Vaeau (front). [Photo late-2013 or early-2014].

Two *Rahui* examples are: harvesting of *pasua* (tridacna clams) is usually closed, but was opened for the 50th anniversary of Cook Islands independence (4th August 2015) so that the *Tere Party* from Tongareva can take part in the celebrations *Te Maeva Nui* at Rarotonga. *Pasua* harvesting was allowed for six days: for 3 days the community collected for the *Tere*, and then a further 3 days for individual use; harvesting then was closed again. This obviously is a very different approach from the profit-driven over-exploitation of resources common in the industrialised world.

The second closure is more interesting. The collection of *pipi* mentioned in the Science Fair rapidly expanded in 2014 when two different foreign buyers wanted to buy these tiny pearls. Consequently islanders were out harvesting shells every day. As was suggested by our research: collecting half a million shells a week was likely to be unsustainable, especially as *most shellfish do not contain pearls*. This proved to be correct and there were noticeably fewer *pipi* growing in 2015; so the harvest is now banned, probably for 2-3 years. It must be stated that selective harvesting improves the bivalve resource. Removing large shells allows the many small ones space to grow and feed. The key is to be wise and sparing instead of ignorant and greedy.

Collecting *pipi* on a *toka*. *Tuakanameitaki* in 2014.

Traditional Knowledge

The importance of gathering Traditional Ecological Knowledge and establishing community-based projects should not be underestimated, particularly for isolated places (Berkes *et al.* 2000; Johannes 2002; White 2012, 2014; White & Galbraith 2013); both are important aspects in the Marine Species Action Plans (SPREP 2012 www.sprep.org). Sustainability and food security are deemed more important locally than the often wordy approach used in westernised legislation, so it seems likely that the best people to manage natural resources are those whose lives depend upon them. We have launched a community project that will strengthen our ability to manage marine resources sustainably (Gadgil et al. 1993; Hickey & Johannes 2002; Johannes 2002; Roberts 2007; Ono & Addison 2009; White 2012, 2014; White & Galbraith 2013).

How can sea turtles and their habitats be best protected?

Undoubtedly education is the most important factor. People and governments waking up to the fact that their activities and behaviour are the major causes of biodiversity loss globally. As folk become aware of how they themselves degrade ecosystems, through actions or inaction, they gain opportunities to make a very positive difference. When islanders participate in project research activities they understand what the real issues are, and tend to modify their behaviour. Often it has been the children who provoke changes in parental attitude.

Is additional legislation needed?

The Outer Islands are best governed by the local communities themselves. The Head of each Island (Mayor) is assisted by the Konisara (Atoll Council): they discuss various issues, then take these concerns to a public meeting. Anyone may speak at these meetings; by the end of meetings the community has agreed on what to do. The greatest benefit is that the Konisara can respond **immediately** to any concern or impact. Some islands still have an ***Ariki*** (King or Queen) and Elders are respected.

Centralised government is poorly suited to deal with problems that occur hundreds of kilometres away. Being a small country, government ministries and departments are also small, with limited resources and staff. If concerns were raised with Rarotonga, then they are subjected to an often-lengthy process of prioritisation, consultation, and would be added to a list of funding requirements; or be ignored altogether.

Legislation to protect sea turtles and their habitats reveals a disconnection between the theoretical intent to do something beneficial on paper (law) and the practical realities of achieving any measure of meaningful protection for migratory animals that dwell in or move through vast sea areas (White 2012). This is not any particular fault of the Cook Islands' government, but rather the consequence of living in a world where everything has been reduced to the lowest comon denominator ~ money. In governmental terms this means there is a need to prioritise all proposals and activities; unfortunately biodiversity and the environment are not deemed important for economic success, thus rarely gain precedence.

Two different approaches are necessary and achievable in the Cook Islands. Rarotonga requires that a punitive and coercive system of regulation, inspection, monitoring, and judicial redress is in place. That island is home to about 85% of the national population and is a westernised cash-based economy that uses international tourism as its main driver. People are largely disconnected from nature and so central government sees little cause to use natural resources sustainably, although mentioned in the legislation.

The Outer Islands are the opposite: largely subsistence-based cultures, but with some peripheral cash requirement, the predominant consideration is healthy and abundant biodiversity, and people trying to remain in harmony with nature. Two factors need considering: i) direct harvesting of natural resources, which is managed best by people themselves (*rahui*); ii) impacts from human activities (including global and regional threats, such as pollution and climate-change, as well as unsustainable resource-use, such as industrial fishing or deep seabed mining).

The consequences of those two factors are self-evident. Large-scale industrial activities affect places around the world, often far from initial points-of-impact. The perpetrators are mainly G20 industrialised nations, which are disinclined to change their behaviour, as this may limit their geostrategic manipulation, or cause a financial disadvantage against competitors. They are less likely to be impacted by their own activities, having both money and resources to mitigate them. Unfortunately this is the dominant model on Earth at present.

Conversely, communities that utilise local natural resources to meet their daily needs, are less likely to cause impacts elsewhere, other than for those species globally threatened. Traditional local management approaches may also create safe havens and refugia for threatened species allowing restocking of degraded populations through natural overspill. However, these subsistence cultures are badly affected by pollution (marine, terrestrial and airborne) mostly emanating from elsewhere; and they have neither the resources, nor the money to resolve these issues. Marine debris can be overwhelming. An imminent and as-yet-not-understood impact concerns deep seabed mining DSM, which is examined in more detail below.

So for the Cook Islands the most sensible solution will be for each community, island or motu to decide for itself which methods to use: parliamentary legislation, traditional practices, or both. This strengthens traditional customary life, costs little, and contributes substantially to the sustainability of biodiversity.

Masked Booby *Sula dactylatra* and chick at Tongareva.

Funding and support from international donors

The Cook Islands Government provides no money for biodiversity research or conservation. Ministry of Education had hoped to extend its Lifeskills programme, but lacked funds, so the course was not repeated in 2014 or 2015. Other research and conservation organisations are interested in the PI's work at Tongareva Atoll. In a spirit of openess and transparency donors are mentioned here; all are acknowledged in our publications. ***Meitaki Poria ~ With thanks to you all.***

1. Rufford Trust www.ruffordsmallgrants.org

Rufford Trust provided a Small Grant [**RSG # 13924-1**] in October 2013 enabling us to conduct further surveys in the southwestern corner of the lagoon: Mangarongaro, Atiati and Vaiere. Birds and major fish species and habitat types were catalogued; a biodiversity assessment gives a better understanding of this important area for sea turtles (forest, reef and lagoon). Half of this grant was to buy outboard fuel, which has always been a logistical challenge in the Outer Islands.

2. SWOT www.seaturtlestatus.org

Although this is a fairly small amount of money it has some prestige. SWOT provide six grants of $1000 per year: 2 for research, 2 for networking, and 2 for community education: so in all the world we've got one of the grants for community education: '*participation in sea turtle research'*. The author works with both villages to record data on honu sightings. We show how to manage a project (honesty, transparency, accuracy, data-entry, how to write reports and give community presentations). We are developing scientific resources in our local language; these did not exist. This open approach is expected to lead to further funding.

3. British Chelonia Group www.britishcheloniagroup.org.uk

BCG have not funded this research phase at Tongareva, but they provided a grant in 2012 for the Rakahanga expedition; also their Journal, *Testudo*, has published three of our papers, and given copyright permission to access them at **www.seaturtle.org**

4. National Oceanic and Atmospheric Administration www.noaa.gov

NOAA provided two grants through their National Marine Fisheries Service:

i) **NA12NMF4540263** Nesting census and genetic-sampling of an unstudied marine turtle population at Tongareva Atoll, Northern Cook Islands.

ii) **NA14NMF4540140** Sea turtle research and Community participation at Tongareva Atoll.[12]

[12] The original NOAA grant title was *"In-water assessment and management of sea turtle habitats at Tongareva Atoll, Northern Cook Islands"*. However, NOAA could not fund the underwater study that year and asked that we concentrated on the nest-monitoring and genetics instead.

DNA-samples

Five skin samples were obtained under the previous award (NA12NMF4540263): three from foraging juveniles and two from hand-reared neonates linked to the local nesting population. DNA-samples were sent to Hawai'i on S/V Kwai in January 2015. Genetic sequences should help identify stock linkages to other honu populations in the Pacific Ocean, and perhaps the wider Indo-Pacific region (Dutton et al. 2014). Novel haplotypes are reported via GenBank. **CITES permit # 13438** was arranged and Erin LaCasella verified it as OK. This was the first shipment, and therefore a steep learning curve. After sailing from Tongareva Kwai spent a month in Kiribati before arriving back home at Honolulu. The number of people involved in this endeavour is amazing, perhaps 100: it was a complex operation. Many of us are aware of things that went wrong in the past. DNA samples collected in remote locations ~ and thus an important part of us learning about regional sea turtle population dynamics ~ were either not allowed into the US, or if they were then the laboratory was not allowed to test them because of irregularities with documentation. The PI guided this process from start to finish, ensuring that information and contact details for each new player were shared in a timely manner.

Briefly, the process was: i) PI collected samples; ii) PI emailed relevant sample data to Cook Island's focal point; iii) Focal point issued a CITES compliant export permit; iv) PI emailed this to NOAA staff for confirmation that it met US requirements; v) PI gave DNA-samples to the super-cargo on S/V Kwai and these were placed in the ship's safe (this was the first step in an unbroken chain-of-custody); vi) Tongareva's Customs Officer witnessed and counter-signed the export permit; vii) this was emailed to NOAA at Hawai'i and San Diego; viii) Dr Peter Dutton's laboratory staff organised the US Fish & Wildlife officials to facilitate entry (this included a complete electronic package of documents); ix) PI kept everyone informed as the Kwai's schedule changed, and of each new ETA at Honolulu; x) Brad Ives (owner of Kwai) organised Customs at the port, and provided a letter of custody for the samples; xii) PI asked George Balazs to forward the samples to San Diego (Fedex); he collected them from Tony Palermo, Senior Wildlife Inspector at Honolulu; xiii) samples arrived at the San Diego laboratory; xiv) laboratory asked the PI to confirm accession numbers and data for NOAA's database; xv) samples then entered the queue for analysis.

This process required hundred's of emails and many hours of work: so a huge thank you to everyone who played a part in its success. **We now know that we have a feasible route to get samples from a remote Pacific Island into the US legally and safely.** So any further shipments should be much easier.

The possibility of using egg-shell fragments for DNA analysis was discussed with Dr Peter Dutton (La Jolla, California). He recommended only partially or fully developed embryos be sampled (i.e. eye-spot stage and beyond). There are some new samples, including a mid-term dead embryo ~ the first one found at Tongareva; most nests hatch successfully, but some may contain a few unfertilised eggs.

Preliminary genetic findings

Dr Peter Dutton has provided the following data based on mtDNA sequencing for the five samples:

Table 4. Mitochondrial DNA for green turtle juveniles sampled at Tongareva Atoll, Northern Cook Islands (2014). Legend: Local field #; Curved Carapace Length; NOAA laboratory record #; initial haplotype.

Field sample	CCL (cm)	Accession #	Haplotype
T1	14	146408	CmP65
T2	14	146409	CmP65
T3	44	146410	CmP77
T4	52	146411	Galapagos?
T5	61	146412	Unknown

Samples **T1 & T2** were from the same nest and their **CmP65** haplotype is quite rare, only found so far in American Samoa and the Marshall Islands.

Sample **T3** has haplotype **CmP77;** common in the Federated States of Micronesia.

Sample **T4** is Eastern Pacific, perhaps from Galapagos* (awaiting confirmation).

Sample **T5** is unknown or novel.

The laboratory will conduct nuclear DNA (nDNA) analyses in the coming months.

Left & right: Sample T4 carapace and plastron

*Dr Dutton wondered if this might have some *'black turtle'* linkages?

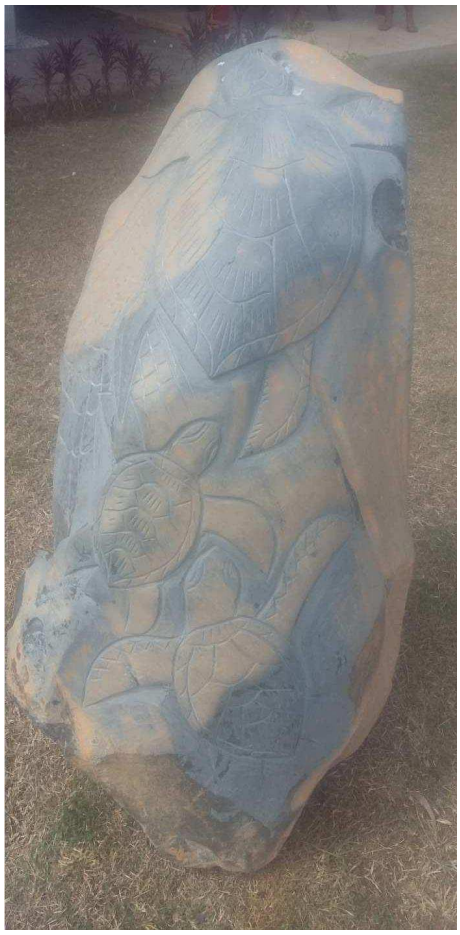
Reaching-out Regionally

Honu sculpture

The author and Oregon's Kerulos Centre www.kerulos.org planned the creation of a monument celebrating *honu* ~ the green turtle. The idea had been bubbling away for a couple of years with emphasis on tribal cultures. The 50th anniversary of Cook Islands' independence (4th August 2015) seemed a good time to launch this project. Part of the campaign was to create an www.indiegogo.org crowdfunding appeal ~ that was a steep learning curve. http://igg.me/at/kerulos-monument

Dr White asked on MTSG's global listserver if other researchers around the world had suitable sites and local carvers or sculptors to create monuments for the other six sea turtle species. The second monument *loggerhead turtle* will be crafted by a Cherokee artist in Georgia, and also link to the *Trail of Tears*. Other proposers can contact the ***Kerulos Centre*** www.kerulos.org

The Cook Islands Honu Monument is carved from stone by Maori master-carvers Ian George and Henry Tavioni. The sculpture is outside the Ministry of Education and UNESCO buildings at Rarotonga and was unveiled in 2016.



Left: the first stone arrives (T & M Heather); Right: *honu* (Photo by Jane Tauraii).

Bula Honu

Another undertaking in 2015 was to collaborate with Dr Cécile Gaspar and her team at Moorea, French Polynesia. Their project ***Bula Honu*** wanted children in different Polynesian countries, and also some in France, to use sea turtle migration as an educational tool bringing together cultures and locations along the voyaging routes of honu. Cook Islands Ministry of Education asked the PI to get involved, and so *Hapi Omoka* became one of the participating schools. Tongareva is much too remote for the students to 'migrate' (international school exchanges), but we established chat and skype connections with other schools. It was deemed successful.

Traditional Resource Management

Another important idea was to ascertain interest in Oceania for establishing a network of locally-managed marine protected areas. Traditional Knowledge and Practices are too precious to be lost, so these will be documented and taught to future generations. The PI began a discussion thread on Oceania MTSG's list-server and initial responses were encouraging, especially from Vanuatu, where most villages still implement some type of customary knowledge (Francis Hickey *pers. com.*).

Also relevant is **Pacific Oceanscape:** an attempt to better manage Oceania. Proposed by the Kiribati President **Anote Tong** it has 23 island nations involved. The aim is safeguarding this ocean and its biodiversity into the future; however, economic growth still seems to be the driving impetus. There is a lack of consultation with local people and management seems very top-heavy and media-driven. It may work. One idea is to not only protect national EEZs of participating nations, but also the entire area surrounding and interlinking these countries; this would include areas of High Seas that create *pockets* between national EEZs. Omoka wharf repairs and increased fuel-storage capacity will assist this by letting the Police patrolboat *Te Kukupa* refuel more easily in the north. The intention is for it to patrol fishing areas of the Northern Cooks looking for *Illegal, Unreported or Unregulated* fishing vessels, whilst Kiribati patrols its own adjacent waters (Kiritimati, Teraina and Tabuaeran) doing the same. In 2014 *Te Kukupa* had worked with the Samoan Police-boat in a similar way.

Marine Litter MOOC

The author participated in a Massive Online Open Course (MOOC) on marine litter hosted by Open University of the Netherlands www.ou.nl from October 2015 to January 2016. It had over 6000 international students enrolled. At long last we may have a gateway for dealing with oceanic pollution. For the final assignment the author created a group to consider the problem of marine debris in Oceania: there is a strong possibility we will continue collaborating once the course completes and take tangible steps to end this major impact on the Biosphere.

Some people consider the oceans to be *"out of sight, out of mind'*, as if these play no part in our lives. The truth is somewhat different: oceans make up 99% of the volume of the Biosphere (Norse 1994).

Playing our part in climate change mitigation

A forward-thinking AID programme ***"Uira Natura ko i Tokerau"*** www.mfat.govt.nz has completely converted the Northern Cook Islands to solar power, thus ending our dependence on shipping diesel-fuel from Auckland. The first atoll was Rakahanga (September 2014) followed by Pukapuka and Nassau that December. Construction began at Tongareva in late-February 2015 and a mere 10 weeks later we were online; Manihiki was done at the same time. The build was by www.powersmartsolar.com and we were very impressed with the quality of the equipment. We actually have two arrays: the Omoka one has 480 solar panels; the much smaller one at Te Tautua has 168 panels. **Meitaki Poria a Aotearoa (Many thanks to New Zealand).**

The Rarotongan government intends to convert the Southern Group too, which will be funded by the Asian Development Bank. The Cook Islands plan to be entirely solar by 2020. Once again a small Oceanic nation sets the road for the world; and will say so at the Climate Change Conference in Paris (December 2015).

NEW ZEALAND
FOREIGN AFFAIRS & TRADE
Aid Programme

PowerSmart
SOLAR ELECTRICITY
a greater choice

The entire solar project was delivered on *Tiare Moana*: it took a week to unload.
Top: unloading aggregate.; Bottom: taking a digger ashore.

Top: getting aggregate ashore; Bottom: unpacking a shipping pallet.

Top: the site before any work began, the big Tamanu tree on the right was lost.
Bottom: trees cleared & the 3 iron posts in foreground are the first site markers.

Top: preparing the foundations for the solar panels.
Bottom: two of five photo-voltaic banks nearly completed.

Top: powerhouse nearly done,the vents are wind-driven.
Bottom: (L) gel batteries; (R) New Zealand's High Commisioner Nick Hurley

The solar arrays give us a perfect start and *Hakono Hararanga* is investigating how we can become a **carbon neutral** atoll. Considerations include replacing all lighting with LEDS to reduce power use; replacing domestic vehicles and outboard motors with solar-charged battery-powered units; battery-assisted pedalling trikes, quads and surrey bikes (solar); and building new wooden houses on stilts to minimise rising sea-level impacts. Instead of using cement and concrete we will focus on **bio-engineering** approaches to reduce coastal erosion. [Manufacturing 1 tonne of cement produces 900 kg CO_2 and then transportation and mixing costs add to this atmospheric impact].

Our preferred shipping provider is S/V Kwai: this has already reduced its fuel use by 50% and once the next mast has been added it will be able to sail for 90% of the time, which fits perfectly with our environmental aspirations.

Failing to join the dots …

An absence of coherent thinking (not seeing the bigger picture) means that achieving *zero pollution* energy use, instead of merely low-carbon power, remains challenging.

China AID, as part of the Chinese mitigation strategy for buying our fish, has donated large machinery (loaders, bulldozers, rollers etc.) and some agricultural equipment: all of it is diesel or gasoline powered. So it is the wrong equipment at the wrong time. Fuel still has to be shipped from Auckland, via Rarotonga, thus our *carbon footprint* will remain excessively high. We should have had all electrical, or electro-hydraulic equipment charged from solar power. The ideal solution is to return this, with thanks, and replace it with zero-pollution machinery.

Anyone involved in arranging or procuring Aid, or infrastructure planning should take a fresh look at the environmental impacts of their decisions.

Seven of these indicators would be expected to increase in a warming world and observations show that they are, in fact, increasing. Three would be expected to decrease and they are, in fact, decreasing.

There is little doubt that global climate change is now occurring. Www.noaa.gov

Another look at Deep Seabed Mining (DSM)

On 15th January 2016 as this document was being finalised, the Seabed Minerals Authority sought information on marine animals using the Cook Islands EEZ. It seems that tenders are available to exploit the polymetallic nodules on the deep ocean floor. We must now discover how to collect these non-renewable metals without damaging the ecosystem, habitats, and dependent species (Drew 2009).

Life on Earth depends upon biodiversity: without the earliest stages of the food-web, complex life will not exist. It is all about energy transfer. Life in the deep ocean (deeper than 1000 metres) slows down. Temperature is near to freezing (2-4ºC); light, other than bioluminesence, is absent; water pressures are high; the environment is generally quiet; growth and metabolic rates are slow; biodiversity high, but species have low resilience. When a habitat is degraded or destroyed, the impacted species may not recover. Because the ecosystem role of deep sea species is poorly understood altering species mixture or richness may have unintended consequences. The nodules themselves also provide habitats for invertebrates. [An article by Prof. Richard Steiner is in **Appendix One**].

The Cook Islands may be the first country to exploit sea-floor nodules in its national EEZ (Exclusive Economic Zone). This means that there are no rules to follow, and it is incumbent on Rarotonga's government *"to get it right first time"*. Thus setting a precedent for other exploitative countries to follow.

Some areas of concern are:

i) The deep ocean is the last undamaged habitat on Planet Earth.
ii) Most (98%) marine organisms are benthic ~ they live on the seafloor.
iii) New marine species unknown to science are discovered every year.
iv) Biologists estimate there may be between 0.5 and 5 million un-named species.
v) Deep sea ecosystems and how they function are poorly understood.
vi) Field research is generally lacking for the deep ocean.
vii) The views of islanders are rarely taken into consideration.
viii) Increasing the pressures on already endangered or critically-endangered species, such as marine turtles and cetaceans will inevitably hasten their decline.

Additionally:

i) Cook Islands intends to be completely powered from renewable energy by 2020, so all vessels and licensed projects should also only operate on renewables (solar or wind): otherwise the Cook Islands will still accrue a high *carbon footprint*.
ii) Cook Islands is an early member of the Alliance of Highly Ambitious Countries (see below), intending to limit global temperature increase to 1.5ºC (*c.f.* pre-industrial levels).
iii) Rarotonga's government proclaimed in December 2014 that it would implement *Te Tarai Vaka* throughout its Departments and staff. One of the central tenets is to *do no harm*.
iv) All operations should be zero pollution.

v) The precautionary principle should be used in all environmental undertakings. This has four central components (Kriebel et al. 2001):

a) Taking preventive action in the face of uncertainty
b) Shifting the burden of proof onto the proponents of an activity
c) Exploring a wide range of alternatives to possibly harmful activities
d) Increasing public participation in decision making

vi) Mining companies (e.g. Nautilus Minerals of Canada) claim there won't be serious problems and that if the benefits outweigh the costs then they will proceed. But their business is to destroy or seriously degrade habitats, so benefits will be profit-driven, and the long-term impacts or costs left for others to cope with.

vii) Given the widespread destruction caused by terrestrial mining around the world it is naive to imagine that similar destruction will not occur underwater. Furthermore the marine environment is a dynamic habitat, whereas a terrestrial habitat is broadly fixed, so sub-surface impacts are likely to affect a wider area and far-ranging species.

The Seabed Minerals Act (2009) contains over 300 subsections, with environmental protection scarcely mentioned. Part 8.1 refers to the Environment Act (2003). Part 8.2 on environmental management is extremely weak and would do little to protect an ecosystem. Part 8.3 on environmental emergencies is reasonable.

The Seabed Minerals (Prospecting and Exploration) Regulations (2015) are better informed, but need strengthening. One example is: Schedule 6C 1(b) mentions *"only being allowed to discharge rapidly biodegradeable substances"*:

Biodegradeable: this needs clear explanation. Does it mean the object will completely decompose to its molecular structure? Or that it will reduce in size or toxicity? Does biodegradation mean oxydegradation (i.e. it will break down in air)? Will said object degrade in the marine environment? At what temperature or pressure? How long does this process take to complete? How have these data been derived? Were there any field tests conducted? What is the fate of the degraded substance?

What does *rapidly* mean? Seconds, minutes, hours, days, weeks, months, years?

Environmental Impact Assessments (EIA): in agreement with the Environment Act (2003) no environmental impact may occur without a permit; and an application for a pemit must include an EIA.

However, EIAs need to be conducted before any activities (including exploratory processes) take place; and during the entire life of any operations or activities; and after activities cease during the habitat restoration phase. It is recognised that there are no baseline data for the abyssopelagic zone.

What is also lacking is a mechanism to assess **cumulative ecosystem impacts**, rather than those impacts at a single site, or block. A cumulative assessment must not only include impacts from other mining sites, in the water column, and at the ocean surface; but also in conjunction with global climate change, ocean warming, increasing seawater acidification, deoxygenation (dead zones), and oceanic pollution, especially plastics. As novel threats are identified they must also be included.

How should benthic mining proceed?

1. Biodiversity assessment.

Undertake comprehensive deep sea ecosystem assessments and catalogue all species. Identify important assemblages of marine organisms and create a priority list for areas that could be mined and those that may not. Define key habitats. Review all novel and previously-known species data for the South Pacific. Contracts should be reviewed mid-term to update species and habitat records identified by other researchers.

2. Equitable sharing of this non-renewable deep water resource.

Seabed Minerals Act (2009) states that ownership of the deep sea minerals rests with the Crown on behalf of the people of the Cook Islands; and the Act binds the Crown. Given that the polymetallic nodules are the patrimony of the people and all their descendants, the government is beholden to share this wealth equitably.

Establish a sovereign wealth fund.

In 1969 Great Britain and Norway each discovered oil deposits under the North Sea. Norway established a sovereign wealth fund that today is valued at US$873 billion; it is owned by the Norwegian People. Westminster didn't bother and wasted all the oil revenue from the last 45 years. Norway's Budgetary Rule allows 4% of the annual profit to be used by the treasury; the capital may not be touched.

The Cook Islands should establish a sovereign wealth fund. Investments ought only to support environmentally-friendly approaches (e.g. solar power, battery technology, clean drinking water projects, waste reduction and circular economies, wind power, alternative transportation etc.). Hydrocarbon-fuels, weapons-makers, environmentally damaging, polluting or non-sustainable portfolios should be avoided. A dividend could be paid each Christmas to every man, woman and child resident in the Cook Islands.

Royalty payments from companies taking the mineral resources.

An annual royalty payment should be paid by each company or consortium to every man, woman and child resident in the Cook Islands. Every share is of equal value.

Resource ownership by individual islands (Pa Henua).

Rather than follow earlier approaches which saw foreign fishery licence fees and the Departure Tax diverted into general treasury funds; seabed mineral revenue & licence fees could be allocated to each island. One guideline might be a 200 km perimeter: anything inside that zone belongs to the island. If the distance between two islands is less, the sea area is split equally between neighbours. Uninhabited islands: Manuae belongs to Aitutaki; Takutea to Atiu; and Suwarrow revenue could be used to create an Environmental Fund accessed through the Prime Minister's Office. This would still leave considerable mineral resources in the wider EEZ for general government use and might reduce public opposition to natural resource exploitation. The wealth fund is likely to be a better arrangement though.

3. Gaining and maintaining public approval.

A system of social acceptance (social licensing) is now replacing a previous model of Corporate Social Responsibility (CSR). Companies often have a poor track-record when interacting with local communities, especially of indigenous heritage. Too often the wishes of tribal peoples are ignored by the profit-centred world. A recent example is Bagabag in the Bismarck Sea, where Traditional Leaders have definitely not given their approval for mining operations in their sea-country. The author has consulted the Cook Islands Seabed Commissioner ~ Paul Lynch ~ and PNG's situation is one being followed closely.

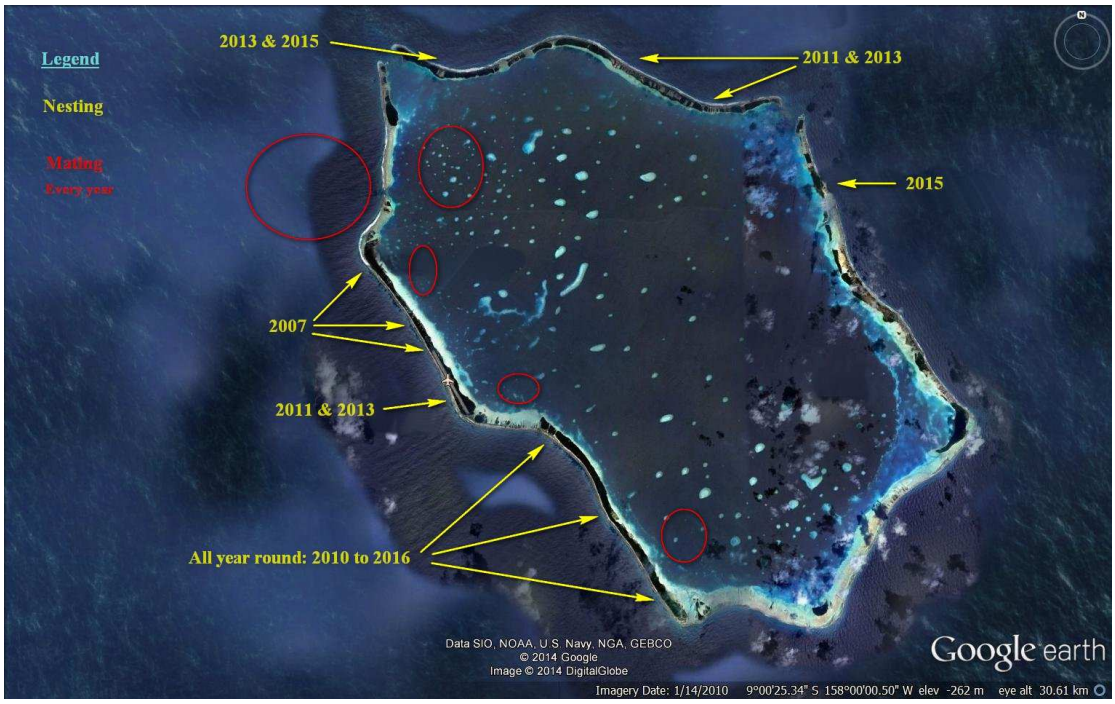
The mining companies attempt to twist these stories by saying that because people want smart-phones or renewable technology, then they *have to* mine the seabed. But the amount of reusable materials in discarded smart-phones and similar technology may already fulfill a large part of current demand for precious and rare minerals. So let's recover existing items, which would also reduce the amount of planetary waste.

A gift to the ocean from the industrial-consumer world. Why does no one care?

4. Protecting threatened species.

The Cook Islands has an obligation to protect threatened species that frequent its EEZ. The endangered green turtle and critically-endangered hawksbill turtle are present all year round. The most important atolls are Tongareva, Palmerston, Rakahanga and Suwarrow. Nassau, Pukapuka, Manuae and Takutea all have some nesting. There are foraging turtles and occasional nesting in the Southern Group; Rarotonga does not have nesting, but turtles do forage on the reefs and in Vaimanga lagoon; the passages through the reefs are important (White 2012, 2013).

The ocean between Tongareva and Rakahanga Atolls is likely to be an important marine habitat. Both atolls have sea turtles year round: Tongareva supports nesting, mating, juvenile development, and foraging for *Chelonia mydas*; rarer hawksbills are still seen occasionally. Rakahanga has adult female *C. mydas* foraging on its western reef, so males are likely to be in this sea area. The whereabouts of male turtles is still poorly understood, but the presence of adult females must be a strong attraction.



The importance of Tongareva Atoll as the paramount honu habitat in the Cook Islands.

Sea turtles are capable of diving to several hundred metres; they use counter-currents to travel easily in the opposing direction to surface flows. They can breath-hold for several hours. The giant leatherback *Dermochelys coriacea* can dive to 2000 metres in its search for jellyfish to eat. A remarkable feat for an air-breathing reptile.

Use of acoustic surveying in the marine environment

A just-published paper reviews this major concern in great detail (Nelms et al. 2016). It is clear that sea turtles have not been properly considered, and that sonic guidelines for marine mammals serve marine reptiles and fish poorly. Of 50 countries that have rules managing marine seismic surveys, only three mentioned sea turtles. Those tried to create a *safe zone* around the ship (0.5-1 km), they relied on visual sightings of turtles entering the safety zone, and concluded that avoiding areas used by sea turtles was the only workable solution. It was not possible to observe turtles at night, nor in choppy seas; the airgun might be 1 km behind the ship beyond the sight of an observer; turtles can remain submerged for long periods of time.

Amongst the rules were 'soft starts' ~ the first explosions were at low volume giving animals time to leave the impact area; volume would be increased gradually. When a turtle entered the safety zone sonic operations ceased immediately. Tongareva Atoll has year-round turtle nesting and development, as well as providing a critical mating

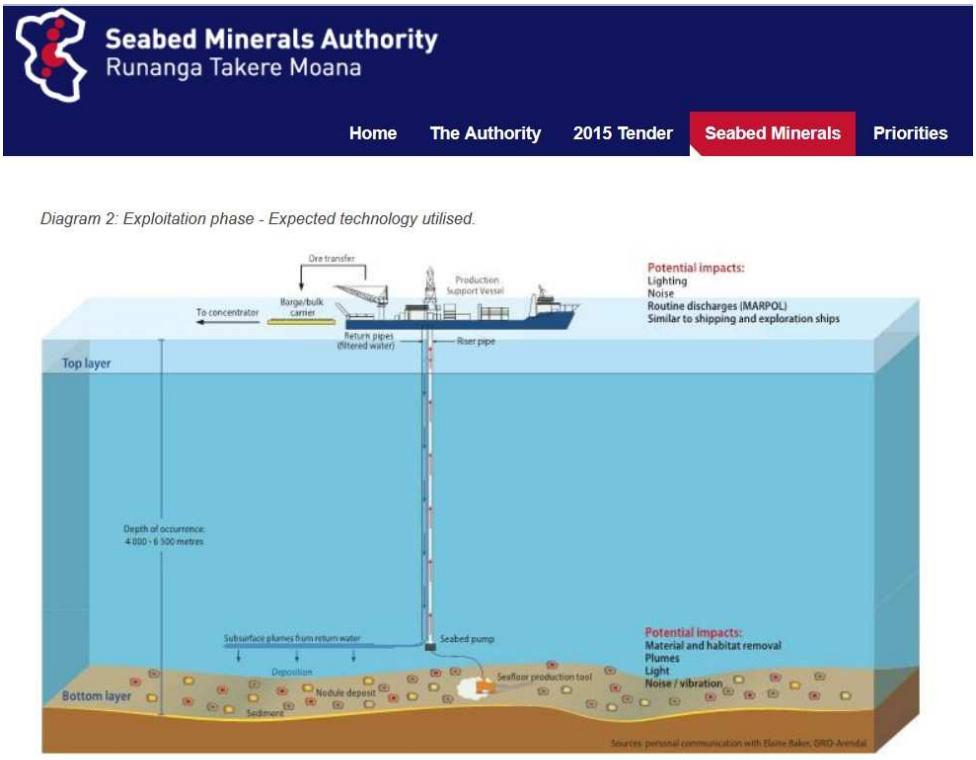
area, so the best advice for the Seabed Authority is to prohibit exploratory and mining activity within an agreed distance of the atoll.

International fishing boats commonly respect a distance of 25 nautical miles (nm). If the prohibition zone is extended to 200 km from an island then the important pelagic habitats between Tongareva and Rakahanga Atolls will be completely protected: benefitting other megafauna besides sea turtles; in particular oceanic sharks, manta rays and cetaceans. Both these atolls have major breeding populations of seabirds, especially frigatebirds (White *pers.obs.*).

The Seabed Minerals Authority *Newsletter Issue 1, April 2015*, suggests an exclusion zone of 50 nautical miles from any island. In general that seems reasonable, but in the case of Tongareva-Rakahanga this author advocates extending that distance to protect the entire area. Assuming such protection extends to the seafloor this would deliver a deep ocean biodiversity protected area; **a novel way of safeguarding nature.**

5. Protecting Traditional Culture and Sprituality.

Traditional Knowledge and Awareness are far too precious to be lost. These practices have allowed islanders to survive for centuries in remote places, even in challenging times. Utilising natural resources carefully and honouring the rights of others to share these gifts from Nature underpins environmental harmony and well-being. People are an integral part of an ecosystem. In common with other indigenous cultures traditional jurisdiction includes coastal sea areas, and tribute *atinga* should be paid. This is often ignored by economists and policy-makers.



Webpage from Seabed Minerals Authority: Potential impacts fail to mention <u>species</u>. The pre-1960's view was that the deep ocean was devoid of life!

Dissemination of Cook Islands Research

i) This project was presented by Karen Frutchey on behalf of the author at the Pacific Islands' meeting (International Sea Turtle Symposium; Baltimore, February 2013).

ii) George Balazs (IUCN Pacific Regional Vice-chair) included the PI's research in his presentation to the IUCN-Species Survival Commission: Marine Turtle Specialist Group; this was well-received.

iii) The first 3-year report was placed in the National Library and made available for download [White M (2012) *Sea turtles in the Cook Islands. Volume One: 2009-2012*]. **Permalink: http://library.seaturtle.org/6724**

iv) Constructed a website: www.honucookislands.com with links to our associates and funders, including NOAA-NMFS.

v) The PI was interviewed by James Borrell (UK) and the link for this is given below: **http://www.jamesborrell.co.uk/2012/12/24/fieldwork-sea-turtle-conservation-on-remote-pacific-atolls/**

vi) PI provided sea turtle information and images to the Ministry of Marine Resources for their developing website: www.mmr.gov.ck

vii) PI provided extensive information to www.sprep.org for the latest Marine Species Action Plans (2012-2016); as did Nan Hauser for cetaceans.

viii) PI is developing educational approaches with the Ministry of Education for sea turtles and various aspects of marine science and global threats.

ix) PI is a co-ordinator for TREDS in the Cook Islands www.sprep.org

x) Sea turtle nesting data are uploaded to the SWOT database www.seaturtlestatus.org

xi) PI provides scientific advice to the Kerulos Centre www.kerulos.org

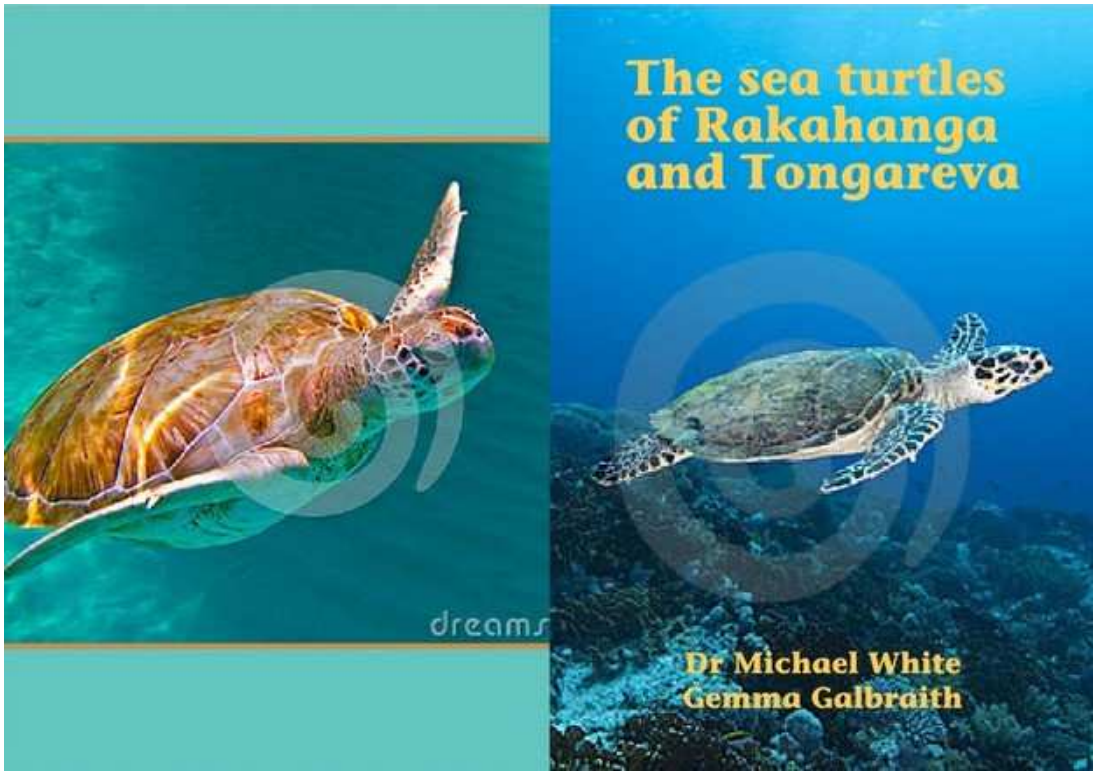
xii) Published first paper on sea turtles at Rarotonga. [White M (2013) *The first study of sea turtles at Rarotonga, Southern Cook Islands*. Testudo 7: 12-29]. **Permalink:** http://library.seaturtle.org/7257

xiii) Published first paper on sea turtles at Rakahanga. [White M, Galbraith GF (2013) *Rakahanga Atoll: Sea turtles at a remote site in Oceania*. Testudo 7: 30-48]. **Permalink:** http://library.seaturtle.org/7258

xiv) Published first paper on sea turtles at Tongareva. [White M (2014) *Tongareva Atoll: The most important sea turtle habitat in the Cook Islands*. Testudo 8: 19-37][13]. **Permalink:** http://library.seaturtle.org/8489

[13] Data were derived from **this NOAA-funded project** & it may be downloaded with kind permission from Testudo, The British Chelonia Group.

xv) A book on sea turtles from Rakahanga and Tongareva to be used in Cook Islands schools is at a New Zealand printers: in time it will be translated into every island's language (Jane Tauraii, *pers. com*). Translation into *Reo Tongareva* is now underway (January 2016).



xvi) Research note in Y BONT FACH (Ocean Sciences, Bangor University, Cymru).

xvii) In press. *Tongareva Atoll: Too hot in Paradise!* The Marine Biologist Issue 6.

Conclusions

"For greed all nature is too little"

Lucius Anneus Seneca, Roman Statesman 5 BC to 65 AD.

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 (White 2012). 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 now confirmed for *C. mydas* from Aitutaki, Manihiki, Manuae, Mauke, Nassau, Palmerston, Pukapuka, Rakahanga, Suwarrow & Tongareva. Rarotonga is quite unlikely to support nesting because of coastal zone development, substantial human presence, and several non-nestable beaches; four Southern Group islands (Atiu, Mangaia, Mitiaro and Takutea) were not visited (White 2012).

Mating by green turtles occurs at Tongareva at various times of year, making this atoll a critical habitat. The entire life-cycle (*Orahanga*) can occur in Cook Islands waters.

The most important nesting site in the Cook Islands is Tongareva Atoll (a reasonable estimate being 500 nests per annum), followed by Palmerston Atoll (estimated at 100 nests per annum): on both of these atolls the majority of egg-laying occurs on the **uninhabited** and seldom-visited motu (White 2012, 2014).

Nesting[14] at Tongareva Atoll alone is sufficient to change Nesting Aggregation (NA) status for green turtles in the northern Cook Islands from the lowest group to a higher one (Dethmers et al. 2006; White 2014). Nesting also occurs at Rakahanga (White & Galbraith 2013), Nassau and Pukapuka (White 2012). For the southern Cook Islands Palmerston Atoll will host enough nests in most years to elevate that NA status too. (White 2012).

For the first time it has been confirmed that the green turtle (*Chelonia mydas*) can be divided into **Distinct Population Segments** (DPS). Seminoff et al. (2015) found that there are 11 distinct population segments globally. DPSs are markedly separated from each other as a consequence of ecological, behavioural and oceanographic factors, and based on genetic and morphological evidence. **Each DPS is genetically unique**, so the loss of any population segment would represent a significant loss of planetary genetic diversity (Seminoff et al. 2015). Tongareva is in the Central South Pacific DPS. Our research is mentioned in that document (Central South Pacific DPS, pages 310-331), however, some of our data (White 2014) arrived too late to be included this time round, but they will make the next species review.

Nesting-effort at Mangarongaro appears stable, although the overwash in late-January might have caused nesting to reduce sharply in February 2015. That autumn also had low numbers of in-water sightings; several weeks could elapse with no honu seen in the lagoon. Then in the winter of 2015 an El Niño event was confirmed (12th May) by

[14]We assumed the mean number of nests laid by *C. mydas* to be 4.5 nests per annum (Van Buskirk & Crowder 1994).

Australian, Japanese and NOAA meteorological authorities. It is unclear if these findings are related, because the migratory nature of honu means that their current reproductive efforts may have begun a couple of years earlier. Over several decades we should be able to find relationships between these longer-term weather patterns and annual reproductive effort. In the present situation it seems more likely that the overwash in late-January and subsequent Cyclone Pam played a greater role with honu moving offshore and returning later in the year. Supporting that contention there were 25 nests laid at Mahera in July (2015); June & July are usually the months with fewest nests. November 2015 had the greatest number of monthly nests (n = 175) in five years' research (2011-2015). One hypothesis is that two nesting cohorts might be present: the returned animals from February and the 2015-2016 contingent. As yet, there is no confirmed evidence.

Nesting at Te Tautua Village supports the concepts of natal homing and long maturity periods in sea turtles. None of the younger people in Te Tautua, say less than 30 years old, have ever known honu to nest on their motu. At some undefined time historically there was nesting there. So perhaps today's honu were born there several decades ago.

The second discovery was nesting at Tokerau. That motu seems a poor nesting site as it is rocky, has a raised nearshore barrier, and emergence onto the shore is difficult. But when a turtle manages to get over the reef and through the jagged reef-top area, it is a short crawl to find deep substrata. The nesting zone is narrow so earlier nests may have been disturbed by subsequent nesters.

The first DNA samples from live *C. mydas* are under analysis at NOAA's San Diego laboratory, preliminary results are provided above. Another five samples have been collected and will be shipped in due course. What can be seen already is that honu population distribution and migration routes are wide, fortunately many researchers in Oceania already treat the Pacific Ocean as one ecosystem (Dutton et al. 2014), which this study supports. Kolinski et al. (2014) reported migratory routes for 13 sea turtles from Ulithi (Yap, FSM), showing connections with Philippines, Japan and Malaysia. As the Northern Cook Islands now has a shared genetic link to FSM: does this mean that there is or was a wider distribution pattern for honu?

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 asymmetrical rather than the more-usual symmetry associated with green turtles; this remains unconfirmed as neither nesting adults nor hawksbill hatchlings were seen. One adult-sized female hawksbill was encountered in the lagoon at Tongareva (White 2012). 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 hawksbills on the reefs at Palmerston, Rarotonga, Suwarrow and Tongareva suggest nesting by this rare species might occur in the Cook Islands archipelago 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 remains a priority.

An important finding from the Northern Cook Islands is that the Mean incubation period for three out of the four green turtle nests laid at Rakahanga (between late-September and early-November 2011) was 58 days[15]; these may be the first such data reported from the Cook Islands (White & Galbraith 2013). Another observation is that most *C. mydas* nests are laid in the vegetation and thus may be important as sources of male hatchlings; nest success rates are also high (95%) and nest predation minimal.

One reason for optimism is 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 is now recognised as an economic problem by the industry (i.e. fish-catch is reduced when bycatch occupies the hooks); loss of turtle nesting beaches, especially from unplanned and often-illegal development (e.g. White 2007), has been challenged judicially, and the more environmentally-aware countries now require EIAs. Trade in endangered species is substantially reduced, e.g. the Japanese *'bekko'* tradition (see Groombridge & Luxmore 1989). 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).

[15] (SD ± 2.7 days; range 55-60 days; n = 3).

The approach adopted by the author 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 explaining implications has been well received by Cook Islanders nationwide. Integrating into each community, rather than outside looking in, our research group (*Honu Kuki Airani*) is well-placed to make a significant contribution for a sustainable future: living in an abundant, well-balanced and healthy ecosystem.

Traditional subsistence-based ways-of-life, and 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). The divide between these two realities in the Cook Islands is essentially the Northern Atolls, including Palmerston, and the Southern Group islands; although only Rarotonga could be said to have a developed cash economy[16].

Atolls in the Northern Cook Islands are perfectly able to maintain their environments in good condition and use resources sustainably, as they have done for centuries. This also places responsibility onto central government to enhance and not destroy this fragile balance of Nature. 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 create several small ponds *roto* on the uninhabited motu to rear *'ava'* (milkfish; *Chanos chanos*): these could be sold to commercial long-liners as bait (Mokoroa *pers. com.*). Such roto already exist, shallow channels or ponds dug in sand and flushed with seawater; t**here is little discernible environmental impact.** In stark contrast would be a fish-processing plant (envisaged under 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 the workers would also have to be imported. The only practical sites for such a development are Rarotonga and perhaps Aitutaki, as these have frequent transport links and worker availability; rigorous and transparent EIAs are essential during planning and construction phases, and then should be ongoing throughout its operational life: closing the facility at the first sign of impact[17].

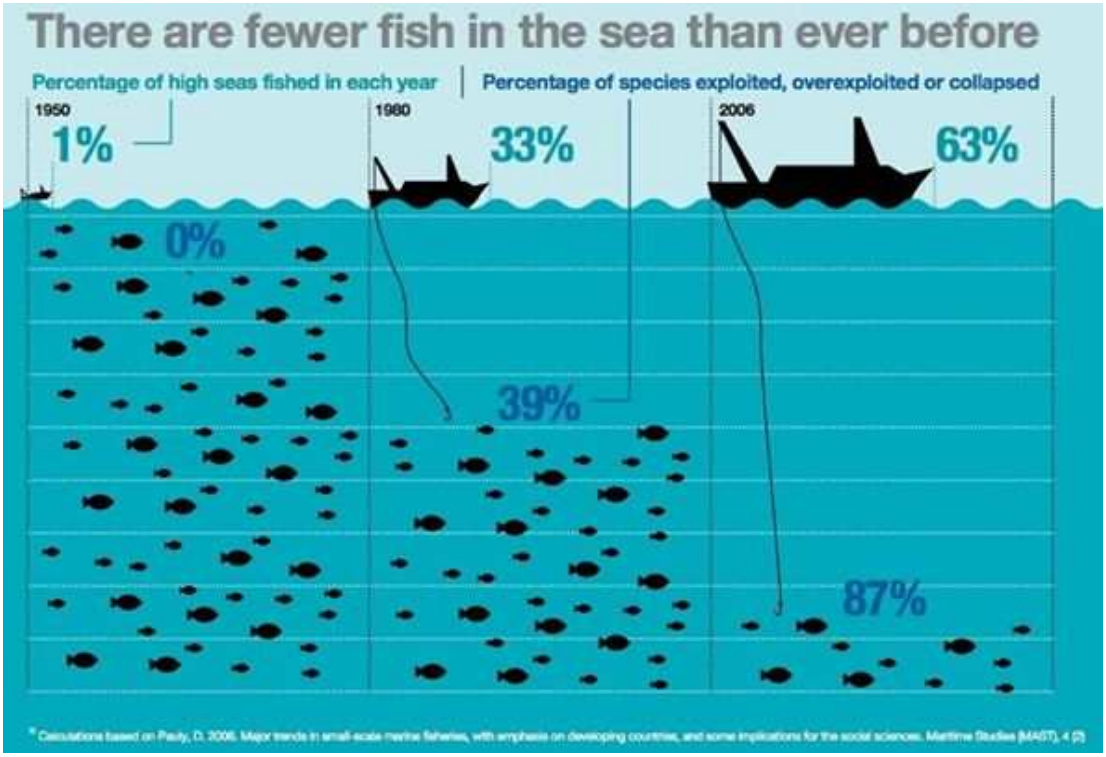
A further problem arises because most planning authorities and much law are stuck in a land-based paradigm. Using Cook Islands Marine Park as an example: Rarotonga's government aims to impose *terrestrial linear thinking* on a 3-dimensional dynamic maritime space. It doesn't work! What is being protected? Is it a fixed geographical area on a map? Are species and their habitats in the Park also protected? Seawater changes every day so will yesterday's water molecules still be protected now they've moved elsewhere? What about the fish from yesterday? Does a migratory species gain protection as it enters the Park and then lose it again as it leaves? Likewise habitats

[16] This distorts concepts like GDP, which suggest Cook Islands is a mediumly-affluent nation (average personal income given as $26,500); Outer Islanders may only earn $8,000 per annum.

[17] This was a lesson learned from the nuclear fuel-reprocessing plant at Sellafield, Northern Britain.

face a similar problem, they may move. A great difference arises between protecting a surface area and a large volume of water. The latter is obviously better. More than 98% of marine animal species are benthic ~ living at the seafloor (Thurman & Burton 2001). The water column is species-rich, home to apex predators, pelagic megafauna, and is the focal area for marine fisheries (Norse 2005). So to only protect the planar surface area is like buying house insurance just for the roof and ignoring everything beneath it. Worth nothing! So protecting the 3-dimensional space would conserve our biodiversity and their habitats, whereas protecting an area on a map will not (Norse et al. 2005). An even better model ecologically would have dynamic boundaries that ebb and flow with the ocean, habitats and species come and go; hotspots are protected in new locations (Norse 2005). For humans that will be challenging to enforce, however, suitable technology already exists: it just requires a revolution in our thinking[18].

Climate change impacts are with us already: shifting weather patterns, the sun is very hot in the afternoons, arrival of some fish stocks seem to have changed (but this could be due to increased industrial offshore fisheries: around 60 foreign vessels operate in our EEZ). Many fish stocks are overexploited or collapsing. Roberts (2007) provides a thorough analysis of the world's fisheries and shows that the last remaining stocks, including in the Cook Islands, are under heavy and increasing pressure. An ongoing attempt to allow purse-seining by European boats in the Cook Islands EEZ is challenged by massive public disapproval (a petition by Te Ipukarea Society got over 4500 votes supporting a ban).



After Pauly (2006).

[18] Policy for *Marae Moana* is still undergoing development.

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 the 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; 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).

The Millennium Ecosystem Assessment (2005) found that: "Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth. Freshwater and marine ecosystems were amongst the most significantly altered globally by human activity".

"Ecosystem services also declined greatly (i.e. *the benefits that people obtain from ecosystems*). These include **provisioning**, **regulating**, and **cultural** services that directly affect people, and **supporting** services needed to maintain the other services. Biodiversity underlies all ecosystem services".

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 (less than 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). 2015 is the hottest year on record, and 2011-2015 the hottest 5-year period www.wmo.int (World Meteorological Organisation).

Data summaries published on 20th January 2016 reveal the following: 2015 was the warmest year on record since 1850; 10 of the 12 months set new temperature records; and the global average was +0.75ºC above the long-term average (1961-1990; British Met Office). NOAA reports 2015 was the hottest since 1880; *December 2015 was the hottest month in the entire record of 1620 months*. NASA's data shattered the previous record; also confirming that 15 of the 16 warmest years occurred since 2001. All three organisations show that human activities are the major cause of global warming.

Paris: UN Climate Change conference

2015 saw an important event take place in Paris, France: a global conference held by the United Nations seeking to achieve a planetary position on human-driven climate change (COP 21). A previous conference in Copenhagen (2009) was deemed an utter failure as international delegates argued over a text some 400 pages long; most Pacific Island nations were not even considered to exist. So COP 21 is widely recognised as being the last chance for humanity to change its carbon-intensive, highly-polluting business practices, energy production, and daily activities.

There is clear evidence from the Intergovernmental Panel on Climate Change (IPCC) to show that human activities are causing global climate change (about 30 years ago

the level of certainty was around 50%; by 2015 it was 95% certainty). Over the last two decades major powers have been unwilling to compromise their national business interests, in order that a globally beneficial way-of-life can emerge. Poorer countries were often blamed for causing these problems (by seeking a similar standard of living to that in developed countries); whereas blame really rests with industrialised nations.

After two weeks of intense negotiations, which required compromise from all sides, the **Paris Agreement** was approved on the 12th December 2015 by 195 countries.

USA immediately proclaimed themselves as *the global leaders* in combatting climate change. But are they? Time-series data for CO_2 emissions (1990-2014, Netherlands Environmental Assessment Agency) show the top three polluters are China - 10,540 Mt (Megatonnes CO_2); USA - 5,334 Mt; India – 2,341 Mt. However, the population of USA is only 320 million; China and India are both approaching 1.5 billion people. So converting to *annual CO_2 emissions per capita* tells a very different story. USA tops the world with 16.5 tonnes per person; China 7.6 tonnes; India 1.8 tonnes.

Furthermore, the USA forced an exemption in the Kyoto Protocol on Climate Change (1997) so as not to report military emissions. The USAF (United States Air Force) is the single largest consumer of aviation fuel globally. Two fuel consumption examples explain why excluding military aircraft emissions is problematic: *F4-Phantom* uses between 1600 – 14400 gallons per hour, depending on speed; *B52 Stratocruiser* uses 500 gallons per minute.[19] The IPCC chapter on commercial aircraft gives two different methods of calculating CO_2 emissions, both show similar results: about 250 kg CO_2 per hour. Military aircraft will produce more than this. Exploding munitions (bombs, bullets, missiles etc.) should also be accounted for.

The Paris Agreement notes that **all sources** of anthropogenic emissions should be included; *or else countries should explain why they excluded emission categories*. Has anything changed or not?

One surprise at the Paris conference was revealing an **Alliance of High Ambition Countries** (created by **Tony de Brum**, Marshall Islands Foreign Minister). Planning took place over six months, and the **Cook Islands is a member** of this Alliance. The intention is to limit global temperature rises to 1.5ºC above pre-industrial levels, seen as essential to avoid low-lying islands disappearing through sea-level rise. As noted above: 2015 was the hottest year, and December was the hottest month in 135 years. Global temperature rose to +0.75ºC above the long-term average; 2014 was +0.57ºC. If this trend continues we have very little time to change our entire way-of-life. We can expect the major ice masses to melt; and indeed they already are.

Schuckmann et al. (2016) propose changing the way we monitor global climate change. Earth's energy budget is the **absorbed solar radiation (ASR) versus the outgoing longwave radiation (OLR)**. When those are equal the planet's energy budget is balanced. If Earth is absorbing more than it radiates back into space then the planetary budget increases (i.e. there is more energy in the system). That imbalance is measurable. The global ocean absorbs most of this energy, but there are some complicating factors. Much of the extra heat content (75%) is contained in the ocean's upper 700 m; the other 25% may enter deeper water.

[19] http://www.truth-out.org/news/item/3181:the-military-assault-on-global-climate

The **Pacific Decadal Oscillation** (PDO) can influence the *Earth's Energy Imbalance*, perhaps for decades. So just measuring sea surface temperature (SST) may not reflect the true energy state. *Argo* autonomous profiling floats have been measuring the characteristics in the upper 2000 m, but the deeper ocean is little studied. Schuckmann and colleagues suggest the best way is to measure changes in ocean heat content, complemented by radiation measurements from space.

The graphs in Hansen et al. (2016) are particularly enlightening.

Oceanic pollution

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. In about 1950 the USA decided it would create a global consumer economy that was heavily dependent on oil: so most of our present problems are, in fact, very recent. 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 hard work for us to collect it all, and the only practical option is to burn it, because there is insufficient soil depth for a land-fill site; this adds to greenhouse-gas emissions (White 2012). The global dispersion of persistent waste can only worsen, given that more plastics have been manufactured in the first decade of the 21st Century than since their invention 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). Most marine litter has come from terrestrial sources and may be as much as 8 million tonnes disposed into the ocean each year (Jambeck et al. 2015). About 5.25 trillion pieces of plastic are presently in the global ocean (Eriksen et al. 2014). The five major *'garbage patches'* in the gyres are well known (North & South Atlantic; North & South Pacific; and the Indian Ocean). Cózar et al. (2014) suggest the 'Great Pacific Garbage Patch' accumulates about one third of the plastic debris. Cook Islands are downstream of the South Pacific gyre (Eriksen et al. 2013) and Tongareva only has the Marquesa Islands between it and South America: so almost all of our rubbish comes from foreign sources. **The remedy is to prevent all litter reaching the ocean.**

The problem of persistent waste in the Outer Islands was brought to the attention of Cook Islands Government by the author in 2011, as well as some practical solutions for resolving it. National government did little for a long time, so atoll-communities are dealing with it themselves. Some aspects remain challenging: disposal of lead-acid batteries, butane lighters, non-rechargeable batteries, disposable nappies, aluminium cans and old plastic water-tanks.[20] The European Union intends to fund South Pacifc waste-management programmes (David Sheppard, *pers. com.* 2014 www.sprep.org).

The global nature of marine litter has finally been recognised as a severe concern. The Honolulu Strategy (2011) emerged from the 5th Conference on Marine Debris held in Hawai'i. It acts as a framework bringing together organisations of any size that are involved with marine debris (e.g. manufacturers, fisheries, concerned individuals, community groups and government departments), and offers a standardised method to record and report data. It does **not** set any targets or time-lines, but focuses on three main Aims: i) reduce land-based sources of marine litter; ii) reduce at-sea sources of marine litter; iii) remove accumulated waste.

The true impact of marine plastic litter is starting to emerge; Nelms et al. (2015) review the global impacts on turtles. Not only do we have macroplastics (that we see easily), but also microplastics that are less than 5 mm. These come from different sources: degradation of macroplastics into smaller and smaller fragments; micro-beads (used in cosmetics and other products); pellets that are used as stock for the plastics industry; and, more recently, micro-fibres from washing synthetic clothes (Andrady 2011). Microplastics have been identified in marine organisms and are now in the food-web (Davison & Asch 2013). In addition these act as vectors for bacteria, transporting them to new locations. The consequence of this is not yet known, but our knowledge of microbiology suggests impacts may be significant. Dumping plastics in the sea probably began in the 1960s and then increased exponentially. As yet we have no method of removing these microplastics from the ocean. Their distribution is unclear, but assumed to be ubiquitous (GESAMP 2015). Pathways and fate within the marine ecosystem are unclear, for instance how do they get into the sediment, how long do they remain there, and do they return to the water column; how long does this take? (Thompson et al. 2004; Van Cauwenberghe et al.2013; Wright et al. 2013).

Reducing at-sea sources of marine litter has progressed further than the situation on land. Until recently anything could be dumped into the ocean outside the 12-mile limit. The International Maritime Organisation (www.imo.org) and their most recent MARPOL laws prohibit all dumping at sea and require ships to maintain a waste record (garbage log). Onboard waste is sorted into categories, compacted, incinerated, or offloaded in port. Reception ports are listed online showing their facilities for waste management; Cook Islands does not have a listed port ~ the nearest is Papeete (French Polynesia). Illegal shipping or fishery operations might not comply with regulations, so an extra problem is ALDFG (abandoned, lost, or otherwise discarded fishing gear). This includes *ghost fishing*, whereby a discarded net continues fishing unattended.

[20] Cook Islands (2013-2016) now aims for a long-term ***zero waste*** approach.

Hooked juvenile loggerhead had been dragging this fishing gear around for weeks. [*Centro Recupero Tartarughe Marine,* 2010].

Reducing terrestrial waste is always problematic: most human activities are based on land. Waste-management strategies, facilities and procedures may seem suitable on paper, but they suffer problems, including mis-management, poorly-trained staff, high costs, and far too much rubbish (Ten Brink et al. 2009). It is not uncommon for land-fill sites to discharge waste into the sea; deliberately or accidentally.

One glimmer of hope is a *circular economy*. This lets waste become a re-usable resource. Instead of continually creating new plastic, and worsening the marine litter problem, consumer goods are recycled to become the new feed-stock for plastics manufacturers. So it is no longer waste, but a commodity of value (Cobb 2010; Cook Islands 2013-2016; Ellen MacArthur Foundation 2015, 2016). This can lead to local industry expansion (collectors, sorters, processors, transporters, buyers) and in time a cleaner environment. The root problem is human behaviour. Educating people so that they understand how all their daily activities contribute to global impacts is essential. The European Union has just published its ideas for a circular economy (EU 2015).

Cook Islands could create a waste recycling industry at Rarotonga. If marine plastics were used that would effectively provide a *'free'* resource. Collecting waste at sea was problematic, however, Boyan Slat's **Ocean Clean-up** (www.theoceancleanup.com) demonstrates a workable solution. Instead of spending money travelling vast distances collecting marine debris, the ocean transports waste directly into a *manta* system. The oceans are full of plastics so removing them has environmental benefits too. Changing human behaviour, particularly consumer habits is difficult: in the Cook Islands many goods arrive in plastic containers and packaging, or are made from plastic. As a nation we could declare ourselves plastic-free. It will not be quick, but once again it shows a small island nation leading the world in a better direction. Tongareva has begun its journey to reduce plastic dependency by investigating stainless steel water-tanks and wooden furniture from sustainable forestry projects.

Nothing to recycle, chairs are wood and table tops marble. Photo from Budapest, 2010.

The importance of trees really cannot be overstated. They provide shade, food, craft materials, traditional medicines; they maintain moisture, improve soil, reduce erosion and terrestrial run-off; help stabilise the coastal zone from wave-action; fix carbon through photosynthesis; provide habitats for many species; they are one of the best ways to mitigate El Niño impacts ~ and they look beautiful.

Flowers of Tamanu *Calophyllum inophyllum.*

Tongareva has begun its new voyage to become the sustainable environmental standard-bearer for the South Pacific. To achieve this requires several things: i) move completely away from fossil-fuel use; ii) replace all vehicles and outboard motors with solar-powered units; iii) only cut down sick or dead trees; iv) replant the forests and restore degraded habitats; v) use all natural resources sustainably; vi) teach the children that it is their responsibility to pass on a healthy, abundant and diverse ecosystem to their own children; vii) reduce use of plastics; viii) reduce use of cement; ix) become thoughtful, caring and well-informed stewards of our atoll.

Above: *Rhoadescar* SOLARide vehicle. It has 24-volt battery assist & solar charging.
Below: Aquawatt 13KW electric outboard-motor.

Tongareva's sustainable environment programme seeks **a zero-pollution, carbon-neutral lifestyle** (LED lighting, electric vehicles and outboard-motors, all with solar-charging). Unsurprisingly the Paris Agreement on Climate Change (12th December 2015) came to the same conclusion: forget fossil fuels, embrace solar technology, reduce power consumption, and plant trees.

Dr Michael White 2016

Te Tangata: The People

The willingness of local communities to participate in the author's work in the atolls is inspirational. Not only is traditional and sustainable resource-use widespread, but the need to have some islanders educated at advanced levels was clearly understood. The risk facing many small communities is 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. Another 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 their patrimony and sustainable food supplies are being sacrificed for short-term revenue. At present there is no national funding for biodiversity research or conservation.

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; 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 $65 pp.), part of which should support the Environment Protection Fund[21]. This initial arrangement was repealed by the Departure Tax Act (2008), which unfortunately failed to mention disbursement of the tax, other than that it now goes into Treasury general funds. Curiously, one suggestion for funding the proposed Cook Islands Marine Park would be to levy a tourist Departure Tax?

Small-scale, low-budget, locally-managed projects are likely to provide much greater benefits than larger, heavily-managed, high-cost programmes. Yet local-scale efforts do require small financial inputs over a lengthy period: i.e. continuous basic-level funding (Horwich & Lyon 2007).

The author shares his knowledge and skills to achieve sustainable use of resources; can provide tertiary-level education in the atolls; assists in the operation of locally-managed environmental monitoring projects: 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).

The most gratifying development is our community environmental society ***Hakono Hararanga***. We have 20 members at Omoka from a population of about 130 people. The other village Te Tautua (population 45) are now joining us. As a project goal was to gather in many of our islanders we have been successful. By including women and girls in our research teams we address gender equality, but more importantly we carry conservation awareness and sustainable use of natural resources into the future generations. We take great pride teaching our young people to be our future leaders, and in time we expect to share our teachings and ways-of-life with other islanders or nations, so that they too can look after our Planet Earth. ***Meitaki Poria!***

[21] Departure Tax Act (No. 10 of 2005; 10th October) Section 6(a) states that one-third of the departure tax is to be paid to the Environment Protection Fund (Section 61 Environment Act 2003). The remaining two- thirds is paid to the Airport Authority (Airport Authority Act 1985).

Pa Te Pou Ariki.

Note the *honu* tatau (tattoos) on his knees. Photo provided by Ian George.

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!

Dr Michael White 2016

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***

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i) **Research Permits # 17/12 & 21/15** Cook Islands National Research Council**.**
ii) Detailed research methodology may be found in White (2012).

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APPENDIX ONE

Richard Steiner* | Huffington Post

https://ramumine.wordpress.com/2015/10/21/deep-sea-mining-a-new-ocean-threat/

"Adding to concerns about the disastrous decline in ocean ecosystems, now there is another emerging threat – deep sea mining. While shallow water mining for sand, gold, tin, and diamonds has been conducted for decades, commercial deep sea mining has yet to occur anywhere. But that's about to change.

Extensive deep sea mineral exploration is currently underway in international waters governed by the International Seabed Authority (ISA), under the United Nations Convention on Law of the Sea (UNCLOS), and within Exclusive Economic Zones (EEZs) of many coastal nations.

There are currently three main types of deep sea mineral deposits of interest to industry and governments:

1. **Polymetallic nodules** (also called "manganese nodules") are potato-sized metal nodules found on the abyssal plain from 4,000 m – 6,000 m deep. These nodules are rich in manganese, nickel, cobalt, copper, lithium, molybdenum, iron, and Rare Earth Elements. Nodules grow slowly over millions of years, to diameters from 5 cm – 50 cm, and host unique invertebrate communities. Currently, 13 national consortia operate exploration leases on 4.5 million km^2 of the Clarion-Clipperton (Fracture) Zone (CCZ), between Baja and Hawai'i. The USA, as a non-party to UNCLOS and ISA, issued exploration leases on its own to *Ocean Minerals Company* (OMCO), a subsidiary of defence contractor Lockheed Martin, to explore for nodules in the CCZ. The only nodule deposits being seriously considered within a national EEZ at present are in the Cook Islands in the South Pacific.

2. **Seafloor Massive Sulphide** (SMS) deposits are found beneath deep sea hydrothermal vents along the 67,000 km of volcanically active mid-ocean ridges and back arc basins, between 1,500 m – 5,000 m deep. These contain high-grade copper, gold, silver, zinc, and other trace metals. Deep sea hydrothermal vent ecosystems were first discovered in 1977 at the Galapagos Rift, and stunned the world of science, as these vent systems rely entirely on chemosynthesis rather than photosynthesis – the first ever known. Over 300 deep sea vent systems have been discovered so far, and it is estimated that perhaps only 500 – 5,000 may exist in the world ocean, making this one of the rarest ecosystems in Earth's biosphere. China and Korea hold contracts to explore SMS deposits in international waters of the Indian Ocean, and Russia and France hold exploration leases on the Mid-Atlantic Ridge. Other SMS deposits being considered are in waters of Papua New Guinea (PNG), Vanuatu, Palau, Niue, Fiji, Micronesia, Solomon Islands, Tonga, and New Zealand. The Nautilus Minerals "Solwara 1" project in PNG waters is fully permitted, the mining ship and equipment are being built, and mining is scheduled to begin in 2018. This would be the first commercial deep sea mining project in history.

3. **Cobalt-rich ferromanganese crusts** are found on summits and flanks of seamounts at 400 m – 4,000 m depth. There are some 10,000 seamounts in oceans rising at least 1,000 m above the seabed (and perhaps another 90,000 smaller seamounts). Many are in EEZs of central Pacific islands (Federated States of Micronesia, Marshall Islands, Hawai'i, Johnston Atoll), and in international waters of

the tropical Pacific. Metal crusts form on shoulders of seamounts, rich in cobalt, nickel, copper, iron, manganese; rare metals such as tungsten, platinum, bismuth, tellurium, etc.; and Rare Earth Elements. Crusts grow slowly, 1 mm – 5 mm per million years, and can reach a total thickness of up to 260 mm. Seamount crusts are currently being explored by China and Japan in international waters of the western tropical Pacific, but many feel actual mining of seamount crusts would be by far the most problematic and least feasible.

Marine phosphate (fertiliser) and methane hydrate (energy) resources found in shallower waters, 100 m – 500 m deep, are often discussed in context with deep sea minerals. Marine phosphate mining is in consideration off Namibia (currently under moratorium), New Zealand (the environmental permit was recently denied, but the developer is considering reapplying this year), and off Baja Mexico, where Odyssey Marine has submitted its EIA for mining the Don Diego phosphate deposit in 70 m water depth, 12-25 miles offshore. Japan has successfully tested methane hydrate, or *"fire ice"* extraction from its offshore waters.

The deep ocean, where mining is proposed, constitutes the largest and least understood biological habitat on Earth. It is an *Alice-in-Wonderland* world of extremes, extraordinary adaptions, bizarre organisms, beauty and mystery. The region is characterised by darkness (infused with sparkling bioluminescence), extreme pressure, cold temperatures, high biodiversity (perhaps millions of species, most yet to be identified), slow growth and reproductive rates, and high sensitivity to disturbance (low resilience). Given our poor understanding of deep sea ecosystems, growing industrial interest, rudimentary management, and insufficient protected areas, the risk of irreversible environmental damage here is real.

Environmental risks and impacts of deep sea mining would be enormous and unavoidable, including seabed habitat degradation over vast ocean areas, species extinctions, reduced habitat complexity, slow and uncertain recovery, suspended sediment plumes, toxic plumes from surface ore dewatering, pelagic ecosystem impacts, undersea noise, ore and oil spills in transport, and more.

Clearly, we need to avoid such ecological damage. Before any deep sea mining moves ahead, we would need much more extensive scientific research – species identification, community ecology, distribution, genetics, life histories, resettlement patterns, resilience to disturbance, and at least a 10-year continuous time series of observations to understand dynamics of proposed mining sites over-time. In addition, we need more robust management regimes at the ISA and in coastal nations, royalty-sharing, liability agreements, stakeholder engagement, and significant advancements in subsea technology. Until these are achieved, the only wise policy is a global moratorium on all deep sea mining.

The need for more deep sea Marine Protected Areas is paramount. New Zealand established its Kermadec Ocean Sanctuary this year on over 620,000 km^2 of the islands and submarine volcanoes northeast of the main islands; Cook Islands established a marine reserve on 1.1 million km^2 (over half) of their EEZ; the U.S. established a 1.2 million km^2 Pacific Remote Islands Marine National Monument; and the ISA established Areas of Particular Environmental Interest (APEIs) over about half (or about 2.3 million km^2) of the area currently under lease in the CCZ. This is a good start, but still insufficient.

Industry and governments recognize the huge challenges in mining the deep ocean, but are resolved to move forward anyway. As justification, they invoke the "peak minerals" argument, depletion of land-based minerals, and a projected increase in mineral demand in the world economy.

But mining proponents habitually avoid discussing the opportunity to reduce mineral demand by increasing the efficiency of metal use in the global economy, cradle-to-cradle design, recycling, and landfill mining. To build a sustainable economy, we will have to break the "economy of waste" – mining raw minerals, using them once or twice, discarding them, and continuing the demand for mining raw minerals. Surely at some point, with smart renewable metal use, we will have enough minerals already up into the global economy and won't need to keep digging holes for more. The sooner we get there, the better.

The Nautilus Minerals "Solwara 1" vent/SMS mining project in PNG waters will likely be the first deep sea mining project, with others following elsewhere in PNG, Tonga, and Fiji. Other projects to watch in national waters include Odyssey's Don Diego phosphate mining project off Baja, and **manganese nodule mining in the Cook Islands**. Mining on the international seabed is likely 5-10 years off, but there is intense political pressure to do so.

This emerging industry would result in serious impacts to our oceans, so it is critical for civil society to engage now, in the early stages of exploration and development. It would be truly unfortunate if we allow the same industrial paradigm that destroyed much of the terrestrial ecosystems of our home planet to do the same in the deep sea. It is time to change this model.

This is a very big deal, and we need to pay close attention. Groups such as the Deep Sea Mining Campaign, MiningWatch Canada, Greenpeace, Earthworks, and Centre for Biological Diversity are doing great work on the issue. The future of our oceans, and thus our planet, may depend on their success."

** Professor and conservation biologist, Oasis Earth (www.oasis-earth.com)*

APPENDIX TWO White M (2016). Honu: Tongareva Henua. Sea Turtles in the Cook Islands: Volume Two (2013-2015).

Observations on coral bleaching at Tongareva Atoll – January 2016

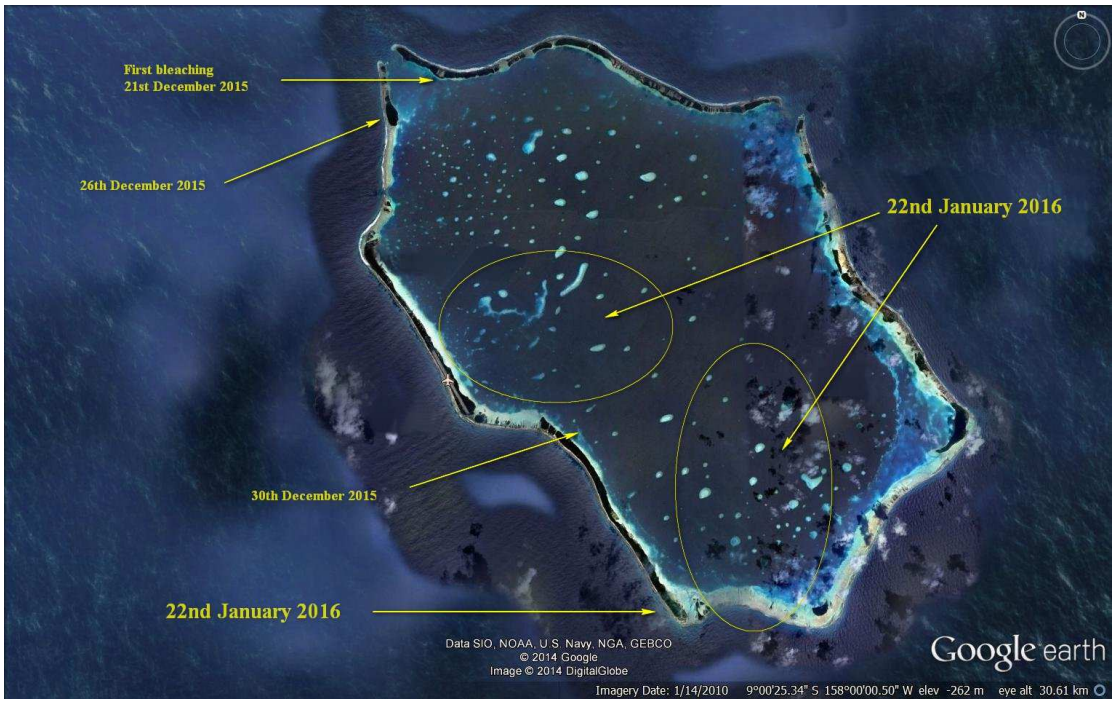

Image shows impacted areas of coral-bleaching confirmed from Tongareva Atoll (2016).

In late-2015 the author recorded impacts of El Niño Southern Oscillation (ENSO) at Tongareva Atoll (09º South, 158º West), Northern Cook Islands. The oscillation was confirmed on 12th May 2015 by Australian, Japanese and NOAA meteorology services. The previous major ENSO event was 1997-1998, when many coral reef systems globally suffered damage and about 16% died. Tongareva Atoll mostly had normal seawater temperatures (29-30ºC). Prevailing easterly winds shifted slightly southwards (East, East-southeast, Southeast, South-southeast); rainfall was limited.

The weather in December 2015 was noticeably hotter; increased solar radiation made afternoons challenging; at times it was difficult to complete turtle track counts on nesting beaches. Overnight winds collapsed and seawater in the lagoon was hot for weeks (33-35ºC). Brief showers occurred every few days. Ocean surface temperature by the leeward reef was also warmer (32ºC) in the latter part of December.

The author found the **first coral bleaching**[22] at Tongareva on 21st December 2015 in the northern part of the lagoon near Tokerau motu. Bleaching seems to have happened within seven weeks, as it was not apparent on a previous survey (28/10/2015); but it could even have been during those very hot three weeks of December (photos below).

Atoni Williams (*pers. com.*) reported that the ocean reef at Molokai was bleached on 28th December (northwest of atoll). The author found several bleached *toka* (isolated coral-heads) at Mahera (southwest of lagoon): these were OK when visited two weeks earlier [12th December OK, 30th December bleached].

[22] Higher water temperatures stress the corals causing them to expel symbiotic zooxanthellae, which means that photosynthetic nutrients from these dinoflagellates are also lost to the coral colony.

First coral bleaching found at Tokerau motu on 21st December 2015.

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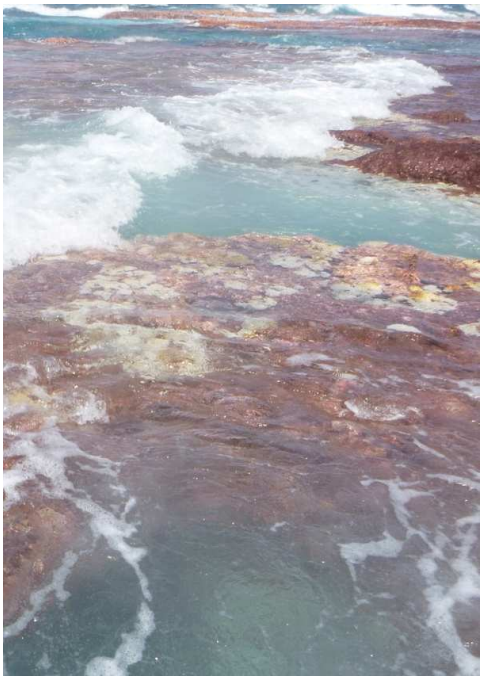
Five *toka* were viewed at Mahera on 30th December 2015: all had bleaching in progress.

22nd January 2016: Rapid Survey in the southwest corner of the lagoon.

Akasusa: during a turtle-nesting survey of southwestern Mangarongaro the leeward reef was found to have several bleached areas: both the red coralline algae and various coral species were bleached or bleaching. Waves made it difficult to see clearly, but underwater areas in the ava appeared white. On the reef top isolated species, including encrusting corals had already bleached.

Bleaching on the southwestern ocean-side reef, January 2016.



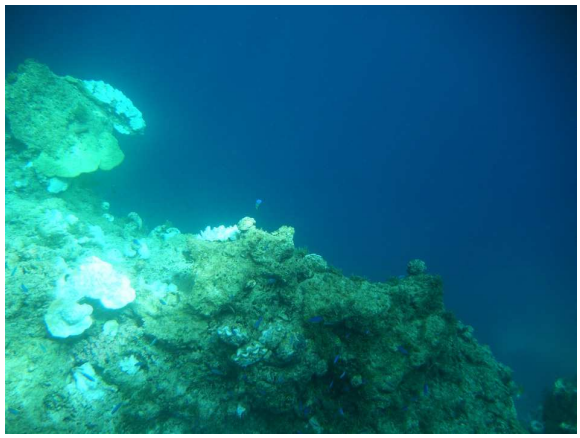
Dr Michael White 2016

Atiati complex: the channel between Ahua Manu and Vaiere had several toka with bleached corals underwater. The tide was too low to go into Atiati, so instead the boat was walked across the shallows towards Moturakina. Only one live *pasua* (clam; *Tridacna maxima*) was seen.

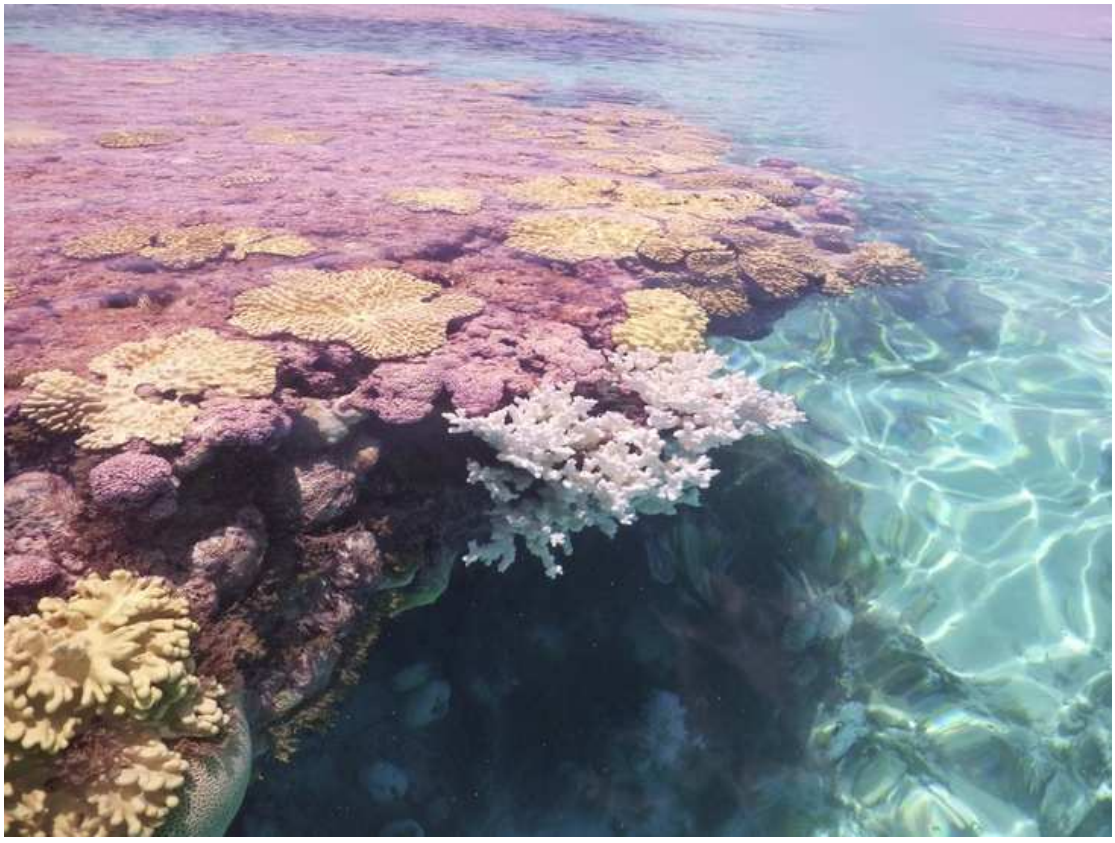
Southern lagoon to Atutahi: this is one of two pristine coral areas in the lagoon, the coral heads are immaculate. Underwater visibility was good: many toka were briefly visited. At every site coral bleaching was present, including in deeper water (8-10 metres). It seemed curious at first that deeper corals had bleached, and surface areas were undamaged; the author then realised the likely story. Throughout December the lagoon was hot (33-35ºC), and presumably water temperatures had risen in most sea areas. The upper surfaces of toka would normally experience a steep temperature increase at diurnal low water (e.g. 30-32ºC), so might have to cope with 2-3ºC more. In contrast the deeper corals may have a lower temperature range, perhaps 23-25ºC, so these might have faced an increase of 8-10ºC. Enough to kill them!

Enroute back to Omoka: numerous toka were checked and bleaching was visible even in deeper water (15-20 metres). Different sizes of pasua were dead; the animals presumably already eaten. One specimen appeared to be in the process of dying. Parts of the mantle still had pigment, others were already white; the process looks similar to corals. Coral species under the overhang were bleached too, these would normally be less exposed to sunlight and ultra-violet radiation, reinforcing the contention that elevated water temperatures extended to some depth, even if not quite reaching the lagoon floor. These bleaching events happened quickly: some within two weeks.

Dead pasua.



Top: Bleaching in deeper water; Below: Bleaching can be seen lower down.



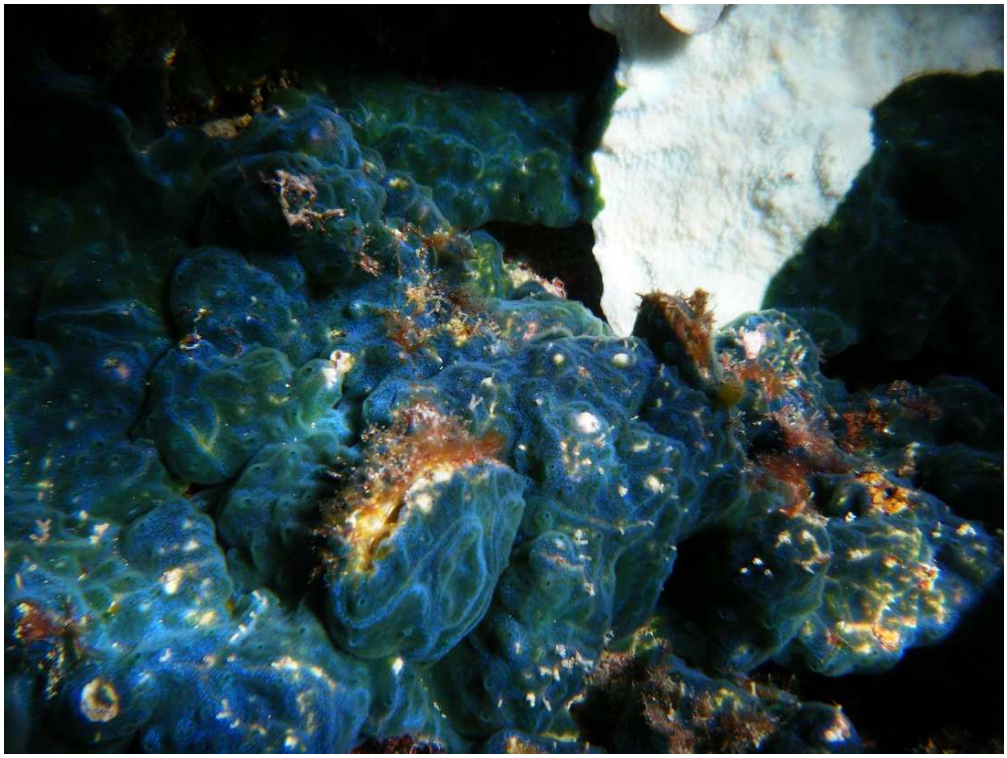
27th January 2016: Rapid Survey in the northern third of the lagoon.

Dr White and Papa Ru Taime (Hakono Hararanga's Chairman) headed north from Omoka to Seniseni (Taruia Passage) and then Molokai. We observed many toka from the surface; some bleaching had occurred on every one. We continued along Tehara, Tekasi, Tapunui and nosed into Siki Rangi passage; where we could see bleaching on the outer reef through the waves. We re-checked the site south of Tokerau where the first bleaching was identified (21st December 2015) ~ it was worse.

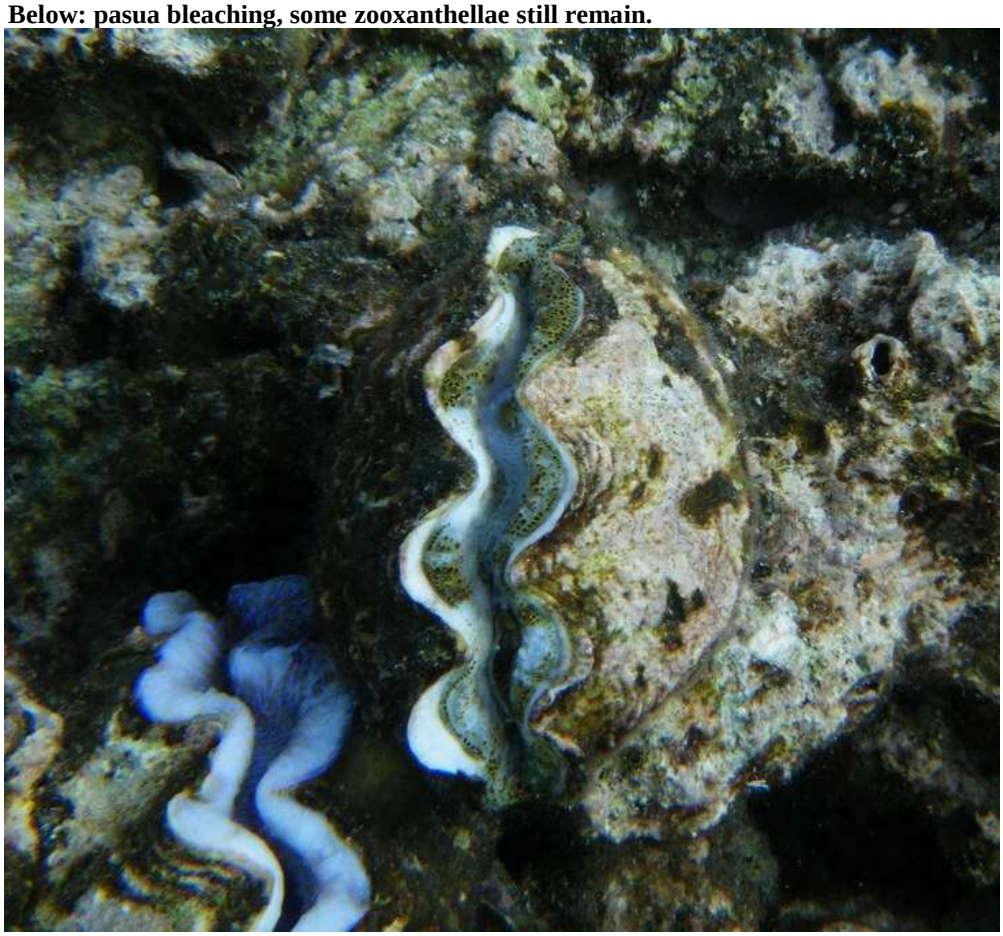
Top: toka with bleaching, Siki Rangi passage in distance;
Below: south of Tokerau, Siki Rangi passage in distance.

Both photos show blue-green algae creeping across bleached corals, northern lagoon.

We moved eastwards and snorkelled on toka in deeper water. All seven had bleaching and dead or dying pasua, but some pasua were still alive; pipi and parau were OK.



Top: blue-green algae growing on live pipi;
Below: pasua bleaching, some zooxanthellae still remain.

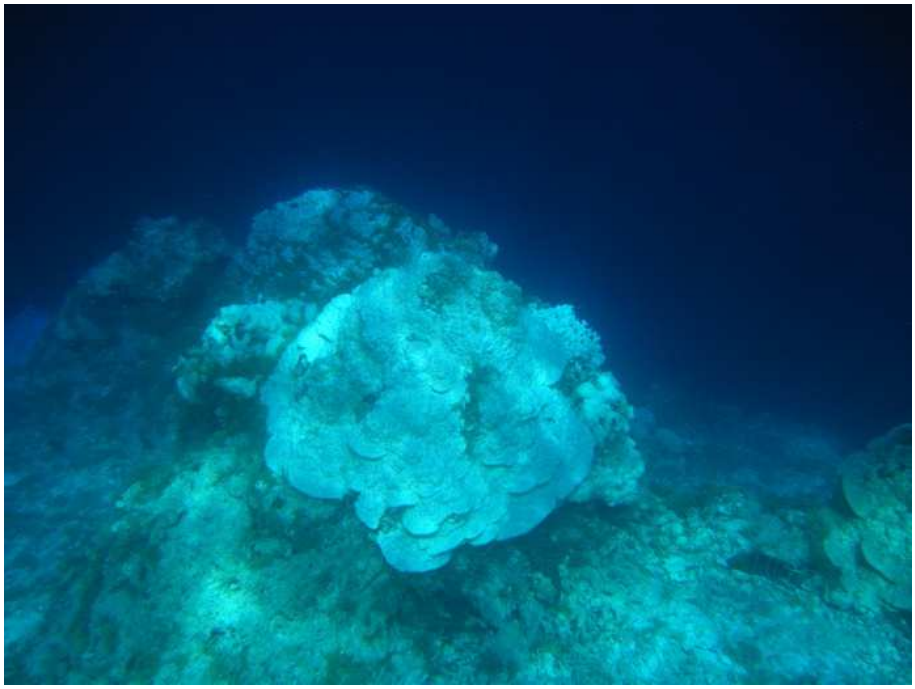


Toka BLT15 [08.57.607ºS; 158.00.967ºW] had blue growth extending across the dead corals and over various bivalves. This is assumed to be some type of blue-green algae, it can be scratched off with a fingernail, however, we have no positive identification. Most corals are still vibrant, but the *'cyano'* is starting to encroach on them.

30th January 2016: Rapid Survey in the southeastern and central lagoon.

Dr White & Papa Ru Taime continued surveys close to Atutahi, Ahua Miria, Tepuka and Tepetepe. Coral bleaching was widespread and most (95%) pasua were dead. A few pasua were still dying. We snorkelled a toka (BLT9: 09.00.641ºS; 157.56.161ºW) near to where the lagoon depth is 64 m; bleaching could be seen around 40 m deep. A future scuba-survey will confirm maximum depth of bleaching. Surface observations of toka enroute back to Omoka confirmed bleaching was everywhere in the lagoon.

Top: large encrusting coral is bleached; Below: looking to deeper water.



Both photos show dead or dying pasua at depth; clams seem more susceptible than corals.

Bleaching occurs in stages: we brought these corals to the surface for clarity.

Aftermath:

Following these rapid-surveys, which covered much of the lagoon, the author reported the findings to the Secretary of Marine Resources (Ben Ponia), who notified fishery officers across the Northern Atolls. The Secretary confirmed **this is a direct impact of climate change**. There is a pool of warm water to the north of Tongareva; and the shifts between La Niña and El Niño are now more frequent.

What we hope happened is that as water temperatures rose the pasua mass-spawned as they became stressed. If correct then in time we should find new sedentary stages of clam. Despite this major environmental disaster what is most clear is how successful our **sustainable resource management** under *rahui* is. There were tens of thousands of clams and different life stages. But neither *rahui* nor legislation can protect us against the folly of man!

Seabirds

The final observation is that many of our avifauna have disappeared. Tongareva, and Rakahanga, are very important refuges and breeding sites for seabirds. There are a few of each species remaining, and larger numbers of **kakaia** (*Gysis alba*) and **rakia** (*Anous tenuirostris*), but about 95% of the larger birds have left: most noticeably the two frigatebird species **kotaha** (*Fregata minor*) and **tarakura** (*Fregata ariel*). Presumably they've gone somewhere cooler, and their return will be a clear indicator of more normal weather arriving.

Above: male & females of both frigatebird species; Below: (L) *rakia*, (R) *kakaia.*

Deepest Thanks to all who have supported this marine research and conservation over the years: your help is very much appreciated.

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