Modifications to natural resource use in response to perceptions of changing weather conditions on Takuu Atoll, Papua New Guinea

Anke Moesinger[1]

Abstract

Takuu Atoll is one of three Polynesian outliers in the Autonomous Region of Bougainville in Papua New Guinea. The local population is inextricably linked to the surrounding ocean for their primarily subsistence-based livelihood needs. One of the main environmental concerns for the people of Takuu is the unpredictability of weather patterns, specifically monsoon wind direction. This causes distress among fishers because these disturbances can affect food security and create dangerous situations at sea. This paper examines key perceptions of wind alterations and other environmental changes. It further explores how fishers, primarily Takuu men, have adapted to these alterations through changes in their fishing methods, including a multitude of line fishing (*matau*) methods, and various net fishing (*kupena*) methods and giant clam mariculture. I conclude that local knowledge and perceptions of changes in weather patterns that necessitate modification of natural resource use strategies are critically important to the adaptive capacity of Takuu Islanders, given their limited livelihood options owing to the infrequent and irregular shipping services that increase economic isolation.

Keywords: Takuu Atoll, local environmental perceptions, food security, fishing practices, environmental change

Introduction

The need for small island developing states to address present and future impacts of climate change has recently been of key concern to academics working in the natural and social sciences. Accordingly, anthropologists, geographers and sociologists have contributed a vast amount of literature exploring the different social aspects of climate change. While literature on the concepts and frameworks of vulnerability, resilience, risk perception, migration and large-scale adaptation is abundant at the regional and global scale (e.g. Adger 2003, 2006; Barnett 2001; Kelman and West 2009), empirical studies of local perceptions of, and responses to, rapid environmental changes remain limited. More specifically, how inhabitants perceive environmental perturbations and adjust their resource use strategies in response is not yet well elucidated.

Inhabitants of low-lying island environments are particularly exposed and sensitive to the impacts of climate change. Changes in sea level, shoreline erosion, increased cyclone intensity, increased flooding, droughts and other changing weather patterns will affect food security and livelihoods, and thus, in some cases, the ability of resident populations to remain in their island homes (Barnett and Campbell 2010; Nunn 2009). However, the potential adaptive capacity and local responses to these negative impacts are poorly understood (Mortreux and Barnett 2009). Not only has inadequate attention been given to the capacity of social and ecological systems to adapt to rapid environmental change, but research has also not determined the constraints and barriers of adaptation as well as the costs of such undertakings. Without the incorporation of detailed knowledge obtained from location- and context-specific studies, discussions of large-scale relocation of low-lying Pacific Island inhabitants remain highly speculative and potentially alarmist.

It is important to note that, at the local level, environmental change is a central feature of everyday life; people understand it that way and have developed coping mechanisms and adaptive capacities to adjust. For example, Lefale (2010) examined traditional knowledge of weather and climate in Samoa, noting that spiritual and mythological views held by participants had a profound effect on how they perceived and reacted to rapid environmental change. Likewise, Duarewa (2009) reports on Fijian women's use of traditional ecological knowledge to adapt to decreases in fish stocks. When faced with having to take on the added dangers of traveling farther out to sea and staying out longer to attain the same amount of fish they typically do, the women collectively decided to

[1] Leibniz Center for Tropical Marine Research (ZMT), Department of Social Sciences, Fahrenheitstrasse 6, 28 359 Bremen, Germany. Email: anke.moesinger@leibniz-zmt.de

shift their resource use patterns and bring back the custom of mariculture. Sound scientific studies at the local level present a clear picture of adaptive practices that individuals and communities employ, provide an accurate assessment of local perceptions of climate change, and when coupled with geological, meteorological and ecological data, can provide a holistic view of not only the impacts of, but also the responses to, environmental change. These in turn can inform better adaptation strategies for future climate perturbations on Pacific Island nations.

Acknowledgement of changes by individuals in a local community is precursory to any adaptive practices taking place. It is also increasingly recognised in the literature that adaptation to extreme weather events and natural climate variability increases resiliency in the long term while decreasing vulnerability to perturbations in the short term. This intimates that the examination and documentation of local knowledge systems of resource use patterns and changes thereof, with regards to rapidly changing environmental conditions, is of paramount importance to gaining an understanding of how communities cope with change and, perhaps more significantly, how they will do so in the future (Beyerl et al. 2018).

On Takuu Atoll, a remote Polynesian outlier in Papua New Guinea, the people are said to be among the most vulnerable to the detrimental effects of climate change. These impacts include shoreline erosion, increased flooding from 'king tides', salinisation of the water table which in turn affects swamp taro (*Cyrtosperma chamissonis*) and true taro (*Colocasia esculenta*) cultivation, and changing wind, current and precipitation patterns. Supposed plans by the Autonomous Bougainville Government to relocate the atoll's population as 'climate refugees' by 2015 have not yet been implemented. While global media reports claim Takuu and surrounding atolls could prove imminently uninhabitable (Cochrane 2010) as soon as within the next decade (Vidal 2005), the islanders' resource use patterns, coping and adaptive strategies have received little attention. The failure to include sociocultural and crucial economic factors in these reports has led to conceivably unreliable and exaggerated predictions for the near future of the Bougainville atolls (Connell 2018).

The local population's perceptions and responses to environmental changes on Takuu Atoll are shaped by numerous sociocultural, economic and political factors. While these critical processes are beyond the scope of this paper, the research presented here aims to contribute to a more holistic understanding of adaptive behaviour to the impacts of rapid environmental change by addressing two main questions: 1) What are the key environmental changes? and 2) How have Takuu Islanders adapted their natural resource use in response to these changes?

Study site

Takuu Atoll, often referred to as Mortlock, is a Polynesian outlier located 273 kilometres northeast of the island of Bougainville in Papua New Guinea (Fig. 1). Although geographically part of the Solomon Islands archipelago, the atoll

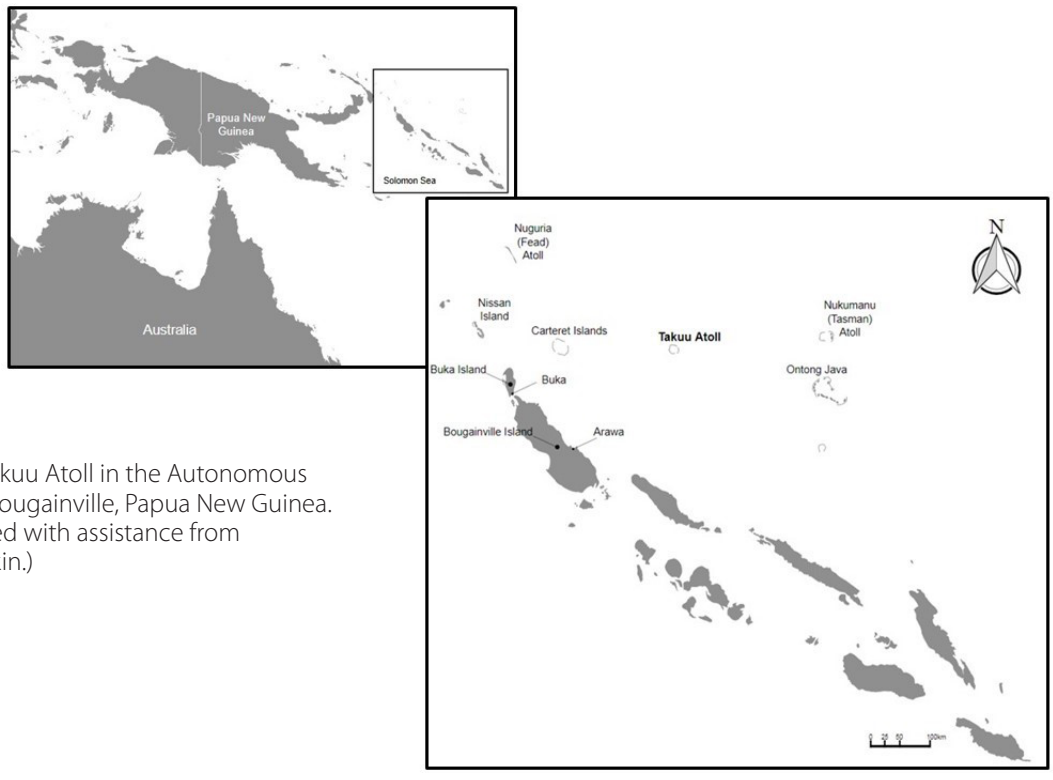

Figure 1. Takuu Atoll in the Autonomous Region of Bougainville, Papua New Guinea. (Map created with assistance from Daniel Boykin.)

is administrated by the Autonomous Bougainville Government. In 1969, the atoll's population was 530 but decreased markedly over the next three decades (Willis 1970; Moyle 2007). By 2014, the population was 316, residing in 86 households. Most of the island's inhabitants are women and children, as the men often travel to urban centres such as Buka, Port Moresby, Lae and Madang for employment opportunities and other socioeconomic activities. Takuu Atoll, at 74 hectares, is the largest and southernmost island within the atoll and serves as the garden island for the population. It is also the island from which the atoll derives its name. All of the inhabitants of Takuu Atoll reside on the village island of Nukutoa, which is approximately 6 hectares in area.

Seasonal variation in the atoll's climate oscillates between the southeast trade winds (*te anake*), which prevail from May to October, and northwest winds (*te laki*), which occur from December to March. There is little seasonality in agriculture, and the island`s population harvests giant swamp taro (*Cyrtosperma chamissonis*) and true taro (*Colocasia esculenta*) throughout the year. Banana plants (*Musa* cvs) and papaya trees (*Carica papaya*) supplement the daily diet of various types of fish and marine invertebrates. Although there are a large number of chickens on the island, they are not consumed regularly. Chickens are butchered primarily for residents who are ill or for special occasions such as the arrival of a ship from Buka, the provincial capital of the Autonomous region of Bougainville. Takuu Islanders overwhelmingly rely on the sea for their protein, and so are experts at canoe construction. Some canoes are designed for the open sea to catch tunas and sharks, while others are crafted for shallow coral reef habitats where men use nets and handlines to catch fish, and dive to spearfish and procure giant clams and sea cucumbers (*lori*). Over the last 30 years there has been a large influx of fibreglass canoes, or *moras*, from the neighbouring atoll of Ontong Java in Solomon Islands. Most types of customary fishing techniques currently employed on Takuu are practiced solely by men, as tradition holds that women contaminate fishing vessels through their presence.

Research methodology

Fieldwork consisted of 14 months of ethnographic research from April 2013 to June 2014 in Bougainville, Papua New Guinea, including 9 months residence on Takuu Atoll. Owing to a lack of shipping services to Bougainville's atolls, five months of research was conducted in the town of Buka with Takuu Islanders who migrated from their atoll for education or employment. Participant observation, augmented by 55 semi-structured interviews with both male and female residents; four focus group discussions with elder fishermen; and myriad informal discussions with key informants, all of whom were at least 35 years of age and long-term fishermen, were utilised to ascertain local ecological knowledge and individual perceptions of changes in wind patterns, rainfall, currents, storms and shoreline erosion. Additionally, the methods used aided in identifying fluctuating marine tenure practices in response to these environmental perturbations. Interviews and discussions were conducted in either English or Tok Pisin.

Results and discussion

Perceptions of changes in environmental conditions

While Takuu Islanders had heard of climate change, few informants said that they understood the scientific underpinnings of this global phenomenon. Despite this, observations of environmental change that were reported in interviews were consistent. The scope of participants' knowledge and perceptions about environmental change are closely tied to land use and their primarily subsistence-based livelihood practices. One main theme about environmental change that emerged from participants was increased monsoon wind variability and overall decreased predictability of weather systems. One fisherman, aged 35, explained:

> We used to ask the elders about good times to go fishing. They will tell you the time the tides and winds are good. But now, they are sometimes wrong. I think they are realising this. At this time, the wind is supposed to come from *te laki* – a very strong wind – but now it is coming from all over the place. When the wind comes from *te laki* we go to fore reef behind the islands, but the last two weeks it has come from the southeast. Now we don't know which way we should go fishing without consulting the elders, and sometimes they do not know now.

Shifting wind and precipitation patterns were the most frequently cited changing aspects of participants' surroundings. Figure 2 shows the direction of the prevailing *te laki* and *te anake* winds in relation to the atoll. During the northwest monsoon winds (*te laki*), strong wind-generated waves make lagoon fishing difficult and force men to fish behind or east of the islands. Participants said that more rain has fallen in recent years than before during the months of December to March, and fishermen stated that this made them less likely to go on longer offshore fishing trips. Southeast winds (*te anake*) were perceived to be less intense, and this season provides more favourable conditions for generally less strenuous lagoon fishing.

Another perceived change in the atoll environment is the availability of fish. There was consensus that one had to spend more time and travel farther away from Nukutoa to acquire fish that were once – just a generation ago – readily available close to the village. Cited reasons for this were numerous: pollution from the island was driving fish away; overfishing on a local scale; and global environmental change caused by industrialised nations were causing changes in migratory patterns of fish in the open ocean. A prominent fisherman, aged 47, asserted:

> We used to have a basket of smoked fish always hanging in the house. This is not our experience anymore. Fish are getting harder to find. The young men now have to go to

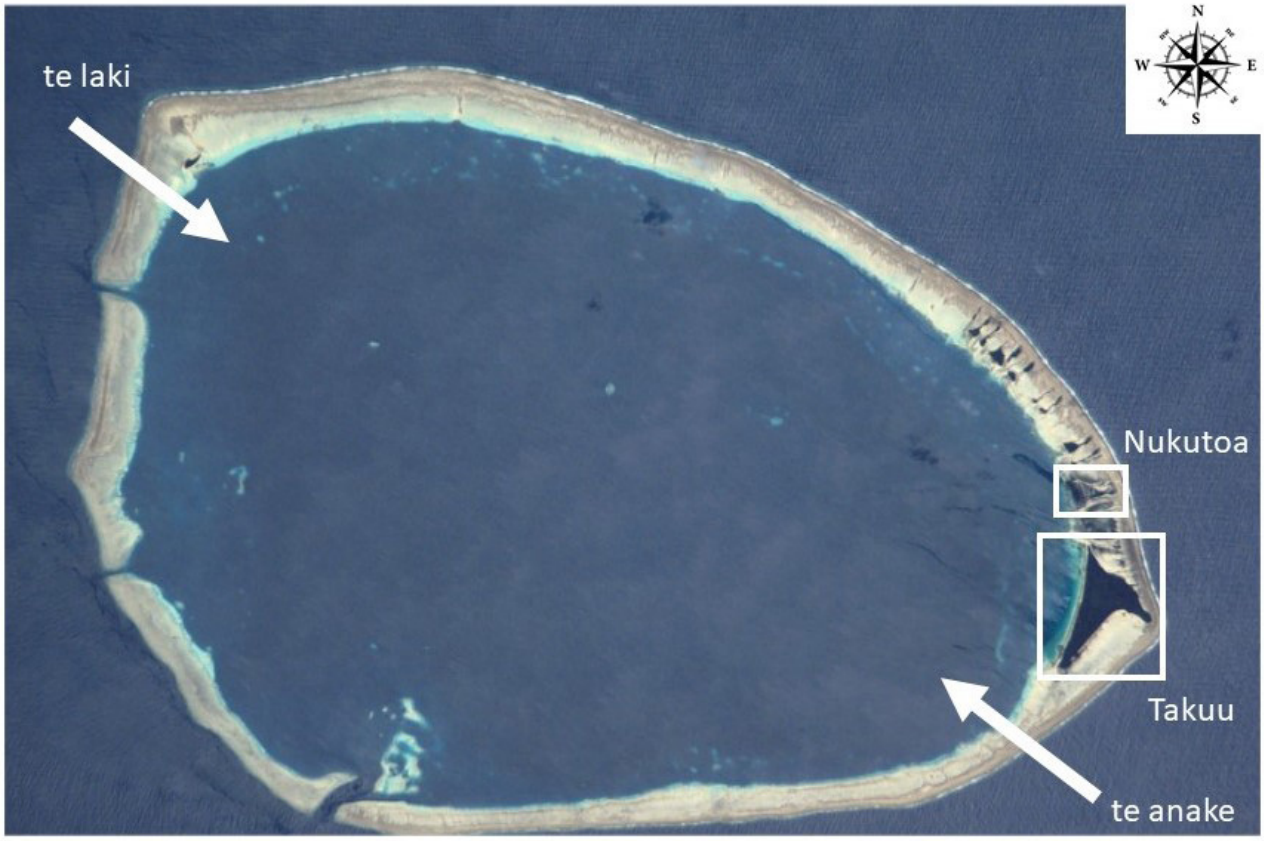

Figure 2. Takuu Atoll, with arrows indicating the direction of the prevailing winds (*te laki* and *te anake*) in relation to Nukutoa, the village island and Takuu, the garden island. (Photo courtesy of NASA)

> the channels or beyond to catch fish large enough for the family. Maybe we used our nets too much. We cannot go with a 3.5- or 2.5-inch net now, we have to go with a 1 inch. There are no big fish around now.

When asked if fish would ever go extinct, all participants stated that they could not envision such a time. The same was asked about sea cucumbers, sea turtles and giant clams. All but one fisherman said that, given the geographically remote location of the atoll, these marine resources were functionally unlimited. However, all fishermen interviewed mentioned the increased difficulty in obtaining giant clams, with the bear paw clam (*vaasua*, *Hippopus hippopus*) being particularly difficult to find in recent years.

Resource use and adaptations to environmental changes

Land and agricultural resource use

Due to the sandy substrate on Nukutoa and Takuu islands, few fruits and vegetables can grow and thrive. Plant propagation from seeds, cuttings or bulbs from most edible plants is not easily achieved. Major food plans include coconuts (*Cocos nucifera*), giant swamp taro (*Crystosperma chamissonis*), bananas (*Musa* cvs) and papaya (*Carica papaya*). Minor plant-based food sources include *aibika* (*Aberlmoschus manihot*), yams (*Dioscorea nummularia*) and breadfruit (*Artocarpus altilis*). Bourke and Bettis (2003) noted that watermelon (*Citrullus lanatus*) was grown next to houses on Nukutoa, but this practice ceased completely by 2014 (see also Willis 1970). Bananas have always been an important food source, and many more banana plants are being newly planted on Nukutoa; one can find them between every house and on all footpaths of the island. Women are active in planting pumpkin (*Curcuma domestica*) patches next to their houses. While this was a rarity as recently as a decade ago, at the time of this research there were seven houses with large pumpkin patches.

On Takuu island, saltwater incursion into the swamp taro (*kano kano*) gardens was a concern voiced by several participants. While quick to attribute salinisation as an effect of climate change, upon further inquiry all informants stated that, given the geomorphology of the island, this has always been an issue. To ameliorate the conditions, farmers replant their crops on slightly higher ground, wherever possible, or when they notice taro leaves beginning to turn yellow. This is not possible for *kano kano*, however, because giant swamp taro plants grow up to six meters in height. Only the suckers can be excavated and replanted.

Marine resource use

Fishing practices

Fishing on Takuu Atoll entails far more than simply putting protein on the table. It is a method of cultural expression, innovation and appropriation. Some knowledge of fishing, such as methods, locations and timing, are closely guarded by families of the five clans that live there as a source of power and prestige. Fishing skill is one way that status is achieved within the community. As in Tokelau and other Polynesian societies, the term *tautai* is a designation for a highly skilled fisherman who is able to lead customary offshore fishing expeditions. A *tautai* possesses vast knowledge about the behavioural ecology of fish, prime fishing locations and fishing methods. This is passed down through generations through each of the clans. Prestige and status are achieved by catching certain highly prized fish such as *parumea* or red emperor snapper (*Lutjanus sebae*), *hailama* or large yellowfin tuna (*Thunnus albacares*) and *alavena* or oilfish (*Ruvettus pretiosus*). On Takuu, fishing meets numerous social obligations, including 'opening houses' after a mourning period with large yellowfin tuna that were caught on customary ritualised fishing expeditions called *sii*. Oilfish are currently used to open houses after a mourning period because *sii* expeditions are no longer performed. Figure 3 depicts an oilfish placed in front of a deceased person's house early in the morning to signify the end of the mourning period. Oilfish are caught on moonless nights using a fishing method known as *hakasoro*. *Hakasoro* is only done by the most skilled fishermen on Takuu, and much ritual surrounds the practice.

Fishing can broadly be categorised as being performed in one of three zones: the lagoon and its shallow reef habitats, the fore reef and the open ocean. Net fishing (*kupena*) is used only inside the lagoon, while line fishing (*matau*) is conducted extensively in all three zones. Although 26 types of line fishing techniques have been documented, only 17 are currently used. The line fishing techniques documented during the research period are described in the Appendix. More than 10 other fishing methods practiced include spearfishing (*korukoru*), and various types of gleaning to procure bivalves, marine worms and crustaceans.

In their fishing activities, fishers have incorporated new adjustments to maximise their catches. Prior to the 2009 Papua New Guinea National Fisheries Authority moratorium on the highly lucrative beche-de-mer trade, many Takuu men harvested and sold beche-de-mer extensively. With their earnings fishermen purchased *moras,* sturdy fibreglass

Figure 3. *Alavena* or oilfish (*Ruvettus pretiosus*) has been prominently displayed early in the morning outside of a house to indicate the end of the mourning period. Before this ritual is conducted, the deceased's family residing there is not allowed to enter the domicile during daylight hours. (image: Anke Moesinger)

canoes popular in Solomon Islands. As the beche-de-mer wholesalers often brought their catch to Ontong Java, where the sale prices were highest, Takuu Islanders often returned with their new sturdy fishing vessels. *Moras* are especially advantageous because they are low maintenance, much more so than traditional outrigger canoes that require extensive repairs after prolonged use. Men go trolling in their *moras* (*paataki*), by paddling rapidly, and catch rainbow runner, several species of tuna and other large pelagic fish by themselves and without having to wait for a supply ship to deliver petrol to fuel small powerboats. More efficient fishing gear has also replaced much of what was customarily used. Stronger test lines, an assortment of steel hooks, and modified rebar fashioned into large hooks for catching oilfish are now used almost exclusively.

Te laki brings strong northwest winds and waves into the lagoon, so the fore reef behind the island chain may be the only place where one can fish during this time. The most common fishing methods employed are *paataki, kkuu, koru-koru* and various *kupena* techniques. If the trade winds are so strong that they create potentially dangerous situations for canoes and *moras,* fishermen opt to stand on the back of the islands on the reef crest to conduct a specific type of handline fishing called *tuutuupaa* or a type of pole fishing called *siisii urutuki*.

Another strategy is to use the net fishing method *osooso sarii*. Several men meet, usually in the early morning, to catch various species of silverside baitfish (*sarii*). Three or four men will hold several nets (*kupena*) and walk in a straight line, generally perpendicular to the shoreline, while another three or four men are tasked with chasing the small fish into the nets. Once they return with the silversides, equal sized piles are divided among the participants. Most men then usually depart for their own fishing excursions in the lagoon or the open ocean. Figure 3 depicts men during *osooso sarii* on the shoreline in front of Takuu, and Figure 4 shows men returning from after netting silversides in front of Nukutoa. If the weather is unfavourable or the wind patterns are unpredictable, men will take their share of the silversides to consume directly rather than using them as bait for further fishing. This is increasingly becoming common practice.

Lagoon fishing is optimal during the southeast trade winds characteristic of *te anake*. *Pepesi, matau va tai, tau muu, taki-taki* and *pakeo* are all commonly used fishing methods (see Table 1) used during this time. Fishermen do not go *paataki* fishing outside of the lagoon during *te anake* winds because the ocean side of the islands experience strong winds and currents during this time.

Figure 4. Fishermen heading out to use the *osooso sarii* method to catch silverside baitfish (*sarii*) early in the morning at the northern end of Takuu island. Forming a line and walking south for the distance of the island, towing their *moras* behind them, men drag their nets while other fishermen are tasked with chasing the *sarii* into the nets.
(image: Anke Moesinger)

Figure 5. Fishermen in front of Nukutoa in the late afternoon after completing *osooso sarii* fishing. (image: Anke Moesinger)

One village elder, aged 72, explained

> December, January and February is the season for *te laki* with strong northwest winds. The strong currents are great for forereef fishing for schooling fish like bonito and rainbow runners, although they sometimes seek shelter in the lagoon. *Te laki* always brings plenty of rain. During *te anake* in March, April and May the wind is always calm with little rain. *Te anake* is good for lagoon fishing like *pepesi, matau va tai* and *tau muu*. *Te laki* starts much earlier and ends much later now, and fishing has become more difficult to provide food for the family. In June, July and August we do not know anymore where the wind will come from.

Another aspect of Takuu fishing culture is the steadily increasing role of women. As weather conditions become less predictable, more fishing is conducted closer to the islands, where women often practice *pakeo, matau mataahiloa* and *matau paaua* (see Table 1) in waist-deep water in front of Nukutoa, and in the shallow channels adjacent to the island. As men become more resistant to travelling away from the islands when the winds or currents are too strong, there will be a greater dependence on nearby resources that engage women more in providing protein for the household.

Mariculture

Much like the example from Fiji, where fisherwomen are intensifying their mariculture practices due to the need to travel farther afield because of depleted fish stocks, Takuu Islanders are also increasing the mariculture of giant clam 'gardens'. Giant clam mariculture has been a part of Takuu Islanders' resource use strategy since precontact time. While previously used to produce tools, weapons, ornaments and other objects of material culture, giant clams are now used solely for their flesh. The gardens are located in the shallow water in front of Nukutoa and the adjacent islands. Three species of giant clams are kept in the giant clam gardens: giant clam, *Tridacna gigas* (*nakohu*), bear paw clam, *Hippopus hippopus* (*vaasua*) and fluted giant clam, *Tridacna squamosa* (*te nai*). While Takuu has a characteristic Polynesian patrilineal kinship system, garden plots are passed down for generations through both male and female family members. Adult men and women possess between one and five garden plots, and married women hold on to garden plots until their sons reach maturity. There is a broad range in the quantity of giant clams that individuals possess. Some may have only a few while others keep up to 200 giant clams in their respective plots.

There is more reliance on the giant clam gardens as a form of nutrition than in previous times due to the unpredictability of winds, currents and precipitation. This adaptation strategy conserves energy and guarantees a meal in unfavourable

Figure 6. A fisherman returning from harvesting giant clams: *nakohu* (*Tridacna gigas*), *vaasua* (*Hippopus hippopus*) and *te nai* (*Tridacna squamosa*). (image: Anke Moesinger)

weather conditions. Figure 6 depicts a fisherman who has returned after harvesting giant clams for a celebratory feast from the three deep channels on the west side of the atoll. Due to overharvesting, one must travel to the far west side of the atoll to collect new replacements for the gardens or to harvest them directly off the reef for large community functions or to send to relatives residing in Buka.

As a village female, aged 39, notes:

> When my grandmother died, I received her garden at *I tai sauti*. It had 30 *nakohu*, but they were close to the beach and covered with sand from *te laki*. There were no *te nai* or *vaasua*. My husband placed 121 inside, but now it is 80 that I am left with. At *te laki* we eat them sometimes. It is so hard to go fishing in *te laki* winds now. When *te anake* comes, that is the best time to replace them.

Greater reliance on the giant clam gardens places more pressure on this resource, and the effects are being felt by all fishermen. Diving for giant clams is a task only suitable for younger more active fishermen, as giant clams can grow at depths of up to 20 meters. As discussed previously, all participants stated that there is no limit to giant clams; some would always be present. However, obtaining replacements for future consumption is proving to be increasingly difficult. The effort that fishermen must expend is compounded by intensifying *te laki* trade winds, which produce stronger currents and waves that affect garden plots inside the lagoon. Fishermen must check their giant clams more regularly to ensure that they are still thriving and not being smothered by sand that gets stirred up from winds and currents.

Implications for food security and adaptive capacity on the atoll

Takuu has not always been as economically isolated as it is today. Even during the Bougainville crisis[2], large supply ships travelled to the island at least on a quarterly basis. At present, not more than two ships visit the atoll each year, and few small fibreglass boats risk the 300-kilometre journey from Buka to bring in supplies. Once a ship arrives bringing large quantities of store-bought goods, fishing activities all but cease for several weeks to a few months until flour-based products and rice supplies have largely been consumed.

Takuu Atoll covers a land area of slightly less 1 square kilometre, and the population has decreased significantly over the last 20 years. As opposed to the neighbouring Carteret

[2] The Bougainville crisis was a bloody civil war that occurred from 1988 to 1998 between PNG's national government and the Bougainville Revolutionary Army. The war caused 20,000 Bougainvillean casualties. The conflict began due to grievances over the Rio Tinto-owned Panguna copper mine, and concluded with the signing of the Bougainville Peace Agreement in 1998, which established the Autonomous Bougainville Government.

Islands with a population of around 1200 and very limited space for agriculture (Connell 2016), the 316 people residing on Takuu still currently place little pressure on the atoll's resources today, even without the regular arrival of supplies. With a larger landmass and lower population than that of neighboring atolls, food security is currently not as dire a concern on Takuu as it is on Tasman Atoll and the Carteret Islands. However, this may well change with increasingly erratic weather patterns, fewer fishermen residing on the island to meet the protein needs of residents, and decreasing levels of fishing skills due to outmigration.

Whereas fishermen customarily had explicit times of the year where they only practiced certain types of fishing, the increasing instability of wind and current patterns necessitate that fishermen possess and continue to pass on extensive local knowledge to adapt to these changing conditions. This knowledge is not replaced by advancements in technology or the use of modern fishing equipment. If the islanders wish to continue their education, students must leave after grade eight because there is no secondary school on the atoll. Thus, adolescents leave the island during their formative years and miss out on much learning with regards to fishing skills and practices. Many men in their 30s and 40s also reside in urban centres. Coupled with a predicted trend towards more environmental perturbations, this hinders adaptive capacity for future generations.

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Appendix I: Summary of line fishing (*matau*) methods currently in use on Takuu Atoll

Takuu name	Brief description	Season(s)	Frequency of use during season(s)	Location	Best tidal and lunar stages	Commonly caught species
Pepesi	A fishing method where a man swings a handline in a lasso-like motion in the direction of a patch reef away from his anchored fiberglass canoe (*mora*) in shallow water (~ 5–10m in depth) inside the lagoon. If a wooden canoe is used, then no more than two men will go on the expedition together to avoid crowding. It is practiced by men only, generally those in their early 20s to late 60s. 20–50 lb test monofilament line is used with J hooks (2/0 or 3/0) along with a small lead sinker purchased in town. Using a sinker is optional.	*te anake*	weekly	lagoon	low tide and *tai maariki* (start of rising tide) all lunar phases	When using octopus as bait: *simu taia mmea* (yellowmargin triggerfish, *Pseudobalistes flavimarginatus*), *hiloa* (yellowlip emperor, *Lethrinus xanthochilus*), *natura* (longface emperor, *Lethrinus olivaceous*) When using *te karo* (juvenile goatfish, *Mulloidichthy sp.*) as bait: *taea* (humpback snapper, *Lutjanus gibbus*), *hiloa* (yellowlip emperor, *Lethrinus xanthochilus*), *hootua* (onespot snapper, *Lutjanus monostigma*)
Tauna	*Tauna* is the same as *pepesi* in terms of equipment and technique used, but is performed solely at night. *Tauna* also refers to the specific places inside the lagoon where this type of fishing is practiced.	*te anake*	monthly to weekly	lagoon	low tide and *tai maariki* all lunar phases	*taea* (humpback snapper, *Lutjanus gibbus*), *hiloa* (yellowlip emperor, *Lethrinus xanthochilus*), *hootua* (onespot snapper, *Lutjanus monostigma*)
Paataki	A fishing method equivalent to the Western method of trolling. Performed by men only, this technique can be done on acanoe while paddling (one person), canoe under sail (one or two people), or fibreglass boats with an engine (four or five people). If lures are not purchased in town, then other common items are used as bait, including condoms, feathers, plastic bags, straws and wool yarn. When practiced on a fiberglass canoe (*mora*), the fisherman drags the line ~ 10–15 m behind the vessel. If a power boat is used, then the line is extended farther, to ~ 20 m. Trolling only occurs early in the mornings (between sunrise and 10:00) and in the late afternoons (15:00 to 18:00 pm). At night, *paataki* is only performed at one of the three channels on the atoll.	both	weekly	lagoon and open ocean	*tai maariki* Daytime: New moon (days 29–5: *maa itu to maa rima*) Nighttime: New moon (days 29–4: *maa itu* to *maa haa*) and third quarter moon (days 20–24: *seni maa rima* to *seni maa sivo*)	Daytime inside lagoon: *naenae* (double-lined mackerel, *Grammatorcynus bilineatus*), *malauseri* (bluefin trevally, *Caranx melampygus*), *kamai* (rainbow runner, *Elegatis bipinnulatus*) Daytime outside lagoon*: *kamai* (rainbow runner, *Elegatis bipinnulatus*), *hoehoe* (mackerel tuna, *Euthynnus affinis*), *te atu* (yellowfin tuna, *Thunnus albacares*), *laueva* (skipjack tuna, *Katsuwonus pelamis*), (*highly variable based on migration patterns) Nighttime at the channels: *matapuku* (bigeye trevally, *Caranx sexfasciatus*), *tahauri* (black jack, *Caranx lugubris*), *tapatuu* (bigeye barracuda, *Sphyraena forsteri*)

Matau va tai	A bottom fishing method performed predominantly by men –aged 18 to late 70s – inside the lagoon on patch reefs in depths of ~ 15–25 m. Men seldom take their wives fishing with them, and this method is not performed by women if they are by themselves. One fisherman may go out on a *mora*, up to three persons will go on wooden canoes, and four or five may go on a small fibreglass boat. A weighted line is dropped next to a patch reef below the fishing vessel. A small lead is used, along with a 20 lb, 30 lb or 40 lb (max) monofilament line and a smaller (2/0 to 3/0) J hook. While some fishers use this method at night, it is mainly a daytime fishing technique.	*te anake*	weekly	lagoon	low tide (occasionally falling tide) all moon phases. When going to the passage, one should go during a new moon (days 5–6: *maa rima* and *maa ono*)	Daytime: *sipopu* (type of wrasse, Labridae), *tausena* (gold-lined snapper, *Lutjanus rufolineatus*), *taea* (humpback snapper, *Lutjanus gibbus*) Nighttime: *taea* (humpback snapper, *Lutjanus gibbus*), *te lona* (spotcheek emperor, *Lethrinus rubrioperculatus*), *saratea* (orange-striped emperor, *Lethrinus obsoletus*)
Saro	A newer fishing technique practiced by younger males (aged early 20s to 50s) during the daytime. It is a type of bottom trolling. Rarely performed in the lagoon, it is primarily done in depths of 30–90 m on a canoe. Alternatively, two men may go on a canoe, or up to five men may go in a fibreglass boat. In preparation for the fishing trip, ~ 50 'stones', pieces of coral rubble (both living and dead), roughly the size of a baseball are collected from the reef crest. A palm frond is also taken along, and the fisherman prepares his lures. These lures are made from cutting the stem off a '*lilly*' plant and peeling the layers. Once the fishing destination is reached, a single leaf from the palm frond is tied around the stone to act as a sinker. A 2/0 to 4/0 J hook with the *lilly* lure is attached to a 70 lb test monofilament line is then placed ~ 5–7 cm below the cut palm frond with the sinker. The line is dropped in the water and, as it hits the bottom, the fisherman thrusts upward in one quick motion to tear the hook and lure from the palm leaf-wrapped sinker. Once detached, the hook and lure are quickly pulled back towards the surface to attract fish swimming by on the fore reef.	both	weekly	starting around 5 m out from the fore reef in ~30–40 m, occasionally extending down to 90 m. On rare occasions performed inside the lagoon	low tide and, if fish are not biting, *tai maariki* new moon (days 30–6: *ku ara* to *maa ono*)	from 5–40 m: *kurakura* (strawberry grouper, *Cephalopholis spiloparae), malauseri* (bluefin trevally, *Caranx melampygus*), *maapilo* (yellow-spotted trevally, *Carangoides orthogrammus*) from 40–90 m: *tahauri* (black jack, *Caranx lugubris*), *kamai* (rainbow runner, *Elegatis bipinnulatus*), *naenae* (double-lined mackerel, *Grammatorcynus bilineatus*)

Kkuu	A deep-sea fishing method introduced from neighbouring Nukumanu Atoll. Seasoned fisherman (males aged at least 20–70) go to catch large pelagic fish. Traditionally, a large sinker was attached to a fishing line and several hooks, separated by wooden spacers, were attached above. The spacers are no longer utilised, and two to four 3/0 to 4/0 J hooks are now attached directly to the 70 lb to 100 lb test monofilament line. While J hooks are the most commonly used hooks, a wide variety of hooks can be used. Very large sinkers, mostly homemade and weighing at least 0.5 lb are produced from cutting iron rods. Alternatively, the lead from old wet cell batteries are removed and melted down over a fire and poured into cylindrical cardboard forms in the ground to harden. Men only go *kkuu* during the day (either early mornings or late afternoons) alone or with a partner on a canoe. No more than two people on one canoe or three people on a fibreglass boat can go because the lines can become tangled, and the valuable sinkers will be lost. This is considered a traditional fishing technique on Takuu that previously involved many rituals, and women are still strictly forbidden from accompanying men on this type of fishing expedition.	both but predominantly *te laki*	monthly to weekly	open ocean	low tide or high tide (least amount of current) all moon phases	*Parumea* (red emperor snaper, *Lutjanus sebae), paru kkehu* (type of deep water snapper, Lutjanidae), *paru natara* (type of deep water snapper, Lutjanidae)
Hakararo	A type of bottom fishing, much like *matau va tai*, but *hakararo* is performed outside of the lagoon on the fore reef. Only fishermen ages ~ 18 to early 70s use this method. A single 30–50 lb test monofilament line with 2/0 to 4/0 J hooks and small lead or iron sinkers are attached and lowered down below a canoe onto the slope of the fore reef. Men who are unsuccessful on a *kkuu* expedition will occasionally move in closer to the atoll to employ this technique. Unlike some other fishing techniques, there is no difference in the species of fish caught during either *te laki* or *te anake*. Marine worms (*te pamu* and *te upo*), octopus and cut bait from *naenae* (double-lined mackerel, *Grammatorcynus bilineatus*) and other reef fish are commonly used as bait.	both	weekly	~5–10m out from the fore reef in water ~30–50 m deep	low tide or falling tide all moon phases	Daytime: *te lona* (spotcheek emperor, *Lethrinus rubrioperculatus*), *taea* (humpback snapper, *Lutjanus gibbus*), *kurakura* (strawberry grouper, *Cephalopholis spiloparae)* Nighttime: *taea* (humpback snapper, *Lutjanus gibbus*), *takape* (bluestripe snapper, *Lutjanus kasmira*), *kainataa* (camouflage grouper, *Epinephelus polyphekadion*), *taamarau* (sabre squirrelfish, *Sargocentron spiniferum)*

Tau muu	A method where a fisherman focuses specifically on catching *te muu* (humpnose bigeye bream, *Monotaxis grandoculis*) on patch reefs inside the lagoon by swinging and throwing a single line about 5 m from the fishing vessel. The fisherman may also go on his *mora* (or up to two fishermen on a canoe) to the fore reef. A 20–50 lb test monofilament line is used with a smaller hook (2/0 up to 3/0) and a very small lead sinker. The fisherman generally dives into the water before fishing begins to look for schools of 20–40 *te muu*, which are mainly found in depths of 7–15 m, near the sandy bottom next to patch reefs. Hermit crabs (*te una*) and marine worms (*te pamu* and *te upo*) are used as bait.	*te anake*	monthly	lagoon (occasionally at the fore reef)	high tide (or *tai maariki)* all moon phases	*tau muu* (humpnose bigeye bream, *Monotaxis grandoculis*), *saratea* (orange-striped emperor, *Lethrinus obsoletus)* (bycatch), *simu taia mmea* (yellowmargin triggerfish, *Pseudobalistes flavimarginatus*) (bycatch)
Tau simu	A fishing method where exclusively men use a large (50lb to 60lb) test monofilament line, 3/0 to 4/0 J hooks and heavy sinkers to target *simu taia mmea* (Yellowmargin tripperfish, *Pseudobalistes flavimarginatus*) and *simu taia uri* (Titan triggerfish, *Balistoides viridescens*) inside of the lagoon. A single line is dropped close to the side of the *Mora* or canoe, and this type of fishing takes a long time as one must "wait" for the *simu taia*. Marine worms are used as bait, but hermit crabs are also occasionally utilised.	*te laki*	rarely	lagoon	high tide or low tide. new moon (days 29–5: *maa itu* to *maa rima)*	*simu taia uri* (titan triggerfish, *Balistoides viridescens)*, *simu taia mmea* (yellowmargin triggerfish, *Pseudobalistes flavimarginatus*)
Takitaki	A fishing method where a (generally older) fisherman uses a large pole called a *tau hakau* – ~ 1.5–2.0 m in length, and 2–3 cm in diameter – made of mangrove or bamboo to fish. The fisherman places the stick upright in the sand on the beach, and then takes the line, baited with marine worms or cut bait, and swims with it to a coral head. There, he drops the line and swims back to shore where he ties the line to the pole and waits close by to see if the pole moves once a fish is hooked. A 20–40 lb test monofilament line and 2/0 to 4/0 J hooks are used. *Takitaki* is thought of as a solitary and casual fishing technique.	both (predominantly *te anake*)	rarely	lagoon	low tide all moon phases	*simu taia uri* (titan triggerfish, *Balistoides viridescens)*, *simu taia mmea* (yellowmargin triggerfish, *Pseudobalistes flavimarginatus*), *hiloa* (yellowlip emperor, *Lethrinus xanthochilus*), *natura* (longface emperor, *Lethrinus olivaceus*)

Pakeo	A fishing technique in which either men, women or children stand in the shallows of the lagoon and cast their single handlines onto the patch reefs in front of the islands. Hermit crabs and cut bait from small reef fish are used along with a 10–20 lb test monofilament line and a small 1/0 to 2/0 J hook attached by a simple fisherman's knot. Two types of *pakeo* are used, *pakeo* and *pakeo va tai*. The latter refers to very shallow bottom fishing performed by older men on canoes with the same single line, small sinker and baited hook.	both but predominantly *te anake*	weekly	lagoon	high tide or low tide all moon phases	*Natara haiahua* (small reef grouper, *Epinephelus* sp.), *sipopu* (small species of wrasse, Labridae),
Siisii urutuki	A fishing method whereby a fisherman takes a bamboo pole that is 3–7 m long and attaches a single 20–30 lb test monofilament line baited with a hermit crab using a 2/0 J hook without a sinker, and stands on the reef crest (during the daytime) and casts the line onto the fore reef. The line is measured to be exactly as long as the pole, and men look for slightly curved poles so that the hooks will attach firmly to the bottom for transport by currents and wave action. Only men between the ages of 20 and 50 practice this type of fishing,	*te laki*	rarely	fore reef	low tide all moon phases	*urutuki* (several species of hawkfishes, Cirrhitidae), *hootua* (onespot snapper, *Lutjanus monostigma*) (bycatch), *natara haiahua* (small reef grouper, *Epinephelus* sp.)(bycatch)
Siisii nanue	The same fishing equipment and technique is used for *siisii nanue* as for *siisii urutuki*, but rather than standing on the fore reef this fishing is performed only at nighttime and at the points of the island towards the lagoon. For bait, either coconut flesh or small balls made from flour and water are used.	both	rarely	lagoon	high tide all moon phases	*Nanue* (topsail drummer, *Kyphosus cinerascens*), *paaua* (white-spotted rabbitfish, *Siganus canaliculatus*), *panoo* (golden rabbitfish, *Siganus guttatus*)
Siisii tanau	*Siisii tanau* is performed mainly by adolescent male and females. The fisher woman stands on the back of the island on rock formations and casts a small baited line, which is attached to a spool made of carved wood or a buoy, into the channels. This technique is used specifically to target juvenile *hootua* called *tanau* (onespot snapper, *Lutjanus monostigma*). A 10–20 lb test monofilament line is used with a hermit crab or silverside baited with a small (2/0) hook. No sinker is used.	both	monthly	lagoon	high tide all moon phases	*tanau* (onespot snapper, *Lutjanus monostigma*), *tapurei* (black-banded snapper, *Lutjanus semicinctus*), *mataahiloa* (several species of juvenile emperors, Lethrinidae)

Matau mataahiloa	A popular fishing method used by both women and children. It is performed daily to catch small reef fish for household meals and for adolescents to feed their pet birds. Women and children wade into the lagoon at low tide (to their waist) and swing the line towards a small coral heard or into the seagrass. A dish that accompanies them is either anchored with a small stone next to the fisher, tethered to the fisher, or left on the beach close by. It contains the hermit crabs that are used as bait as well as the small fish that are caught. No sinkers are attached to a small monofilament line, and the fisher uses the smallest hook available. While the fishing method is named for juvenile *hiloa* (yellowlip emperorfish, *Lethrinus xanthochilus*), a wide variety of juvenile reef fish are targeted and caught.	both	daily	lagoon	low tide all moon phases	*mataahiloa* (several species of juvenile emperors, Lethrinidae), *saaripo* (blacktail snapper, *Lutjanus fulvus*), *sipopu* (type of wrasse, Labridae) *simu* (several species of juvenile triggerfish, Balistidae)
Matau paaua	While identical in technique and equipment as *matauu mataahiloa*, with this method fishers cast their lines into seagrass meadows instead of patch reefs. Women and children often stand on *te pae* (sea wall) and cast their lines from there. This technique targets *paaua* (white-spotted rabbitfish, *Siganus canaliculatus*) and other small rabbitfish that live in seagrass.	both	daily	lagoon	low tide all moon phases	*Paaua* (white-spotted rabbitfish, *Siganus canaliculatus*), *mataahiloa* (several species of juvenile emperors, Lethrinidae)

Tuutuupaa	Rarely used, this method can be used both during the day and at night. Only men aged 20–60 partake in this method. They walk to the back of Nukutoa, and occasionally Takuu, and stand on the reef crest to cast their lines onto the fore reef. Usually performed by a single fisherman, a group of up to three fishermen will each cast a sturdy (50–70 lb test) monofilament line with a single large hook (4/0) and heavy sinker attached, with the fisher standing ~ 10 meters out from the reef crest on the slope. The line is attached to a spool as this technique targets larger reef fish. Men unroll their lines from the spool beforehand and cast out with a lasso-like motion. Some fishermen dive down and jam the line and hook between coral heads, as there is usually a strong current. A firm cut bait is usually used to ensure that it remains on the hook in the swift current. Once a fish is hooked, the fisher will feel the line momentarily go slack, followed by a strong pull. The fisherman must then act quickly since fish will attempt to hide in the crevices in the reef. Rather than standing still and swiftly collecting the line by hand, the fisher holds the line tightly and runs away inland, away from the forereef. This motion pulls the fish out of the water and onto a dry area of the reef crest where the fisher can retrieve it.	*te laki*	rarely	open ocean (fore reef)	low tide all moon phases. Best at new moon (days 29–4: *maa itu* to *maa haa*)	Daytime: *hiloa* (yellowlip emperor, *Lethrinus xanthochilus*), *natura* (longface emperor, *Lethrinus olivaceus*), *sanapiki* (blubberlip snapper, *Lutjanus rivulatus*) Nighttime: *manoo tea* (blacktip reef shark, *Carcharhinus melanopterus*), *hanamea* (red snapper, *Lutjanus bohar*), *sanapiki* (blubberlip snapper, *Lutjanus rivulatus*), *natura* (longface emperor, *Lethrinus olivaceus*), *hiloa* (yellowlip emperor, *Lethrinus xanthochilus*)