2009
ANNUAL REPORT

PACIFIC BLUE FOUNDATION
Sustaining Reef Communities

THE PACIFIC BLUE FOUNDATION (PBF) provides basic research, education, encouragement, and implementation of sustainable practices in coastal regions with the ultimate goal of preserving and promoting the biological and cultural diversity of the region.

2009

Annual Report

The Value of

CORAL REEF CONSERVATION

Coastal communities rely heavily on their fisheries; ecosystems so fragile that minor changes can lead to dramatic impacts and lasting repercussions. Human activity from nearby villages and communities greatly affect coral reefs, resulting in the declining health of the reef and its dependent marine organisms.

Just as coastal inhabitants rely on coral reefs, the preservation of coral reefs greatly depends on their neighboring communities. Tradition and culture have helped uphold a respect for the ocean and its resources, but modern, industrial lifestyles have shaken this relationship.

Recognizing that culture and tradition are imperative to sustaining coastal fisheries and communities, the Pacific Blue Foundation focuses not only on environmental protection, but also on cultural preservation, both of which can be fostered through education.

Pacific Blue Foundation realizes that coral reef conservation cannot be done alone and looks to local villages for their support and involvement. Thanks to the cooperation of locals on Yanuca Island, a Marine Protected Area has been created. In 2009, Pacific Blue Foundation worked with villagers to create reef management strategies that would continue to guard the reefs and their fish.

In addition to incorporating reef management into village life, Pacific Blue Foundation has funded coral reef research in Panama, Australia, and Fiji. By learning more about the impacts of anthropogenic effects on the reef, including global warming, researchers have been able to better determine the future of the reef's health and the necessary steps to improve the state of the coral reef.

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Wildlife Conservation Society
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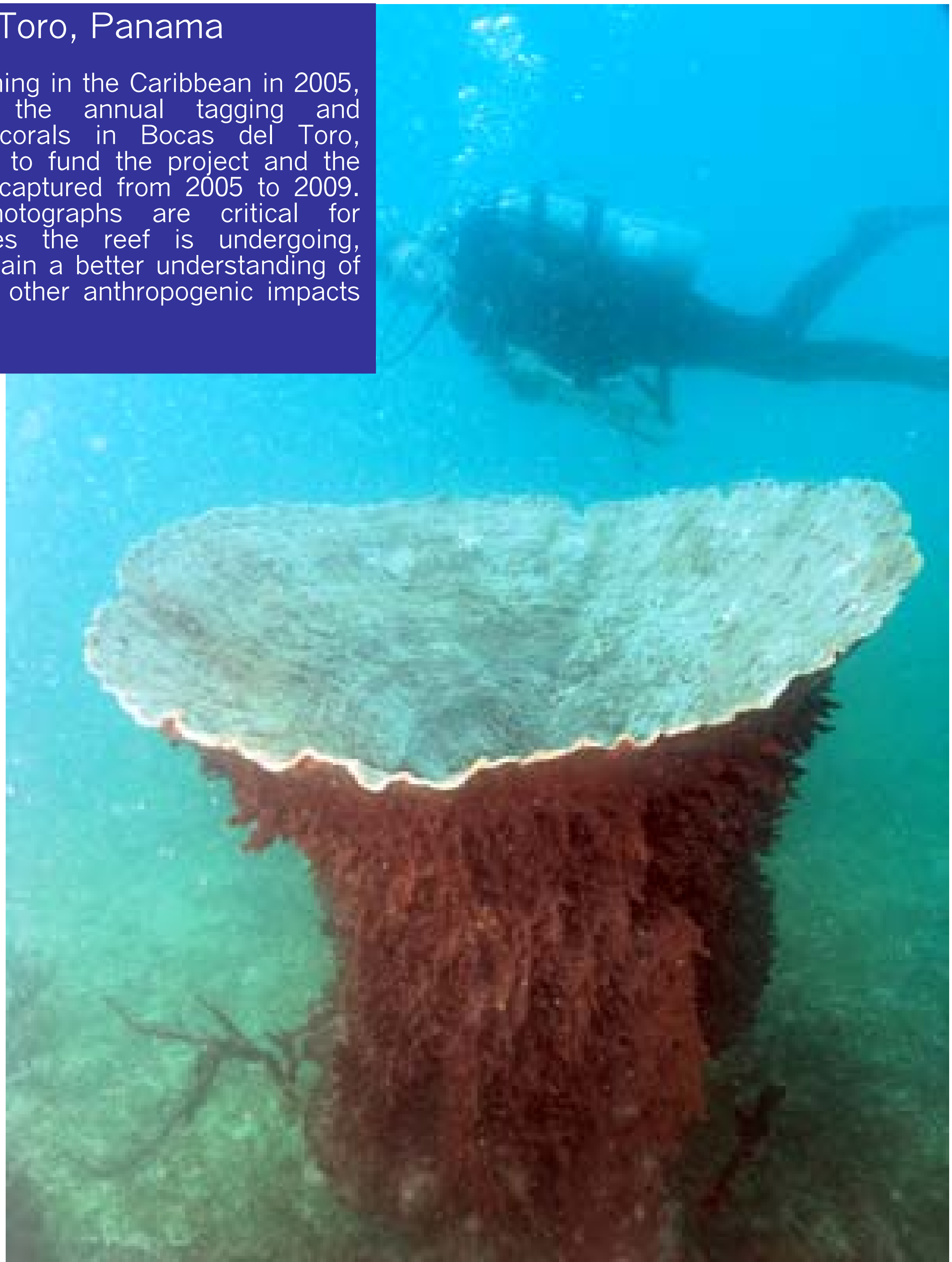
SeaAid
Austin Bowden-Kerby
Corals for Conservation

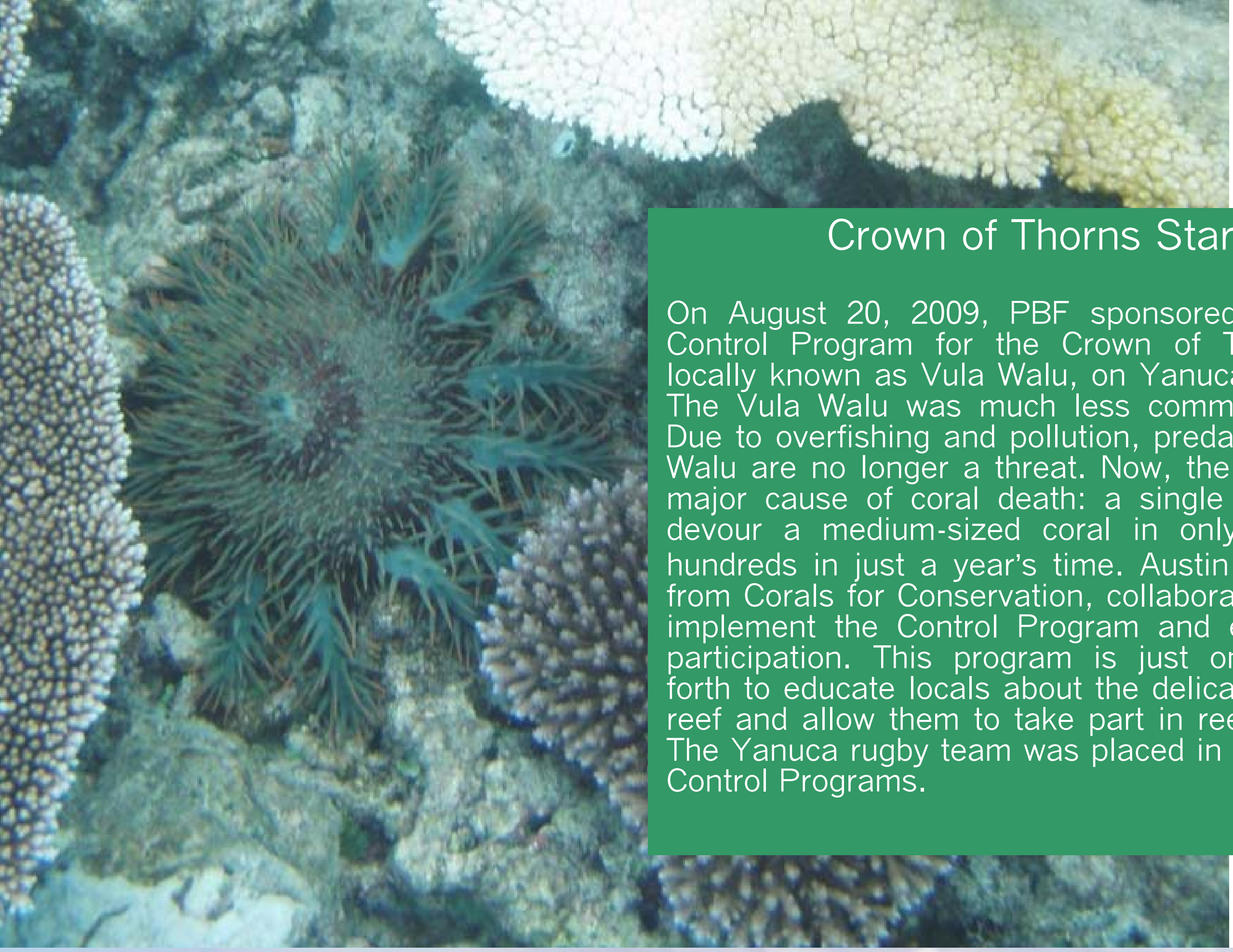
Highlights

This year, PBF continued to fund research, support programs, and implement solutions that would strengthen education, preserve culture, and conserve coastal ecology.

Bocas del Toro, Panama

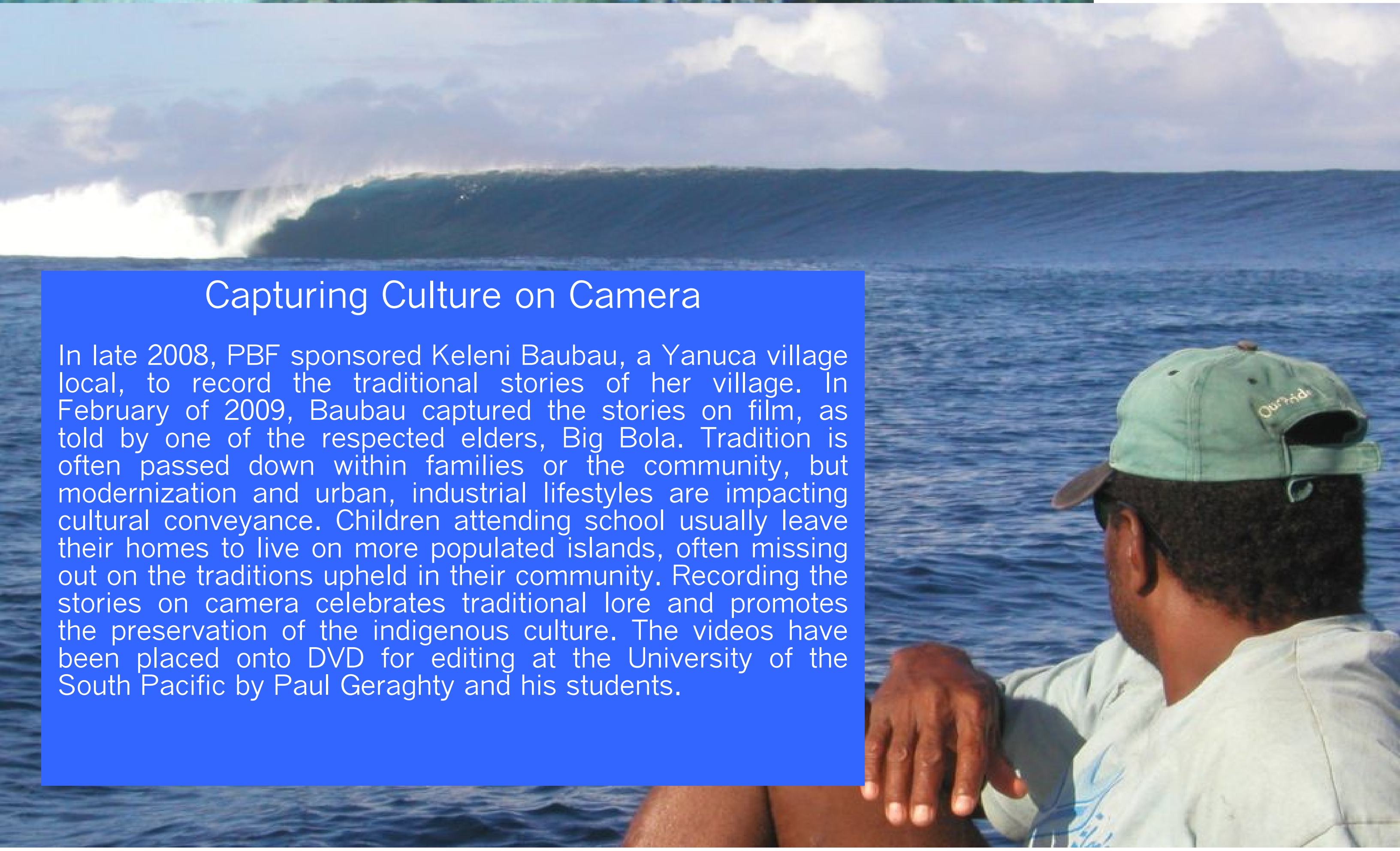
After a mass coral bleaching in the Caribbean in 2005, PBF began to fund the annual tagging and photographing of 500 corals in Bocas del Toro, Panama. PBF continued to fund the project and the analyses of the images captured from 2005 to 2009. These time series photographs are critical for determining the changes the reef is undergoing, allowing researchers to gain a better understanding of how climate change and other anthropogenic impacts affect the coral reef.





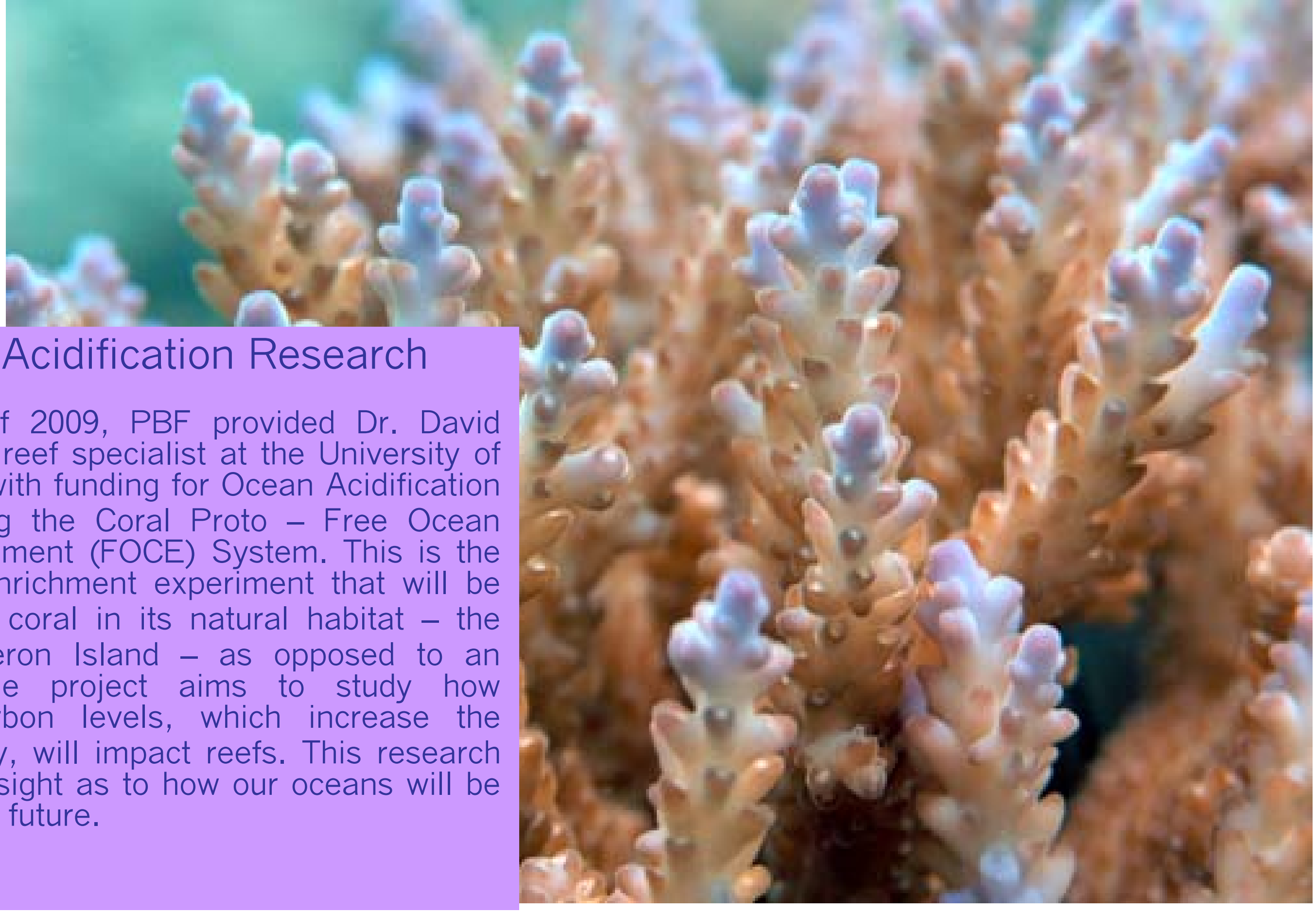
Crown of Thorns Starfish

On August 20, 2009, PBF sponsored an infestation Control Program for the Crown of Thorns Starfish, locally known as Vula Walu, on Yanuca Island, Serua. The Vula Walu was much less common in the past. Due to overfishing and pollution, predators of the Vula Walu are no longer a threat. Now, the Vula Walu is a major cause of coral death: a single Vula Walu can devour a medium-sized coral in only a day, killing hundreds in just a year's time. Austin Bowden-Kerby, from Corals for Conservation, collaborated with PBF to implement the Control Program and encourage local participation. This program is just one strategy put forth to educate locals about the delicate nature of the reef and allow them to take part in reef management. The Yanuca rugby team was placed in charge of future Control Programs.



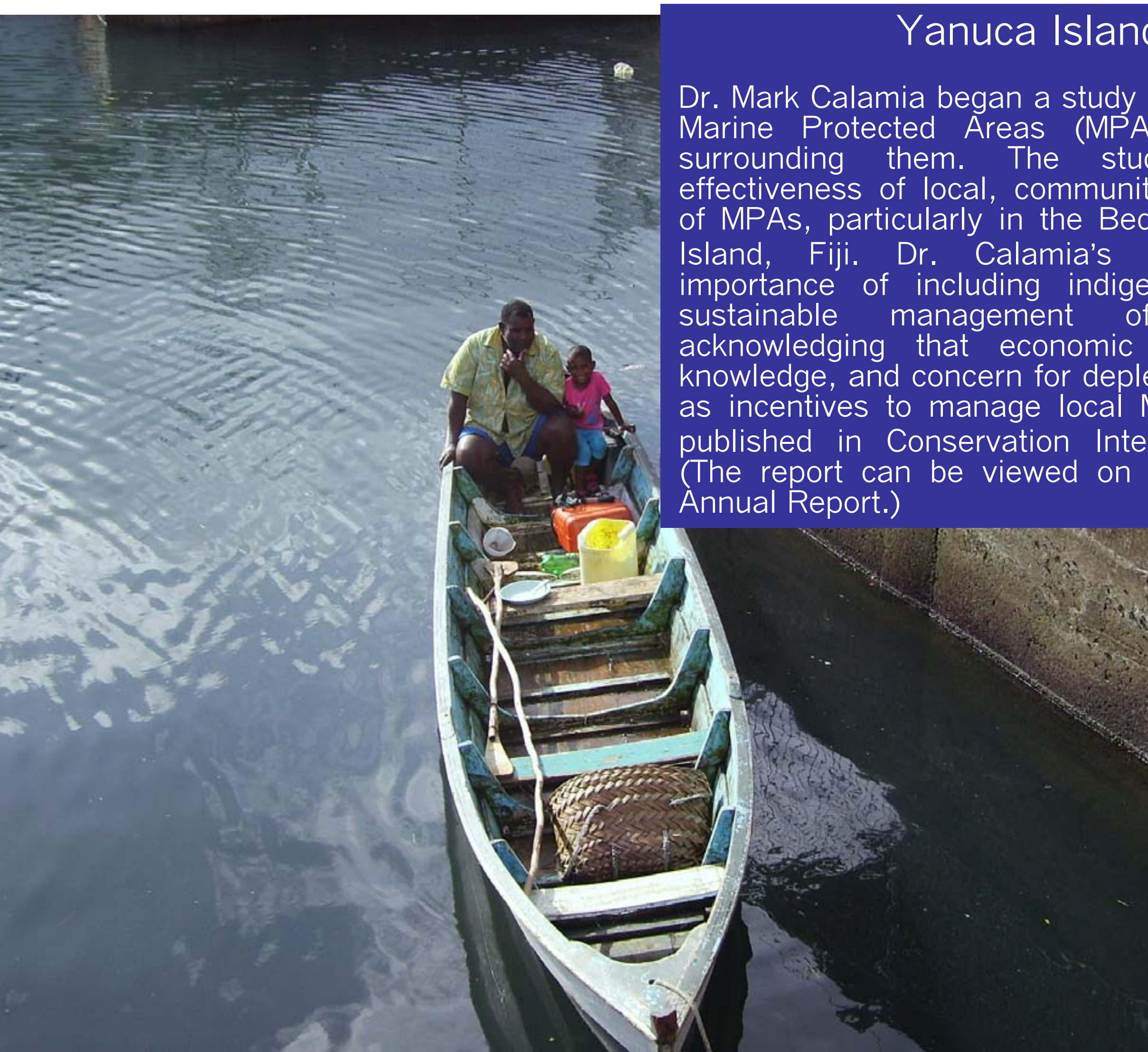
Capturing Culture on Camera

In late 2008, PBF sponsored Keleni Baubau, a Yanuca village local, to record the traditional stories of her village. In February of 2009, Baubau captured the stories on film, as told by one of the respected elders, Big Bola. Tradition is often passed down within families or the community, but modernization and urban, industrial lifestyles are impacting cultural conveyance. Children attending school usually leave their homes to live on more populated islands, often missing out on the traditions upheld in their community. Recording the stories on camera celebrates traditional lore and promotes the preservation of the indigenous culture. The videos have been placed onto DVD for editing at the University of the South Pacific by Paul Geraghty and his students.



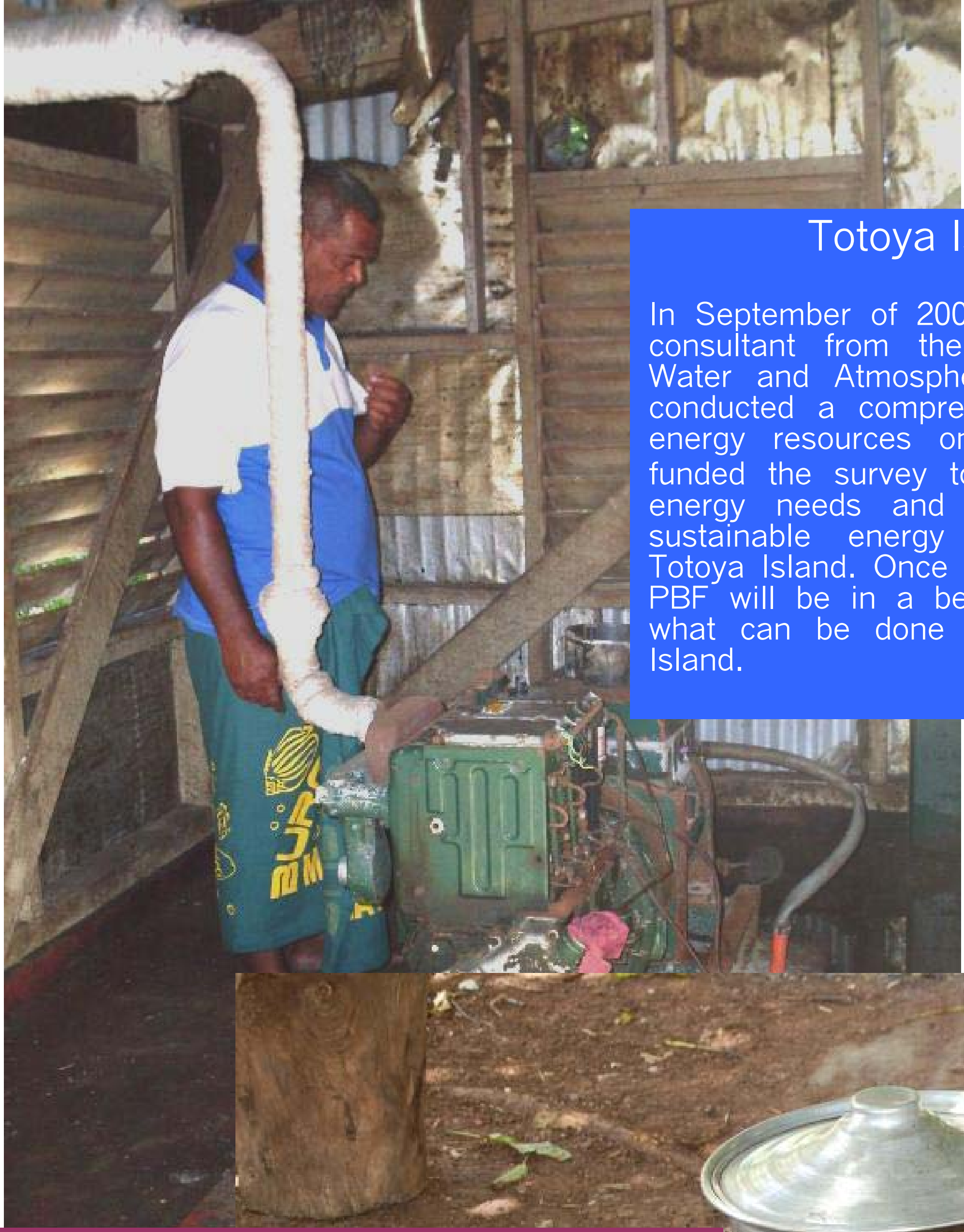
Ocean Acidification Research

At the end of 2009, PBF provided Dr. David Kline, a coral reef specialist at the University of Queensland, with funding for Ocean Acidification research using the Coral Proto – Free Ocean Carbon Enrichment (FOCE) System. This is the first carbon enrichment experiment that will be conducted on coral in its natural habitat – the ocean, off Heron Island – as opposed to an aquarium. The project aims to study how increased carbon levels, which increase the ocean's acidity, will impact reefs. This research will provide insight as to how our oceans will be affected in the future.



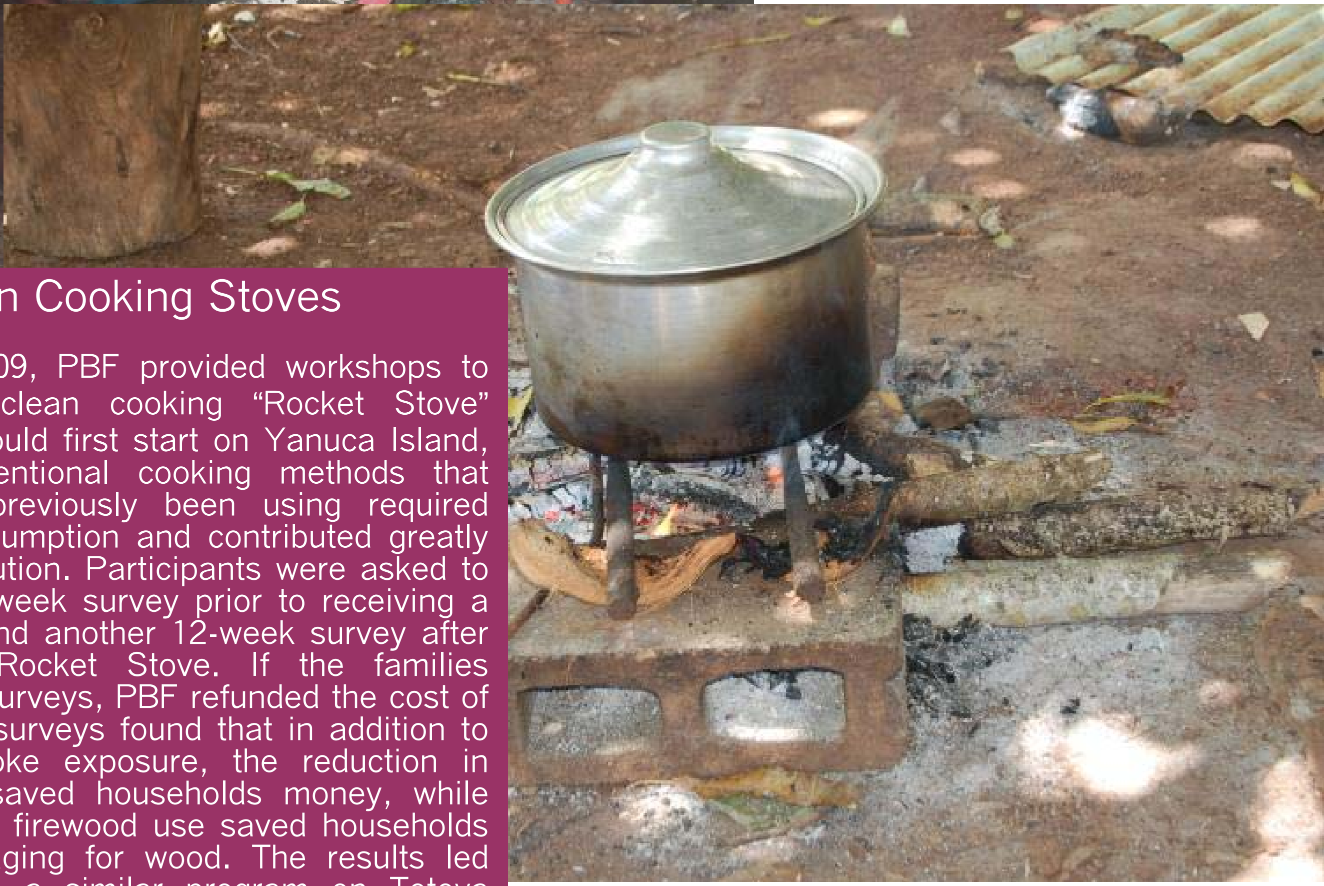
Yanuca Island, Fiji

Dr. Mark Calamia began a study in 2009 that examined Marine Protected Areas (MPAs) and the villages surrounding them. The study looked at the effectiveness of local, community-based management of MPAs, particularly in the Beqa Lagoon off Yanuca Island, Fiji. Dr. Calamia's research notes the importance of including indigenous people in the sustainable management of their resources, acknowledging that economic interests, traditional knowledge, and concern for depleted fisheries all serve as incentives to manage local MPAs. The study was published in Conservation International's magazine. (The report can be viewed on page 12 of the 2009 Annual Report.)



Totoya Island, Fiji

In September of 2009, Dr. Andy Hamm, a consultant from the National Institute of Water and Atmospheric (NIWA) Research, conducted a comprehensive survey of the energy resources on Totoya Island. PBF funded the survey to quantify the island's energy needs and determine alternative, sustainable energy options suitable for Totoya Island. Once the report is produced, PBF will be in a better position to decide what can be done next to assist Totoya Island.



Clean Cooking Stoves

In February 2009, PBF provided workshops to introduce the clean cooking "Rocket Stove" program that would first start on Yanuca Island, Fiji. The conventional cooking methods that villagers had previously been using required larger fuel consumption and contributed greatly to local air pollution. Participants were asked to complete a 12-week survey prior to receiving a Rocket Stove and another 12-week survey after receiving the Rocket Stove. If the families completed the surveys, PBF refunded the cost of the stove. The surveys found that in addition to minimizing smoke exposure, the reduction in kerosene use saved households money, while the reduction in firewood use saved households time spent foraging for wood. The results led PBF to provide a similar program on Totoya Island, Fiji.

Projects, Research & Funding

Australia

Heron Island

Funding for Ocean Acidification Research with CP-FOCE system

- Dr. David Kline with the University of Queensland with Pacific Blue Foundation Sponsorship

Panama

Bocas del Toro

Funding for Time Series Photographs & Coral Reef Analysis

- Dr. David Kline with Pacific Blue Foundation Sponsorship

Fiji

Suva Island

Funding for Carpentry Course for Villager, Jim Makoto, with Training & Productivity Authority of Fiji (TPAF)

- Pacific Blue Foundation Sponsorship

Totoya Island

Energy Resource Survey

- Dr. Andy Hamm from the National Institute of Water and Atmospheric Research with Pacific Blue Foundation Sponsorship

Grants Received to Create Suitable Housing for Disabled Totoya Child

- Fijian Department of Social Welfare with Pacific Blue Foundation Sponsorship

Funding for Travel Expenses of Family & Press to Attend Installation of High Chief

- Pacific Blue Foundation Sponsorship

Yanuca Island

Recording of Traditional Stories

- Keleni Baubau with Pacific Blue Foundation Sponsorship

Control Program for Crown of Thorns Starfish

- Dr. Austin Bowden-Kerby from Corals for Conservation with Pacific Blue Foundation Sponsorship

Education Funding for Five Tertiary Students

- Pacific Blue Foundation Sponsorship

Training Workshop for Accounting and Revenue Building

- Pacific Blue Foundation Sponsorship

Funding for Basic Accounting Courses for Village Leaders

- Pacific Blue Foundation Sponsorship

Clean Rocket Stove Program and Fuel Surveys

- Bret Diamond from SeaAid, Dr. Hamm from National Institute of Water and Atmospheric Research, & Pacific Blue Foundation

Publications And Scientific Literature

Marine-Based Community Conserved Areas in Fiji:
An Example of Indigenous Governance and Partnership

Mark A. Calamia
David I. Kline
Sireli Kago
Kerry Donovan
Sirilo Dulunaqio
Taito Tabaleka
B. Greg Mitchell

Quick Facts

Country: Fiji

Geographic Focus: Yanuca Island, south central portion of the Fijian Archipelago

Indigenous Peoples: Yanuca clan.
Population 241

Author Information

Mark A. Calamia is owner and principal investigator of a small consulting firm Ethnographic Inquiry. He is a cultural anthropozoologist with a specialty in ecological anthropology. E-mail: markcalamia@hotmail.com

David I. Kline earned his PhD from the Scripps Institution of Oceanography. He is an expert on coral reef ecology with a special emphasis on climate change and factors that lead to disease and mortality.

Sireli Kago is a member of the *Mataqali Nukutabua* of *Yavusa Nukutabua*, Yanuca Island, Fiji. He has the title of turaga ni koro, a position that serves as coordinator for the Village Council.

Kerry Donovan is the Pacific Blue Foundation Coordinator for Fiji. He has extensive experience in financial planning, boat operations, commercial fishing, and construction.

Sirilo (Didi) Dulunaqio is an employee of the Wildlife Conservation Society, Suva, Fiji. He focuses on underwater surveys of coral community ecology.

Taito Tabaleka earned a *Master's* degree in *Management* from Southern Cross University, Australia. He is a member of *Mataqali Batiluva* of *Yavusa Nukutabua*, Yanuca Island, Fiji.

B. Greg Mitchell is the Director of the Pacific Blue Foundation and a PhD Research Biologist and Senior Lecturer at the Scripps Institution of Oceanography in La Jolla, California, USA. He is an expert in algal photosynthesis, satellite remote sensing, aquatic optics and modeling. E-mail: mitchell@spg.ucsd.edu.

Introduction

In the last decade, the Southwest Pacific island nation of Fiji (Fig. 1) has been the focus of considerable attention from international conservation NGOs and consultants as they have assisted indigenous Fijians in establishing Marine-based Community Conserved Areas (MBCCAs) in areas of local customary fishing rights. Over-harvesting together with pollution, soil erosion, and land run-off has led to a crisis in Fijian fisheries. Overfishing tends to be prevalent in both deep water and near-shore fisheries (The Austral Foundation 2007). The Manado Ocean Declaration of the World Ocean Conference, in Manado Indonesia, 11–14 May 2009, included among its 21 points the need to:

> Further establish and effectively manage marine protected areas, including representative resilient networks, in accordance with international law as reflected in UNCLOS [United Nations Convention on the Law of the Sea] and on the basis of the best available science, recognizing the importance of their contribution to ecosystem goods and services, and to contribute to the effort to conserve biodiversity, sustainable livelihoods and to adapt to climate change. (World Ocean Conference 2009, Point 15).

The MBCCAs have been established primarily to ensure sustainable management of local coral reef ecosystems that provide habitats for tropical fish and marine invertebrates, many of which are essential protein and economic resources for local residents.

The Fiji Islands have exceptional marine biological diversity (South and Skelton 2000) and cultural diversity (Derrick 1974; Ravuvu 1983). They are located in a region of strong gradients in coral diversity; and many of the coral species are at the easternmost extent of their natural range. The precise number of species in Fiji for most marine organisms is not known. Many regions have not been extensively surveyed, especially the more remote islands. Fenner (2006) estimated that the number of coral species might be as high as 500. Zann (1992) recorded 298 species of scleractinian corals, while Lovell and McLardy (2008) reported 72 genera and 342 species, along with five genera and 12 species of non-scleractinian corals, for a total of 354 species of corals. The diversity of other organisms in Fiji has been reported to include five species of gorgonians (Muzik and Wainwright 1977), 15 zoanthids (polyps and sea mats) (Muirhead and Ryland 1981), and 1,900 fishes of 162 families (Vuki *et al.* 2000). The dominant corals (hard and soft), food fish, and regularly harvested reef invertebrates of the Beqa Lagoon region of this case study are listed in Table 1.

Lovell and Sykes (as reported in Kaur and Swarup 2006) found that from 1999 to 2004 live hard coral coverage on Fijian reefs averaged 22–24%. Pollution, elevated nutrient concentrations, outbreaks of the crown-of-thorns starfish, and mass bleaching events have caused significant damage to Fijian coral reefs (Vuki *et al.* 2000). A mass coral bleaching event in 2000 affected 80% of the coral species in the Beqa lagoon (Vuki *et al.* 2000), the region of focus in this report. Fiji's reefs are recovering from the 2000 bleaching event, as well as a less serious event in 2002 that together caused the loss of 40%–80% of the hard coral cover in Fiji (Lovell and Sykes 2004). Surveys from 2004 indicate, however, that over half of the reefs surveyed are within 10% of the pre-bleaching levels of coral cover (Lovell and Sykes 2004).

Shell collection for sale to tourists has resulted in a decline of the giant triton shell, *Charonia tritonis*, the main natural predator of the crown-of-thorns starfish (Vuki *et al.* 2000). Two species of giant clams have also been extirpated in Fiji; *Tridacna gigas*, last seen 50 years ago, and *Hippopus hippopus*, which could only be found as dead shells or fossils, but has recently been reintroduced for the aquaculture trade (Lewis *et al.* 1988; Vuki *et al.* 2000).

In this case study, we address the development of indigenous governance for effective and equitable management of a Marine-based Community Conserved Area (MBCCA). In particular, we explore the establishment of a MBCCA in the customary fishing rights area (*qoliqoli*, pronounced 'ngolee-ngolee') surrounding Yanuca (pronounced Yanutha) Island, which belongs to the people of Yanuca village. The island is situated in the south central portion of the Fijian Archipelago, in the 352-km² Beqa Lagoon (Figs. 1 and 2). The large MBCCA west of Yanuca Island is in a region known for considerable marine biodiversity, some of which is threatened from overfishing (Mitchell *et al.* 2006; PCDF 2007b). This protected area was made possible through a partnership between Yanuca village and the Pacific Blue Foundation (PBF) — a small development and conservation NGO based in La Jolla, California, USA. The nexus between traditional knowledge, culture, resource management, external capital and conservation (cultural and ecological) is the focus of the PBF, as represented in this case study, and influenced by contemporary Fijian researchers such as Joeli Veitayaki who wrote: "Indigenous knowledge, wisdom, and experience are valuable, appropriate, and still

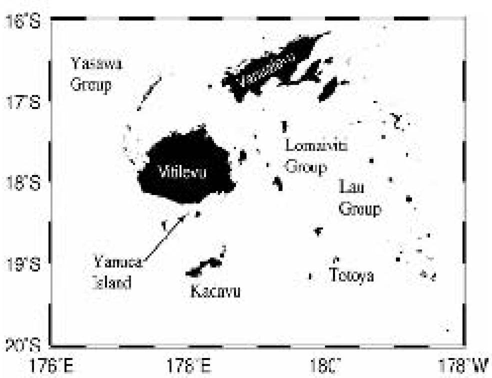


Figure 1. The Fiji Islands. This project focuses on promoting community conservation and ecological management with the Yanuca Island village, 10 km south of Vitilevu (black arrow) in the Beqa lagoon. Base map courtesy of Google Images.

Table 1. Common scleractinian (hard) and octocoral (soft) corals, food fishes, and commonly harvested reef invertebrates of Yanuca.

Scientific Name	Common Name	Fijian Name	Other Fijian Names
Scleractinian (hard) corals			
Acropora tenuis	Staghorn coral	Lase tagane	
Acropora valenciennesi	Staghorn coral	Lase tagane	
Acropora nasuta			
Montipora digitata	Velvet finger coral		
Stylophora pistillata	Club finger coral		
Pocillopora meandrina	Cauliflower coral		
Diploastrea heliopora	Moon coral		
Porites lobata	Lobe coral	Vatubuso, Puga or Ravuga	
Octocoral (soft) corals			
Sinularia	Finger coral		
Sarcophyton	Toadstool Leather coral		
Lobophytum	Lobed Leather coral		
Melithaea	Gorgonian fan	Baka	
Dendronephthya	Carnation Tree coral		
Litophyton	Tree coral or Colt coral		
Nephthea	Broccoli or Cauliflower coral		
Fishes			
Epinephelus merra	Honeycomb rock cod	Kawakawa	Senikawakawa,
Epinephelus caeruleopunctatus	White spotted grouper	Kawakawa-ni-tiri	
Epinephelus spp.	Camouflage grouper	Kawakawa	Kerakera,
Polyphekadion spp.			Kasala
Plectropopmus spp.	Big spot coral trout	Donu	Lava
Plectrochinus chaetodonoides	Many spotted sweetlips	Sevaseva	Drekeni
Lethrinus harak	Thumbprint emperor	Kabatia	Kabatiko
Scaridae spp.	Bi-color parrotfish	Ulavi	Ulavidraniqai, Dogosasa
Chlorurus sordidus	Daisy parrotfish	Bose	
Chelinus spp.	Wrasse	Karakarawa	
Reef invertebrates			
Trochus niloticus	Trochus shell	Vivili	Sici, Leru
Microthele nobilis	Sea cucumber, Black teat fish	Loaloa	Lolo
Bohabschia marmorata	Sea cucumber, Brown sandfish	Vula	
Charonia tritonis	Tritons trumpet	Davui	Tavui
Holothuria atra	Black sea cucumber,Lollyfish	Loli	Loliloli
Lambis lambis	Spider shell	Ega	Yaga

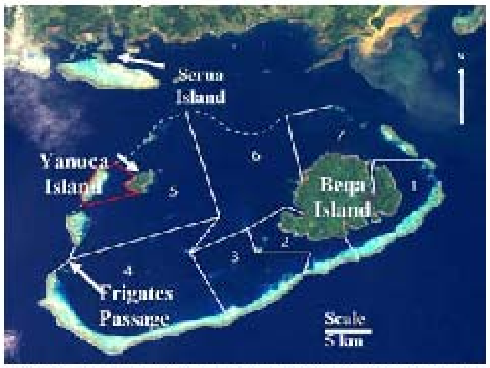


Figure 2. High resolution (30 m) "true color" image of Beqa Lagoon observed 4 February 2001, using the NASA Landsat 7 Enhanced Thematic Mapper. The Fiji Government, with input from local villages, has established geographic borders for *qoliqoli* (customary fishing regions) for all Fijian communities. The *qoliqoli* boundaries for the Yanuca Island and Beqa Island communities are shown by white borders, and were obtained from the Fijian Government. Area 5 is owned solely by Yanuca, while Area 4 is shared with two *yavusas* on Beqa Island. The area bound in red within area 5 is the Kauvili MBCCA, created through the process reported in this case study. Image courtesy NASA and USGS.

relevant for people in developing countries like Fiji. It must be incorporated into sustainable development planning, contemporary development strategies, and resource management." (Veitayaki 2002, p.401). Lovell *et al.* (2004) classified the Beqa lagoon (Fig. 2) as having a medium overall threat to its reefs, a high threat level from overfishing, a medium threat from coastal development, and a low threat from pollution, sediment damage, and destructive fishing. The economic value of Fijian coral reefs has been estimated at between F$200,000 to F$1 million per km² per year (Kaur and Swarup 2006). There is great merit in pursuing a well-structured management of the coral ecosystems in Fiji for the conservation of their biological diversity, for their cultural links to the marine ecosystem, as well as for their sustainable economic use.

Since 2006, the Pacific Blue Foundation has supported Ethnographic Inquiry (EI) consultants in a multi-year process with the Yanuca Community. The EI consultant had prior experience in sociocultural and ecological studies on Kadavu Island, Fiji, and recommended collaboration with Partners in Community Development Fiji (PCDF). PCDF is a Fijian-based affiliate of the Foundation of the Peoples of the South Pacific International (FSPI), and its focus on community awareness, sustainable management of marine resources, small-business development, and good governance are key areas of mutual agreement among PBF, EI, PCDF and the Yanuca Island Community. Facilitating dialogue with the Yanuca community regarding the establishment of a MBCCA involved both traditional and non-traditional aspects of ecological and cultural information in decision-making and implementation processes. As part of the discussion about indigenous MBCCA governance, we employed management concepts and policy guidance established by the Convention on Biological Diversity (CBD) and the First International Marine Protected Areas Congress in 2005 (Day *et al.* 2007). The successful collaboration between PBF, EI, PCDF and the Yanuca Community resulted in the establishment of MBCCAs, along with a governance framework for their long-term management.

Convention on Biological Diversity Resource Governance and Management Categories

After the 5th IUCN World Parks Congress (Durban, South Africa, September 2003), policy guidelines for protected areas worldwide were drafted by the Program of Work on Protected Areas, and subsequently endorsed by the 7th Conference of the Parties (COP 7, Kuala Lumpur, Malaysia 2004) of the Convention of Biological Diversity (CBD) and the First International Marine Protected Areas Congress (Day *et al.* 2005). These guidelines have been broadly adopted by organizations such as the Locally Managed Marine Network (LMMA; <http://www.lmmanetwork.org/>), which has a country network in Fiji (Govan 2009). These organizations, and their guidelines, have had an influence on our implementation strategies and efforts, as outlined in this case study.

In many indigenous conservation efforts, governance needs to take into account power struggles, social relationships, responsibility to local groups (including familial lineages), and accountability to socio-cultural institutions (Borrini-Feyerabend 2008). When authority is centralized, communication ineffective, and the globalization of natural resource markets infringes on traditional local management, decisions can be influenced by external capital, which may be counter-productive for the local communities. Good community-based governance and decision-making is essential to minimize the tendency of external capital (focused on resource extraction or tourist development, for example) to distort local decisions in a way that may result in ecological economics which are unsustainable and unfavorable to the local communities that depend on healthy ecosystems. The CBD Program of Work (PoW target 4.1) encourages parties to develop and adopt standards, criteria, and best practices for managing and governing regional, national, and local protected areas. Ultimately, goals can only be achieved by integrating locally-managed projects to balance conservation, traditional culture and resource use in a sustainable and equitable way. Management addresses what is carried out in a particular protected area, while governance addresses who makes the decisions and who defines the processes. For protected area governance, it is essential to understand who is responsible for making which decisions. Authority depends on institutions, formal mandates, and legal and customary rights. Decisions are also influenced by access to information, economic sustainability, history, culture, and other relevant factors (Borrini-Feyerabend 2008).

Four types of governance over natural resources have been distinguished by the CBD PoW. They are based on who holds management authority and responsibility and who is held accountable according to *de jur, de facto*, and customary rights (CBD 2004). They are as follows: 1) Government Managed Protected government/social Areas (government agencies, at various levels, make and enforce decisions); 2) Co-managed Protected Areas (different government/social groups collectively make and enforce decisions); 3) Private Protected Areas (private landowners make and enforce decisions); and 4) Community Conserved Areas (indigenous peoples or local communities make or enforce decisions). Each of these governance types has two or three sub-types that pertain to particular management structures. These categories were later revised and incorporated into the International Union for Conservation of Nature (IUCN)'s *Guidelines for Applying Protected Area Management Categories* (Dudley 2008).

Ultimately, goals can only be achieved by integrating locally-managed projects to balance conservation, traditional culture and resource use in a sustainable and equitable way.

Community Conserved Areas (CCAs) are natural and/or modified ecosystems that are voluntarily conserved by indigenous communities through customary laws or other means. Decision-making authority is largely with the community, but state authorities retain significant influence through specific conditions, for example, approval of management plans, policies, laws, administrative frameworks, and financial support (Borrini-Feyerabend 2008; Pathak *et al.* 2004). In the last decade or so the South Pacific has witnessed considerable progress in the application of community-based coastal resource management. A combination of traditional knowledge and resource ownership together with a local awareness of the need for immediate action are often the commencement points for these community driven initiatives. The majority of documented CCAs in the region have been (re)established only recently (Govan *et al.* 2009). The Yanuca Island marine reserve initiative is considered a CCA based on the definition cited above and, in principle, there is broad acceptance in Fiji of the customary fishing right's areas being controlled locally by the indigenous owners.

As they exist today, both land ownership and customary fishing rights reflect the social and traditional organizations of the Fijian people and the legislative structures that were developed by the former British colonial government to protect the tenure rights of the indigenous Fijians. Traditional communal ownership of lands rests with the lineages or *mataqali* (Ravuvu 1983). In Fiji, as in many other island countries throughout the South Pacific, coastal waters or near-shore resources are shared under dual ownership. Thus, the state has rights to the land beneath the sea and the Fijian tribes or clan units exercise their rights to fish these areas by virtue of the waters being the customary fishing grounds for subsistence. State ownership of marine resources includes all coastland and inherent resources below the high water mark to the outer reef system as well as archipelagic waters and beds, and the inherent resources underneath up to the 200-mile economic zone boundary (Native Lands and Fisheries Commission [NLFC] pers. comm. 1999). The customary rights of Fijian clan (*yavusa*) units are restricted to recognized fishing grounds, typically from the low water mark and including the fringing reefs on the coastal waters and around isolated islands, up to the barrier reefs. As the law stands now, Fijians have statutory and traditional rights to fish in but not own their fishing grounds; the latter has been reserved for the state (see, however, Williams [2006] for review of the draft *Qoliqoli* Bill tabled in 2006).

The IUCN have also identified Indigenous and Community Conserved Areas (ICCAs) as special areas for conservation because of their stewardship by indigenous peoples. The IUCN definition of ICCAs is as follows:

> ICCAs are natural and/or modified ecosystems containing significant biodiversity values, ecological services and cultural values, voluntarily conserved by indigenous peoples and local communities, both sedentary and mobile, through customary laws or other effective means. ICCAs can include ecosystems with minimum to substantial human influence as well as cases of continuation, revival or modification of traditional practices or new initiatives taken up by communities in the face of new threats or opportunities. Several of them are inviolate zones ranging from very small to large stretches of land and waterscapes. (See <http://www.iccaforum.org>).

The Yanuca MBCCAs also qualify as ICCAs because the communities relate culturally to the ecosystem and species, as seen in many other CCAs throughout the world (cf. Pathak *et al.* 2004). The community management decisions and efforts are now beginning to lead to the conservation of habitats, species, ecological services, and associated cultural values, although the conscious objectives of management are focused more on livelihoods. The community dominates in decision-making and implementation regarding the management of the sites, implying that the Yanuca institutions have the capacity to enforce regulations with the assistance of other stakeholders in partnership.

Indigenous influence over the Yanuca MBCCA is substantial, with new initiatives being taken up by local residents who perceive threats to their coral reefs and fisheries. In the case of Yanuca, the PBF serves as a significant facilitating partner, but primary decision-making resides with the Yanuca community itself.

Overview: Environmental and Village Setting[2]

Yanuca Island is approximately 2 km^2 and is just south of the main island of Viti Levu (Figs. 1, 2 and 3). This volcanic island has a few rolling hills and is surrounded by an exclusive customary fishing rights area (*qoliqoli*) (see Region 5 in Fig. 2 and

2 Much of the information in this section is adapted from the Partners in Community Development Fiji workshop reports (PCDF 2007a, 2007b) and personal communication with the Pacific Blue Foundation.

Table 2). It is in the Beqa Lagoon (~20 km × 15 km), which has a fringing reef on the perimeter of an extinct submarine volcano, and has indigenous Fijian residents living in a village also called Yanuca. The village is on a large cove on the southeast side of the island (Fig. 3 and 4). In April 2007, the population consisted of 241; 125 males and 116 females, and 34 households in all. The small village includes a church, a primary school, and an older church building that serves as a community hall. Most of the Yanuca villagers are devout Methodists. They are members of *Yavusa* (clan) Nukutabua. There are three *mataqali* (patrilineages), and each has two *toka-tokas* (extended families). Derrick (1974) and Ravuvu (1983) provide additional details on Fijian customs, history, familial structure and governance. Customary fishing rights to the *qoliqoli* are held communally by the *yavusa*. Their exclusive *qoliqoli* is approximately 77 km² (Region 5, Fig. 2; Table 2) and has coral reefs and deep water passages surrounding the island. *Yavusa* Nukutabua also shares qoliqoli rights with two *yavusas* on Beqa Island in Region 4 (Fig. 2; Table 2). The land on Yanuca is owned by the three *mataqali* in three discrete parcels, while two small areas are owned by the Vunivalu (paramount chief of Serua province) and the Raralevu patrilineage of Serua Island, about 10 km northwest of Yanuca Island, very close to Viti Levu. Much of the subsistence and non-subsistence economic activity on Yanuca is based on fishing and a small-scale agriculture that includes taro, cassava (manioc), kava, and various other Pacific root and tree crops.

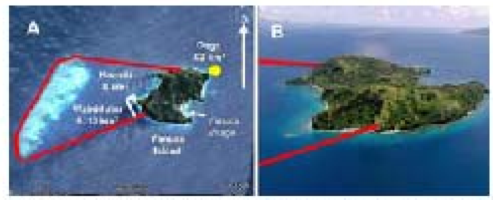


Figure 3. A. Google Earth image of Yanuca Island including part of the Beqa Lagoon perimeter boundary reef that is closest to the island. Boundaries drawn are for the three MBCCAs with the Wainidubu MBCCA shown in white (total area of 0.13 km²), the Daga MBCCA shown as a yellow dot (total area of 0.02 km²) and the Kauviti MBCCA shown in red (total area of 8 km²). Image courtesy of Google Earth. B. Aerial view of Yanuca Island form the southwest. The red lines show the boundaries of the Kauviti MBCCA close to the island. Photo © Kerry Donovan.

Figure 4. The Yanuca Island village viewed looking east from the trail that leads to the school. Beqa Island is visible in the background. Photo © Mark A. Calamia.

The indigenous residents of Yanuca rely heavily on fish for their protein, while plant root crops, fruits and vegetables provide carbohydrates. The people of Yanuca also sell their fishery products as a source of cash income to purchase clothing, pay school fees, support village functions and church activities, and sundry items. These cash needs have helped the local people understand the importance of managing their marine resources in a sustainable manner. Approximately 8 km² of Yanuca's exclusive *qoliqoli* has been set aside as a 'no-fishing' MBCCA, leaving about 68 km² of the 77 km² *qoliqoli* as fishable. They also share fishing rights in the adjacent 91 km²-Region 4 (Fig. 2). Presently the shared *qoliqoli* has no MBCCA sites, but there is strong communication between the Yanuca community and their counterparts on Beqa Island.

The 352 km² Beqa Lagoon has both hard and soft corals and their associated tropical marine vertebrates and invertebrates (Table 1). Scuba diving sites in the Kauviti MBCCA are known especially for soft coral formations as well as several shipwrecks. In the reefs surrounding Yanuca Island, the live coral cover in both MBCCA and non-MBCCA sites is between 15% and 50% (PCDF 2007b). Overall, the coral cover surrounding the edge of Yanuca Island is in good condition and is expected to improve while the MBCCA is maintained and enforced (PCDF 2007b). During a major warm-water bleaching event that took place throughout Fiji in 2000, areas adjacent to the Yanuca MBCCA

Table 2. Surface areas of *qoliqoli* regions for the Beqa Lagoon and the MBCCAs in the Yanuca *qoliqoli* (region 5). See also Figures 2 and 3.

Region	Area (km²)
1	28
2	19
3	38
4	91
5	77
6	68
7	31
Total	352
MBCCAs	
Kauviti	8.00
Wainidubu	0.13
Daga	0.02

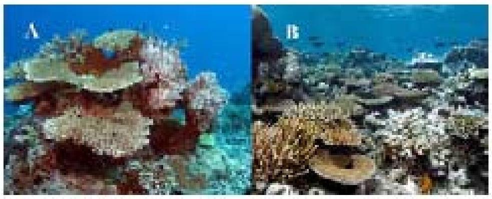


Figure 5. Photos of the Light House Reef, which is representative of the Yanuca Island coral reefs found in the Kauviti MBCCA. (A) High diversity of scleractinian corals. (B) Close-up of the reef benthos indicates that many of the coral colonies are young, replacing those that died in the 2000 and 2002 bleaching events. The Yanuca Island reefs appear to have strong recruitment and growth leading to good recovery from the bleaching mortality. Such strong recovery with high diversity can only be attained for reefs that already are in good health before major stressors such as warm water bleaching. Establishing areas of conservation help ensure healthy populations that will support recovery following natural or anthropogenic stress and damage. Photos © David J. Kline.

were severely affected, and continue to exhibit dead corals beside those that survived. Fortunately, new coral recruits have settled, and recovery is strong (PCDF 2007b, Fig. 5). For the last 10 years, the site of Kauviti MBCCA has been used for commercial live coral trade and collection of aquarium fish.

Many of the best dive sites in Beqa Lagoon are in the Kauviti MBCCA (Figs. 3 and 5). Regional resorts and tourist dive boat operators pay fees to the community for access to these dive sites. Conservation within the Kauviti MBCCA will, therefore, likely contribute to revenue from ecotourist scuba diver fees. Frigates Passage is part of an off-shore fringing reef that is renowned for its world-class surfing. The passage is about 10 km south of Yanuca Island (Fig. 2). The local people of Yanuca are paid a fee by resorts and individuals who surf there or dive in their *qoliqoli*. The community also operates Yanuca Island Resort that can accommodate about 15 guests who are usually budget-conscious backpackers or surfers. They also obtain revenue from commercial divers collecting live aquarium organisms, and from small-scale commercial fishing enterprises operating from Vitilevu. One objective of the PBF and the PCDF is to assist the community to develop sustainable economic options that minimize exploitation of the natural system and consolidate their commercial use within the Yanuca community

Establishing the MBCCAs through a Workshop Approach

Since 2004, the PBF has coordinated approximately two visits per year by various consultants who research the ecological, sociocultural, subsistence, economic and marine conservation needs of the Yanuca people (Mitchell and Donovan 2006, 2007). The Pacific Islands Coordinator for the PBF lives in Pacific Harbour, 17 km from Yanuca Island. He works full time with members of the community on matters related to the management of the MBCCAs, the island environment, and socio-economic needs. In that regard, he is assisting the Yanuca community with their relationships and dealings with national and provincial government departments, non-governmental organizations, educational institutions, and businesses. For the work reported here, consultations have been coordinated with: the Ministry of Fijian Affairs, the Department of Lands and Fisheries, the Native Lands Trust Board, the Serua Provincial Council, The University of the South Pacific, Partners in Community Development Fiji (PCDF), and the Wildlife Conservation Society (WCS).

In October 2004, the Yanuca community invited the PBF to carry out initial underwater surveys, to review the status of the marine ecosystems in their *qoliqoli*, and to make recommendations for next steps (Mitchell *et al.* 2006.). The recommendations made by the PBF were to organize ecological studies and community consultations, to establish a MBCCA, to reduce commercial fishing by outside enterprises, to reduce anchoring, to organize a community evaluation concerning options for balanced management, and to document the fishery harvest. PBF, with the assistance of the village headman (*turaga ni koro*), presented the concept of a MBCCA to the village council and chief. After deliberation, the community recommended that PBF consult with the Department of Fisheries Lami regarding the process for establishing the MBCCA. PBF, with the *turaga ni koro,* consulted with the Department of Fisheries, who informed them of the required protocols, which needed to be followed to achieve the community's goal. First the community needed to define the area and prepare a proposal. The proposal would then need to be evaluated by the village and the Department of Fisheries and, upon approval, implemented. Subsequently, the small 0.13 km² Wainidubu MBCCA was established through a preliminary partnership between the village and Yanuca Island Resort (YIR), their locally-owned resort at Wainidubu beach. The establishment of this initial MBCCA involved a traditional institutional process — a village meeting where the manager and the boat captain of Yanuca Island Resort offered a ritual presentation of kava roots known as a *sevusevu*, followed by ritualized kava drinking and *talanoa* (open discussion about the topic being considered). The Wainidubu MBCCA was approved and declared a no-fishing and no-anchoring area, forty-four juvenile giant clams were seeded, and the community initiated periodic snorkel surveys. The clams continue to grow, and small fish species returned to the area. Surveys in 2007 and 2008 indicated the coral was recovering in areas that had previously suffered damage from anchoring and bleaching. Surveys in 2009 revealed a crown-of-thorns starfish threat indicating incomplete recovery of predators of this coral-killing starfish. Plans to remove the starfish are in progress.

The Wainidubu MBCCA (Fig. 3) was the first to be formed by the community. Its northern boundary meets the island at Dakurukua, a known fish aggregation area (Fig. 2, Table 2). It was subsequently incorporated into the 8 km² Kauviti MBCCA, but its proximity to the Yanuca Island Resort allows for a more effective enforcement of no-take and no-anchoring rules. Although subsumed into the larger Kauviti MBCCA, the precedence that was set by its formation is very important to the community. Since it is near the shore, it is more rigorously protected from illegal poaching. The easily observed coral recovery following the ban on anchoring, and the success of the reintroduction of the giant clams and of the coral gardening project are a source of pride, and evidence of the potential of MBCCAs. A serious problem yet to resolve, however, is the frequent presence of illegal poachers in the deep water passage and reef of the Kauviti MBCCA to the west of the Island, and the discovery in 2009 of a crown-of-thorns starfish outbreak.

In May/June 2005, the PBF returned to Fiji and consulted with Yanuca leaders and the Department of Fisheries, who agreed to let them assist with village meetings regarding conservation initiatives. During that visit, the PBF consultants collaborated with Fijian marine ecology and community experts who were working with the Wildlife Conservation Society (WCS) to conduct scuba surveys in the exclusive *qoliqoli* (Region 5, Fig. 2) along with community consultations and surveys. The WCS is routinely involved with major programs on Fiji's Great Sea Reef Project north of Vanua Levu, and the Namena marine protected area. The experience of the WCS staff was invaluable in helping with the underwater surveys and also in promoting effective communication with the Yanuca village about the status of their *qoliqoli*, options for sustainable management, and concepts for alternative economic development that do not deplete their natural resources.

A year later, in May 2006, the PBF sponsored the first Yanuca Village Marine Awareness Workshop, led by Ethnographic Inquiry (EI), an ecological anthropology consulting firm based in the US, with assistance from the PBF coordinator and the *turaga ni koro* of Yanuca, and others in the village. The workshop provided an opportunity to address issues pertaining to the use of marine resources, governance, and the boundaries of their customary fishing rights area. It was at this workshop that the idea of a large MBCCA was discussed in detail, based on concepts first introduced by such as the PBF and the Department of Fisheries (see Mitchell *et al.* 2006).

In March 2007, the PBF coordinated a Marine Awareness and Participatory Learning and Action (PLA) workshop, led by Partners in Community Development of Fiji (PCDF) with support from members of the Serua Provincial Office, and the Department of Fisheries office at Navua, Serua. The goal was to initiate the development of each village's *qoliqoli* Marine Management Action Plan, outlining strategies to restore the surrounding coastal fishing areas for all villages in Serua Province (PCDF 2007a).

The island and marine resources map created by the Yanuca Community at this workshop is shown in Figure 6. Figure 7 shows the workshop where Powerpoint presentations were given to present underwater digital images. Many of the following conservation measures, as outlined in the workshop, have, or will be, initiated in the Yanuca *qoliqoli* with the strictest rules implemented for the Kauviti and Daga MBCCA (PCDF 2007a):

- Limit anchoring to very small areas that are sandy, and prohibit anchoring for most of the *qoliqoli*;
- install moorings at main fishing, diving, surf and other tourist locations;
- reduce removal of live corals and aquaria fish, and prohibit this activity within the MBCCAs;
- reduce gleaning and spear-fishing with scuba, and prohibit these activities within the MBCCAs;
- prohibit the use of poison derived from derris (*duva*), an illegal fishing practice with devastating indiscriminate effects on all surrounding organisms;
- establish coral replanting programs within the MBCCAs, and set up coral farms that have the potential to generate sustainable local income through live coral sales; and
- train members of the community as government-certified fish wardens.

During the PLA workshop, the PCDF conducted a socio-economic survey in the seven villages of the district (PCDF 2007a). It revealed that the fishery was primarily subsistence, and commercial fishing by the Serua villages was very limited. This brought to the fore the option for the community to develop its own fishery cooperative, and eliminate, or greatly reduce, the number of licenses to non-local commercial fishers. The PBF is exploring a micro-finance scheme to establish a sustainable fishery cooperative with Yanuca to support the villagers' economic needs and their subsistence protein requirements. Much of the subsistence and non-subsistence economic activities on Yanuca are based on fishing and small-scale agriculture, but the soil and limited freshwater on Yanuca are not ideal for farming. Some members of the Serua villages get their major income from working in tourist resorts or providing other services to tourism, while others focus on small-scale fishing, farming, and other activities (PCDF 2007a). The Yanuca community has very small tourist resorts that generate a modest income. Scuba and surf fees also provide some revenue.

The workshop and survey also showed that there was significant overfishing of Serua's *qoliqoli*, including Yanuca (PCDF 2007a). Poaching in MBCCA sites was identified by the communities as an issue. In May 2009, the fisheries warden workshop for Yanuca and other Serua Province villages further raised awareness of the poaching problem and was featured in the June 6, 2009 *Fiji Times* (Anon. 2009). The *Fiji Times* pointed out that the district, provincial, and government authorities could help mitigate or eliminate poaching by assisting with patrols. Overall, the PCDF marine awareness and participatory learning workshop and the socioeconomic survey of Serua District indicated that the people were well informed of conservation concepts and had the framework for various actions to improve their natural environment while also promoting long-term social and economic sustainability (PCDF 2007a).

In collaboration with the WCS and with support from the PBF, in July 2007, EI conducted an ethnographic study of Yanuca Island cultural history and its trade relations with nearby islands. The WCS and PCDF helped us communicate with the Yanuca village about the options for the sustainable management of their *qoliqoli*, and the alternatives for an economic development that does not deplete their natural resources. Consistent with the March 2007 workshop recommendations, in April 2008, under the supervision of PCDF, coral farming structures were installed on non-coral, sandy-bottom areas 50 m from Wainidubu Beach. By November 2008, the PBF surveys revealed that these structures were ready for harvest and would allow the sale of live, farmed coral for a sustainable income.

The Socio-Political Decision-Making Process on Yanuca and Indigenous Governance of MBCCAs

Making decisions about the Yanuca MBCCAs has always rested in the hands of the indigenous community members. In October 2004, the village headman (*turaga ni koro*), a paid administrative position under the Office of Fijian Affairs, was approached in a traditional manner by a prominent elder of the Batiluva patrilineage who requested a meeting of the village elders (the heads of the three patrilineages and others) in response to an overture by the PBF. Shortly after this 2004 visit by PBF, the Yanuca Island Resort manager and the resort's boat captain approached the village elders in a traditional way (with kava roots for the *sevusevu* ceremony) to request the initiation of the small MBCCA at Wainidubu (see Fig. 3). According to the *turaga ni koro*, the manager and boat captain "asked for permission to place marker buoys at the site, to chase people away if fishing or anchoring [at the site], and [for] the power to keep it a no-fishing reserve."

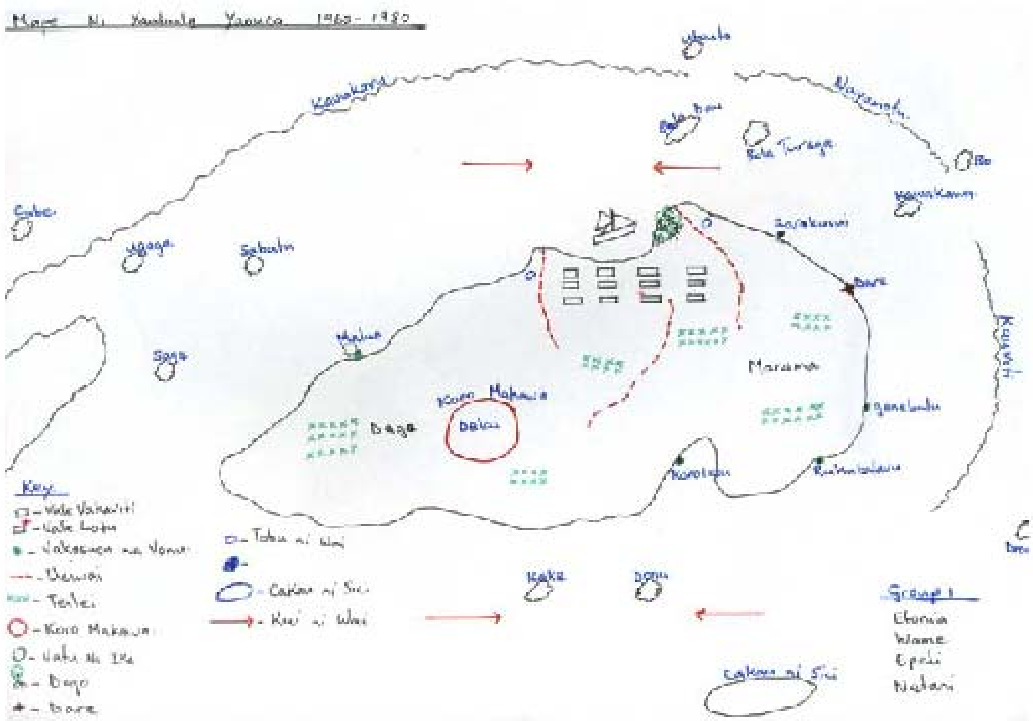


Figure 6. Hand drawn map with annotations of regions of highest value specified by the Yanuca community. During the March 2007 workshop, villagers assigned no-take or rest zones, and designated other areas to be actively fished. This workshop process captured the intrinsic cultural, economic and ecological value to the community of the diverse habitats within their *qoliqoli*. Based on balancing the use of these different areas, the community specified the MBCCAs summarized in this report. Sketch map courtesy of Yanuca Community and Partners in Community Development Fiji.

Figure 7. Children join the March 2007 workshop coordinated by the PBF and led by the PCDF. This workshop established the three community conservation areas within the Yanuca *qoliqoli* described in this report, and a preliminary set of conservation guidelines regarding fishing, anchoring, and live coral/fish extraction in the newly designated MBCCAs. The community also made long-term commitments to continue to re-evaluate and balance implementation with respect to economic sustainability and conservation; a process required for viability of MBCCAs. Photo © Kerry Donovan.

They also asked the villagers "to be aware of the MBCCA and observe it as a start towards protecting [their] own waters, as an example and a beginning. This talking and open discussion is the traditional way [for example, *talanoa*]." The *turaga ni koro* added "the non-traditional way was to accept help and workshops from two NGOs and [the] fisheries department."

Following this non-traditional and traditional *talanoa* (consultation), the *turaga ni koro* contacted the village chief, the Tui Daga, who lives on the main island of Viti Levu, to notify him of the meeting and the ensuing recommendation to form the MBCCA. He approved of the village recommendation. However, given that the chief does not live on Yanuca Island for most of the time, he deferred his decision-making authority to the *turaga ni koro* and the village elders. The leadership of several elders was particularly powerful, including that of (the late) Doko and Big Bola (Fig. 8). As mentioned above, the community approved the small MBCCA at Wainidubu in May 2004.

Although the majority of the community is in favor of collective decisions for the common good, some individuals can disrupt the process and threaten the achievement of community goals. In 2003, a member of the Yanuca clan, *Yavusa*

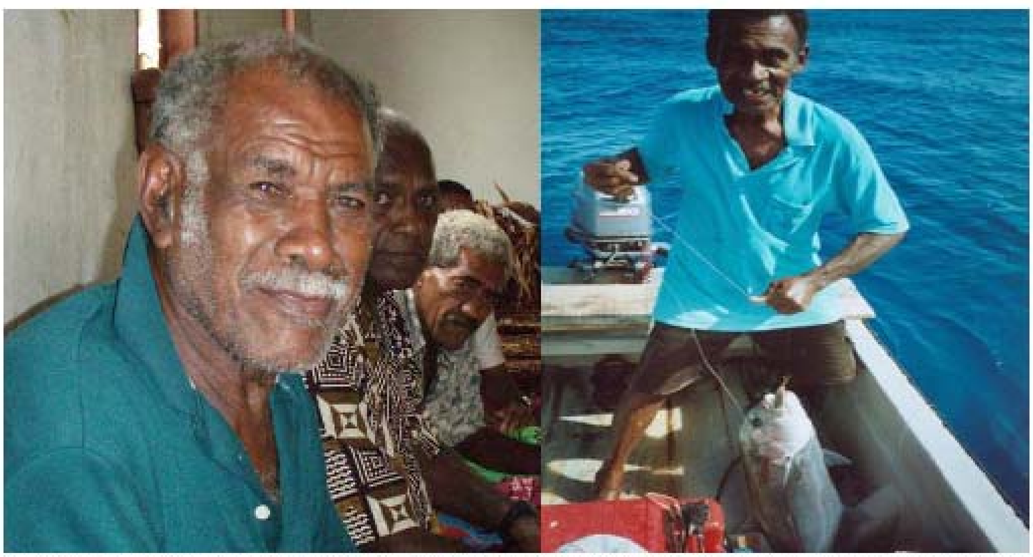


Figure 8. Photograph of Epeli "Big Bola" Bolatagici (left) and Etonia "Doko" Dokonivalu (right), two of the most inspiring elders who championed the establishment of the MBCCAs reported here. Big Bola and Doko were superlative fishermen and craftsmen whose smiles were infectious. Their knowledge of the fish and ecology of the *qoliqoli* and the trust the community had in their knowledge and wisdom, were very important in the MBCCA planning process that was based on traditional knowledge and customary approaches to marine conservation. Doko passed away in February 2008 and Big Bola in April, 2009. Documenting the traditional knowledge of the elders relative to both cultural and ecological conservation is part of the mission of the Pacific Blue Foundation, and this report is dedicated to their memory and the hope that their leadership will be emulated by their descendants. Photos © Kerry Donovan.

Nukutabua, began harvesting sea cucumber with scuba in the Yanuca *qoliqoli* while employed (on wages) by a man from Nairai, Lomaiviti Island Group, who was living in Suva. The man evidently believed that just being a member of the clan *Yavusa* Nukutabua was sufficient to be an owner of the *qoliqoli* and did not understand (or wish to understand) that the activity was illegal and unsustainable. By Fijian law, it is illegal to use scuba for any form of fishing. In 2006, he began harvesting sea cucumber using his own boat and scuba gear. He employed untrained divers from the village. Despite continuous appeals from the elders to stop, the clan member continued the lucrative enterprise. Sadly, on 13 May 2006, a Yanuca diver died while diving from the clan member's boat; other divers reported he was using a faulty buoyancy vest. The clan member was asked by the elders to stop, but he defied them. From his sea cucumber sales he was able to buy more tanks and a larger boat; on 29 November 2006 another Yanuca man went missing while in his employ, and his body was never recovered. The clan member was forced to stop illegal harvesting in the Yanuca *qoliqoli* by the elders, and he left the area to fish and harvest sea cucumber illegally elsewhere. The chief of Yanuca wrote to the Serua Provincial Office, Commissioner Central, and the Minister of Fisheries, asking them to decline any application for harvesting sea cucumbers with scuba. These sad events galvanized the will of the majority and led to a strengthening of support for traditional communal governance informed by modern concepts for sustainable resource use.

During the PCDF workshop in April 2007, further decisions were made by community members to recognize the large Kauviti reef MBCCA and a smaller MBCCA at Daga (Fig. 3; Table 2). Two weeks after the workshop, the village *turaga ni koro* called a meeting of the elders and the *Tui Daga* to discuss the proposed expansion of conservation areas. Following traditional protocol, the clan chief listened to his village elders and council, and eventually gave his approval. As mentioned above, the larger Kauviti MBCCA encompassed the original small Wainidubu MBCCA. The Daga MBCCA is a marine area around an underwater pinnacle reef 200 m from the island (Fig. 3). It rises from the seabed to about 6 m below the surface, and is ecologically important because large schools of juvenile and adult Trevally (*saqa*) fish routinely aggregate there. In the past the fishermen speared or trolled for Trevally at Daga, and it was chosen as a MBCCA to determine if a fishing moratorium during the next five years would result in an increase in numbers; the decision to forego fishing at Daga was a testament to the community's ability to make compromises to achieve their conservation goals.

Managing and Monitoring the MBCCAs for Effective Conservation

The indigenous people of Yanuca are in the nascent stages of managing their marine resources, as well as exploring other potential economic development incentives that will provide needed income on a sustainable basis. Similar marine resource conservation efforts and community-based marine species' identification work have also been undertaken on the nearby islands of Ono and Kadavu (Calamia 2003, 2008). Although the Yanuca villagers rely heavily on fishing for their protein, they recognize the importance of maintaining the sustainability of their resources and have worked with partners to establish several MBCCAs in their *qoliqoli*. The community has become active in monitoring the status of their *qoliqoli*, and they are considered leaders in Serua Province and the Beqa Lagoon area. The underwater surveys conducted during the 2007 PCDF workshop revealed that the most abundant fish were Parrot fish (Scaridae spp.) and Wrasse (*Chelinus* spp.). Other important food species, such as Rock cod (Gadidae), Coral trout (*Plectropomus*, Serranidae), Sweetlips (*Plectorhinchus*, Haemulidae), Unicorn fish (*Naso*, Acanthuridae), and Emperors (*Lethrinus*, Pomacanthidae) were not seen during the survey (PCDF 2007b). All these species are targeted for both subsistence and small-scale commercial fishing. Since the surveys were not rigorous ecological studies, the presence/absence and relative abundance are not considered quantitative. However, the data collected from these surveys imply the area has been prone to intensive fishing pressure, substantiated by the information that night diving has been prevalent around Yanuca. (PCDF 2007b).

The local people and the NGOs involved, expect that the fish will increase in numbers within the MBCCAs leading to "spill over" to adjacent areas that are fished PCDF 2007b). Underwater surveys conducted as part of the training indicated that the invertebrate count near Yanuca Island was similar for MBCCA and non-MBCCA sites. This was not surprising, given that the MBCCAs have only recently not been created. The main exception was the successful reintroduction of the giant clams, and the coral transplanting and gardening near Wainidubu MBCCA. Invertebrate populations, especially of sea cucumbers which have been heavily over-exploited, are expected to increase as a result of the MBCCA's. Future surveys of invertebrates will indicate the success or otherwise of the MBCCA initiative in Yanuca's waters (PCDF 2007b).

The community is now able to monitor and manage its marine resources because of the collaboration reported here. Local Yanuca residents continue to improve their MBCCAs by installing moorings to prevent anchor damage, and by replanting coral, removing crown-of-thorns starfish, and creating coral gardens that can provide sustainable income without the removal of the natural corals. To help the Yanuca in the management of the MBCCAs, in April 2007, the Serua Provincial Office, the Fisheries Department, and PCDF organized the Serua District Fish Warden Training and Biological Survey. Fish warden training included instructions on conducting underwater surveys to assess resource abundance and biodiversity. Twelve members of the Yanuca community were trained as Honorary Fish Wardens (PCDF 2007b), adding to the three already trained with support from the PBF in August 2006. The Fish Wardens have established their own committees, and they coordinate patrols to reduce poaching, conduct periodic surveys to monitor the health and number of fish and coral populations, and take an active role in communicating the status of the *qoliqoli* to the villagers (PCDF 2007b). According to the Fisheries Officer in charge of Serua Province, non-local poachers routinely engage in night fishing; a major problem for the authorities throughout Fiji. The Fish Warden committee continues to plan with the PBF to devise more effective methods for preventing poaching that does not require excess use of fuel. These plans are being developed with coastal villages in Serua Province, and island villages on Beqa Island (Rewa Province).

The Development of a Community Trust as a Governance Tool

The need for clear and present leadership is the single most pressing issue; one that has impeded the development of "good governance" of the Yanuca MBCCA. As recently as November 2008, the *Tui Daga* (*Yavusa* chief) was continuing to sign commercial fishing permits for non-Yanuca fishers to operate within the Yanuca *qoliqoli* without consulting the community. Fees for these licenses were paid directly to the *Tui Daga*. Typical of issues related to the failure of communication, consultation and governance, some of these licences allowed fishing within the Kauviti MBCCA. Once signed, the permits were processed through the district office and the Fisheries Department, the staff of which were not aware of the lack of community consultation. In the past, the chief often signed permits without consultation with the community, but agreements were made during the PBF and PCDF workshops described above that community consultation would be assured in the future. Currently, there is an agreement that no further permits will be issued for commercial activities (fishing, scuba, surfing, harvesting) without community consultation. New licenses and permits will be granted for a maximum of one calendar year; this facilitates future protection of the fishery itself as well as the MBCCAs.

To address these governance issues on Yanuca (which are common throughout Fiji), the PBF helped the Yanuca village council to draft a *Yavusa* Nukutabua Deed of Trust (*Yavusa* Trust), naming the members of the *Yavusa* Nukutabua as the beneficiaries. With agreement from the community and a learned businessman from the village who vets all "Western" negotiations involving Yanuca, the community gave approval for the PBF to hire a Fijian attorney knowledgeable in customary governance and protocol to assist in drafting a revocable deed of trust that would include traditional aspects of the Fijian governance structure. The village elders are also in the process of obtaining an independent review. The Yavusa Trust is being drafted with the help of the *turaga ni koro* and the PBF attorney to ensure that the indigenous peoples' ownership and use rights will be legally conveyed into the trust. The trustees selected by the community will decide collectively on fair and equitable compensation for the use of their marine resources by external stakeholders. This instrument will only hold those assets that the beneficiaries (*Yavusa* Nukutabua) agree should be placed in the trust. Once legally executed, the trustees selected by the community will be able to enter into agreements on behalf of the beneficiaries, including lease agreements made with various stakeholders, for example, use of the MBCCA for dive tourism, sport fishing, surfing and commercial fishing outside the MBCCA. A set of bylaws for the *Yavusa* Trust is in the process of being drafted as well. The expectation is that rules established for the MBCCA by the community will be adhered to in all decisions by the trustees, minimizing the risk that the chief, or other powerful members of the community, will make individual decisions that are not supported by the community.

Two representatives from each of the six extended families (*tokatoka*) will be selected as trustees to initiate the *Yavusa* Trust. The heads of the three patrilineages (*mataqali*) and the village chief (*Tui Daga*), have been involved in the selection of trustees, which is consistent with traditional governance of Fijian communities. A fixed number of trustees (12) has been specified, but they may be changed over time. The trust has a structured plan for re-election of a subset of trustees at regular intervals. A parallel process has been initiated to develop a deed of trust for each *mataqali* that has ownership rights to land on Yanuca. It is anticipated that the *Yavusa* and each of the three *mataqali* will finalize the *Yavusa* and *Mataqali* Trusts in 2009 and proceed to a full community vote on the four separate deeds of trust.

It is important to stress that developing effective partnerships that support governance of Marine-based Community Conserved Areas is an ongoing process that typically takes several years to accomplish and requires transition to a sustainable economic base which can enable the community to be vigilant in their conservation goals.

Several village-wide meetings have already been convened to explain how the *Yavusa* Trust will work and to solicit input in traditional ways. A small committee coordinated by the *turaga ni koro* has been formed to work with the attorney in revisions. As is customary, the chief may express his approval or disapproval before the other members offer their decision on matters. However, the *turaga ni koro*, who in this case also has the role as spokesman for the chief (*mata ni vanua*), and the heads of the *tokatoka* and *mataqali* all recognize that the trust will reduce the chief's influence by ensuring that all decisions involving the MBCCA and other assets of the Yavusa *qoliqoli* will be approved by a majority of the trustees. Through this process, the community hopes to eliminate chiefly permitting of outside commercial fishers who seek to exploit Yanuca's marine resources, and prevent any individual or smaller group of *mataqali* landowners from allowing use of marine resource without community consultation and consent. For instance, in 1995 a number of *mataqali* elders gave permission to two foreigners to build and operate an unregistered back-packer style motel at one of the beaches. During the occupation different members of the *mataqali* received unequal—and minimal—amounts of small cash rental payments, which created jealousy and concern among some. The resort's owners also exploited the marine resources of surfing, swimming, and fishing at little benefit to the community. Although a legal eviction was issued by the Native Land Trust Board, the resort continues its operations. The community recognizes, following consultations with the PCDF, that the equitable representation of the trustees and a more efficient decision process will facilitate progress on other economic projects of interest, including forming a Yanuca commercial fishing cooperative or creating partnerships with investors for ecotourism, resorts and other sustainable economic options for which the community has expressed interest.

Conclusion and Next Steps

Community Conserved Marine Areas were defined at the First International Marine Protected Area Congress (IMPAC I) in 2005 as "marine and coastal ecosystems including significant biodiversity, ecological services, and cultural values voluntarily conserved by indigenous and local communities through customary laws or other effective means." The three MBCCAs of Yanuca Island reported here are in accordance with The World Congress of Protected Areas Management Category VI (Protected Area with sustainable use of Natural Resources) that may include coastal marine areas under restricted use and/or communal rules that assure sustainable harvesting through time (Borrini-Feyerabend *et al.* 2004; Dudley 2008). These also follow the general guidelines of community-based management encouraged by the Locally Managed Marine Network (LMMA).

The Yanuca Island community has exhibited decision-making authority as seen through their ability to diagnose problems in workshops and capacity building exercises and to determine specific actions to resolve problems and to carry them out. They are devising solutions and beginning to take action to protect their resource base, combining centuries-old institutions of customary access rights and responsibilities for marine resources with modern conservation and legal methods. Their customary rights and traditional decision-making institutions, however, cannot be fully effective unless they are nested within collaborative and supportive institutions at national or regional levels (TILCEPA 2005; TGER 2005). The Yanuca MBCCAs are an example of conservation areas that are governed beyond "consultation" initiatives; the deeds of trust, for example, will be registered with the Fijian authorities so that decisions of the trustees will be more formalized and publicly disclosed.

Two effective avenues to empower indigenous and local communities to manage and conserve their marine resource are the use of the Community Conserved Areas (CCAs) and co-managed resources and protected areas (shared stewardship). In the case of Yanuca village, we have seen the former, where traditional institutions and values continue to be recognized, respected, and supported as a way to promote institutions capable of effective response to changes in ecological, economic, and sociopolitical circumstances. At this time the MBCCAs do not qualify as co-managed protected areas because authority, responsibility, and accountability are not fully shared among partners, such as non-governmental organizations, the Fiji government, and the rights holders. Yanuca's newly created MBCCAs were established with ongoing assistance from the local NGO Partners in Community Development Fiji (PCDF), and Yanuca's primary partner Pacific Blue Foundation (PBF) and their consultants, but the indigenous community retains all authority over decisions. As mentioned above, the Yanuca MBCCAs also qualify as Indigenous and Community Conserved Areas (ICCAs) since the community dominates decision making and implementation regarding the management of the site.

The PBF is currently engaged in discussions with the *Yavusa* and the three *mataqali* to define opportunities for sustainable economic alternatives to harvesting their reef resources, to resolve issues of enforcement and patrolling of the large no-take Kauviti MBCCA, and concerning the creation of small business enterprises that can generate revenue to offset lost revenue from the MBCCA. This latter may include a fishery cooperative and some form of ecotourism (catch-and-release fishing, surfing, diving, sailing and hiking). Through the development of a revocable deed of trust, the

Yanuca community is hoping to establish a protocol for "good governance" and accountability to ensure that Yanuca's marine resources are managed sustainably for its future generations and to provide the community with a mechanism for more efficient and formal governance and decision making as related to external partners.

Following successful mooring initiatives on Namena reef, one central component of the plan will be for the PBF to help finance the installation of moorings at diving and access points on the island that will also serve as points of pay for services such as diving and tourism. This is expected to minimize damage to the reefs from anchors, and also provide a way for the community to establish a uniform fee-basis for use of their *qoliqoli*. As of this writing, no final agreements have been established but there has been considerable consultation by experts focused on detailed surveys and studies of the socio-economic status of the community, their specific aspirations, and concepts for steps forward. It is important to stress that developing effective partnerships that support governance of MBCCAs is an ongoing process that typically takes several years to accomplish and requires transition to a sustainable economic base which can enable the community to be vigilant in their conservation goals.

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First and foremost we wish to thank the indigenous Fijian people of Yanuca Village for their generosity, kindness, and dedication to finding sustainable solutions to their marine resource conservation and development challenges. This work is dedicated to the memories of Sireli Drivatiyawe and Mosese Bati who died while working with illegal sea cucumber fisherman, and of Epeli "Big Bola" Bolatagici and Etonia "Doko" Dokonivalu, whose elder status, ecological vision, and leadership were essential in the progress made by the Yanuca Island community in initiating marine conservation. Sadly, Doko passed away in February, 2008 and Big Bola in April, 2009. This work was partially sponsored and coordinated by Pacific Blue Foundation. Partners in Community Development Fiji were supported separately. The authors thank Taito Tabaleka who first invited the PBF to consult with the community, the Tui Daga, Chief of the *Yavusa* Nukutabua, the Yanuca Women's Committee, and the entire Yanuca community, for inviting our team to carry out this work, and for their gracious hosting of many events, their patience and their enthusiasm. Mark A. Calamia offers a special *vinaka vakalevu* (thank you very much) to the family of Sireli Kago (Yanuca's *turaga ni koro*), especially his wife Merelevu Rokolewa who graciously hosted him in their home during his 2006 and 2007 visits to Yanuca. We acknowledge the PCDF for their excellent assistance with Fijian customs and in defining priorities; PCDF consultant, Austin Bowden-Kerby, for guidance on community interaction and local ecology; Aisake Batibasaga of the Fiji Department of Fisheries; the Wildlife Conservation Society Fiji for allowing PBF to hire their expert Fijian marine ecology and community consultants; illuminating discussions, and encouragement from members of the faculty and staff of University of South Pacific—in particular Professors Paul Geraghty, William Aalbersberg, and Joeli Veitayaki—for their constructive comments and insights during numerous meetings and correspondence; Bret Diamond of SeaAid who assisted with surveys and planning future initiatives; Talina Konotchick for her efforts during PBF scuba surveys in 2005, Mati Kahru and Haili Wang for their in satellite graphics, and Mary Anderson for outstanding assistance in editing the manuscript.

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NIWA
Taihoro Nukurangi

Results and Lessons Learned from a Rocket Stove Trial on Yanuca Island

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January 2010

NIWA Project: PBF10101

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2 Introduction

Cooking fires and kerosene stoves represent the highest energy uses as well as the greatest source of local air pollution in many rural Fijian communities. In order to mitigate both, the Pacific Blue Foundation (PBF) started a rocket stove pilot project in one such community – Yanuca Island.

In this program, the PBF surveyed weekly firewood and kerosene consumption before and after the trial over a total six months period.

In this report we review conventional cooking practices on Yanuca and describe design, use and limitations of the new rocket stove. We describe the survey and its results, and discuss lessons learned.

NIWA originally planned to go to Yanuca in order to verify the survey results through interviews with residents who took part in the programme, but this was not possible because of constraints in boat service to the island. Instead Sireli Kago interviewed every participating household in order to verify that the data sheets had been filled in correctly.

The survey form and survey raw data are included in an appendix.

3 Cooking stoves on Yanuca

Residents of Yanuca typically use four types of cooking facilities: open fires, kerosene stoves, LPG stoves, and the traditional lovo (earth cooking) fires. This section discusses these four conventional stoves, introduces the PBF rocket stove, and puts the different stoves into perspective.

3.1 Open wood fires

Figure 1: Typical cooking fire in Fiji (photo: A. Hamm).

From personal observation, it appears that open wood fires are by far the most common cooking method, and many households use cooking fires three times a day. Firewood on Yanuca is not a scarce resource, but men often walk for more than twenty minutes one way for collecting firewood. Heavy bundles of wood have to be carried back to the village. Typically the firewood is a mix of branches and other dead wood of various ages, and is collected on demand for one or two weeks in advance. Firewood is not stockpiled, dried and seasoned as is common practice in the West. Particularly during rainy periods this translates into poor wood combustion which in turn leads to increased smoke and increased wood consumption. Firewood moisture on Yanuca is estimated to range from 20% to 40%[1], it is likely to average at around 30%. Table 1 shows energy contents and combustion properties of firewood at different moisture levels. The numbers are indicative only, since the actual energy content varies between different wood species.

The people of Yanuca may greatly benefit from constructing and using well ventilated firewood shelters where firewood is dried for at least 6 months before use.

Table 1: Energy content of firewood (Energy content data source: (MED 2007)).

Moisture	Energy content	Combustion efficiency
20%	17 MJ/kg (gross)	High, little smoke, bright flame
30%	13 MJ/kg (gross)	Poor, smoky, acceptable flame
40%	12 MJ/kg (gross)	Extremely poor, very smoky, smouldering flame

[1] This estimate is based on random samples of firewood which we measured on Rotuma (2004) and Totoya (2009).

Open cooking fires achieve an efficiency of roughly 10% (Siwatibau 1981). The efficiency of heat transfer from fire to cooking pot can vary greatly with different kitchens due to drafts and wind. Some kitchens are outside in the open and fully exposed to winds, while others are in half enclosed shelters.

3.2 Kerosene stoves

Figure 2: Typical kerosene stove in Fiji (Photo: A. Hamm).

The second most preferred cooking stoves appear to be multi-wick kerosene stoves. These kerosene stoves are relatively inexpensive to buy ($30 range), last a long time and kerosene is widely available. The cooking efficiency of simple multi-wick kerosene stoves was measured to be around 43% (World Bank 1985) which is in the same range as modern gas stoves. The biggest two disadvantages are that kerosene is releasing toxic fumes[2] into the kitchen, and kerosene is increasingly expensive to buy. People on Yanuca are currently paying $2 per litre of kerosene at the local shop on the island.

3.3 LPG ranges

Several households on Yanuca own Liquefied Petroleum Gas (LPG) cooking ranges. While they are often regarded as the most convenient and cleanest form of cooking, LPG use on Yanuca is not widespread: the fuel is relatively expensive and the heavy gas bottles need to be brought in from the main island with small outboard boats. The efficiency of an LPG stove averages around 45% (Duncan, Hamm et al. 2007).

[2] Kerosene has significantly higher emissions than LPG gas.

3.4 Lovo earth cooking fires

Figure 3: Rocks are heated for traditional lovo cooking fire (Photo: A. Hamm).

All across Polynesia, food has been traditionally prepared in earth holes on hot rocks. Rocks are heated by fire until glowing red. After the remaining embers are removed, wrapped food is placed on the rocks and everything is covered with banana leaves and dirt until cooked. This method of cooking is no longer practiced for everyday meals because of long setup times and labour intensity. Today people on Yanuca typically prepare lovos every Sunday as well as on festive occasions.

3.5 The Pacific Blue Foundation rocket stove

Figure 4: PBF Rocket stove.

In an attempt to mitigate the disadvantages of the common cooking stoves used on Yanuca to date, the Pacific Blue Foundation researched alternative cooking stoves to suit conditions on the island. Results of this research pointed towards an internationally proven rocket stove design brought to them in Fiji by Bret Diamond from SeaAid who had proven success with it. The rocket stove seen in Figure 4 was selected for the pilot project for the following benefits:

- Affordable to manufacture
- Uses traditional fuel source (firewood)
- Uses fuel efficiently
- Heats up fast
- Reduces emissions and smoke

Rocket stoves have become popular in many developing countries. Hundreds of different designs are available, but the distinguishing characteristic remains the same: firewood is combusting in a vertical tube. The heat of the flames is inducing an upward draft, drawing the air in through an opening at the bottom. Commonly, firewood is fed through a horizontal tube to the side, which doubles as air inlet. The combustion efficiency increases with increasing temperatures in the combustion tube. A well insulated draft tube allows the inside temperature to rise quickly and makes for an efficient burn.

Figure 5 shows a drawing of the PBF rocket stove design. The stove body is manufactured from an empty 5 gallon metal paint pail, approximately 400 mm high and 300 mm in diameter. The only custom made parts are the combustion and firewood inlet tube, a galvanized steel elbow of 100 mm diameter, and a simple steel dividing plate. The steel plate ensures sufficient draft while the firewood can be placed on top. Pumice is loosely poured around the combustion tube and acts as insulation as well as holding the tube in place.

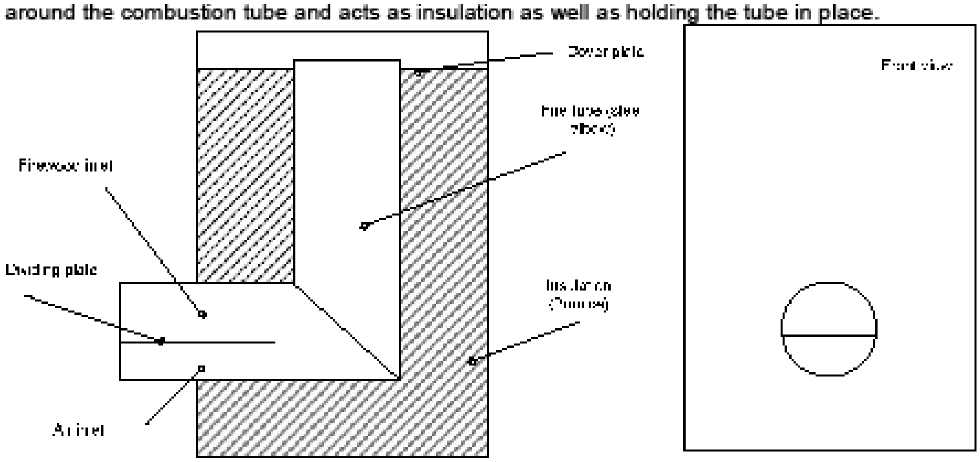

Figure 5: Drawing of PBF rocket stove.

Similar rocket stove designs have been laboratory tested and show significant improvements in fuel efficiency when compared to open fire cooking. Firewood consumption was reduced by approximately 50% compared to open fire cooking. It is important to note though, that the actual fuel savings could be significantly higher in non-laboratory situations where open cooking fires are exposed to wind.

3.6 Comparing cooking stoves

The previous five sections introduced five different stoves on Yanuca. Every stove has advantages and disadvantages. Every stove has strong and weak points and naturally lends itself to achieve different cooking tasks best.

Figure 6 shows a qualitative overview of fuel effectiveness and suitability of different types of stoves for different cooking services. While LPG and kerosene stoves are more efficient than rocket stoves, they use expensive imported fossil fuels. However, these stoves are roughly as efficient for heating up a cup of coffee as they as for cooking a family dinner. Rocket stoves are more fuel effective than open wood fires for a small meal, but in either case there is a fixed initial energy requirement to bring the stove up to heat before cooking begins.

The chart indicates where rocket stoves "fit in" when replacing conventional cooking stoves: they best suit meal sizes from small snacks to family meals. These meals are likely to cover 80% of cooking activities on the island. Kerosene or LPG stoves still have a place mainly for very brief cooking task such as heating up a cup of coffee. Open fires still have a place for large cooking tasks where a rocket stove does not produce enough heat. Lovos have a traditional standing and the introduction of rocket stoves is unlikely to have an effect on the use of lovos for Sunday meals and events.

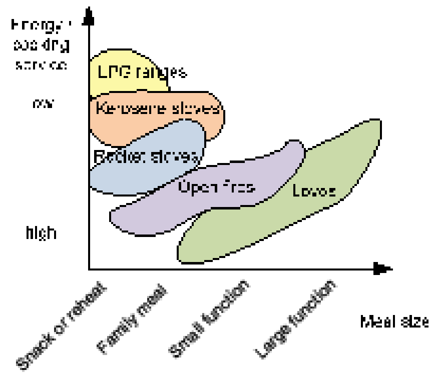

Figure 6: Qualitative overview of cooking stove efficiency ranges for different types of meals. The chart is not based on actual data and ranges are indicative only.

A World Bank study on cooking stoves remarks that "the manner in which a stove is used plays an important role in determining the fuel consumption" (World Bank 1985). This important statement underlines: the technology brings the potential for fuel efficiency, but adequate training and instructions are essential in developing this potential.

Cooking fuel survey

3.7 Survey method

Kerry Donovan and Sireli Kago of PBF officially initiated the rocket stove pilot project on Yanuca with an information workshop in February 2009. Most adult women from the island attended. The workshop explained the benefits of rocket stoves and demonstrated how to use them. The people of Yanuca showed great interest in the stoves, particularly as they started to understand how the stove could save them real money. The workshop was held in English and their own dialect of the Fijian language and included an extended practical session on using the stoves so there was a high success rate of user understanding.

After the workshop PBF offered residents the following deal: if households fill in a weekly cooking fuel survey form for a period of 12 weeks they would receive a stove at a subsidized cost of $30 (The full cost to PBF is $50). If they filled in the cooking fuel survey form for another 12 weeks after receipt of the stove they would receive a full refund for the $30 paid, and effectively get the stove for free.

The stove introduction workshop was followed up by the village head man, Sireli Kago. Sireli visited households for follow-up training wherever residents had initial difficulties with using the stove to their best advantage. Also every Saturday a young delegate of Sireli's would visit every house to remind householders to complete their forms data entry for the week.

An example survey form is shown in the appendix. Survey results follow below.

3.8 Rocket stove survey results

The rocket stove program was deployed on Yanuca with good success. A number of 19 households participated in the program. After initial inhibitions to the uptake of the program, most households reported they started using their rocket stoves regularly.

The graph in the Figure 7 shows the development of fuel consumption over the survey period of 24 weeks. The first 12 weeks of the survey period are before the rocket stove introduction. After 12 weeks, every participating household received one rocket stove. The survey results show a 43% reduction in firewood consumption and a 35% reduction in total kerosene consumption. However, all but one resident reported that they stopped using kerosene for cooking after the rocket stoves were introduced (people use kerosene in hurricane lanterns). The reduction in kerosene use for cooking alone is therefore nearly 100%.

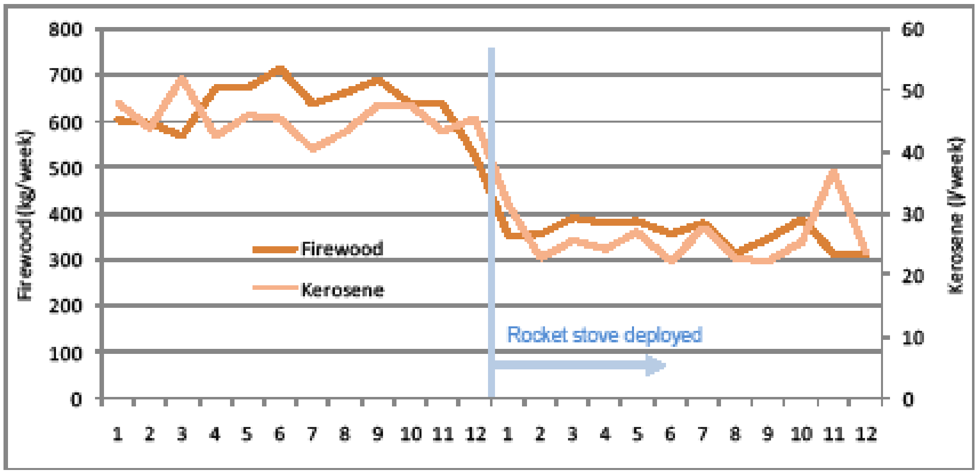

Figure 7: Household cooking fuel consumption in weeks before and after the introduction of rocket stoves to Yanuca. The results are based on a total of 19 participating households.

Figure 8 shows the distribution of surveyed households across different fuel saving levels. While the overall reduction in fuel consumption is a clear improvement, the magnitude of fuel savings varies significantly from household to household.
The first bin marks an actual increase in fuel consumption. Three households recorded increased firewood consumption following the rocket stove introduction. There is a peak of 5 households in the 60% fuel saving range. The majority of households achieved fuel savings between 30% to 70%. Kerosene fuel savings are distributed relatively evenly across the scale, with a weak majority of households saving between 30% to 70%.

The broad distributions suggest that fuel use patterns are very different from household to household. Although the survey forms were clear and people were well instructed and periodically reminded to keep the forms up to date, the responses may also contain some inaccurate figures. It is important to remember that recording fuel consumption figures on a survey sheet is far from anything people on Yanuca do in everyday life. Nonetheless, the survey should be considered statistically representative for cooking fuel use on the island due to the weekly checks by Sireli and his helper, and the positive willing participation of the residents.

Overall firewood savings achieved through the use of rocket stoves are well aligned with what we would have expected from previous laboratory test results: (Hudelson, Bryden et al. 2009) found rocket stove efficiencies to range from about 20% to 35%, depending on specific design and way of use. This translates to theoretical firewood savings of 50% to 70% over open fire cooking.

Overall the pilot project produced very encouraging results for Yanuca. To date, the rocket stove program has:

- significantly reduced firewood consumption
- eliminated kerosene consumption in cooking
- reduced exposure to smoke from open wood fires.

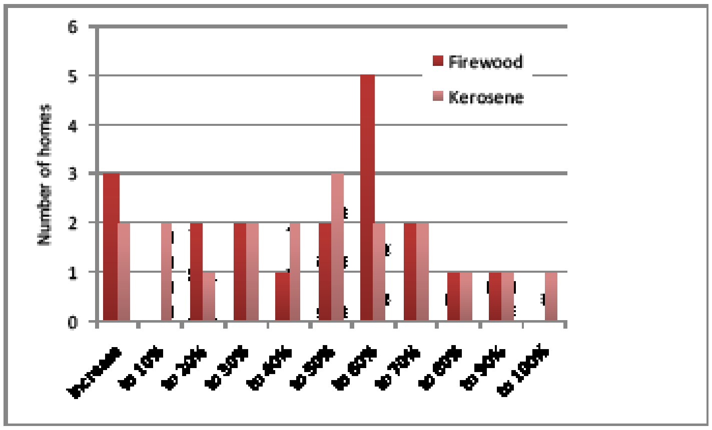

Figure 8: Spread of overall cooking fuel consumption changes since rocket stove introduction by household.

In energy terms, the use of rocket stoves produced a total reduction of cooking fuel demand of 44% for the participating households, i.e. from 104GJ to 58GJ through the survey period. While firewood is collected for free on the island, kerosene is purchased from the main island. Money savings from the replacement of kerosene with rocket stoves average to $107 per household per year.

At a cost of $50 per rocket stove, incurred Kerosene savings suggest a very short average payback period of 6 months.

3.9 Lessons learned from PBF rocket stove roll-outs

At the time of writing, PBF has introduced rocket stoves on Yanuca and Totoya islands. This section discusses some of the practical experiences and lessons learned.

Yanuca roll-out

Six months after introduction of five stoves on Yanuca (this was a pre launch preceding the official one described above) Kerry noticed that three were not used because the owners lacked on training in how to light and use them. One of the five trial stoves was situated too far from the cook who has a habit of weaving mats while dinner was simmering on a kerosene stove in her field of view inside house. For her, it was not practical to cook on the rocket stove in the outside cooking hut which she could not watch (Sireli found himself in a catch22 situation since he loves rocket stoves but hates burned dalo).

Eventually one of the five stove users took the initiative and demonstrated to the others how he cooked. By doing so, he spurred interest from the others to participate in the rocket stove pilot project. So it was one single stove user from inside the village who inspired the entire village to join the rocket stove pilot project.

Within the first week of the survey 15 survey forms were already lost. The solution was that households were reissued with new forms and an assistant was employed in the village at $10 per week to visit each house each week to check that each week's data was entered into the form.

At mid survey time, after the first 12 weeks data collection, only 4 households had their mandatory 50% ($30) contribution paid. Even though 19 households wanted the rocket stove, they had not budgeted for it because they had donated all their recent weeks' income to the church fundraising that week.

The solution involved the village council providing a $30 loan to each willing household. It was important that each stove user knew they owed this money but would have it refunded on survey completion, as an added incentive to complete the data entry. This loan was later repaid to the council during the next 12 weeks survey, and the householder was refunded their $30 at end of survey.

As turned out, the use of kerosene for lighting kerosene was added to the amount of cooking kerosene on all forms, perhaps because the survey instructions were only in English. At the end of the survey the forms were taken back to each household to inquire about this, and Sireli confirmed that figures for kerosene use included lighting kerosene use for all households and that second part of survey contained ONLY lighting kerosene amounts, none for cooking.

Totoya roll-out

PBF launched the rocket stove pilot project in Totoya's four villages in September 2009. Preceding this, trial stoves had been distributed to one household in each village approximately six months prior.

On arrival at each village in September, each trial stove was inspected and the users interviewed. After that inspection we held a group demonstration for the entire village to show again how the stove was lit and used. We introduced the pilot project program and conditions for survey. We gave out two more stoves to each village. This spurred interest in participating in the survey to get a free stove.
On Totoya, the survey forms were worded more carefully in English as well as the local Totoya dialect to ensure better completion with more accurate data than on Yanuca, and to eliminate entry of lighting kerosene figures.

To minimize the loss of forms from the beginning, at each village an assistant was trained on the day of introduction of the survey form. The assistants were requested to visit every household each Sunday and ensure that the forms were present and filled in, for which they would receive $10 for each round at the end of the survey. Plenty of spare forms were left with the assistants.

To maximise data collection after returning to Fiji's main island Viti Levu, Roko Joe (chief of Totoya) phoned each assistant at each village each Monday and obtained the numbers of forms that had up to date data entry. This practise instilled an awareness and a habit amongst the householders to complete the form. The first three weeks saw 95% form completion. For the susequent weeks onwards PBF has been receiving a consistent 100% completion of all forms on Totoya.

Householders on Totoya were told on the form that only $20 was needed from their village council as a bond for the stove when introduced mid-survey, and this is hoped to keep householders interested in completing the form during the second half of the survey when they will have their stoves. Householders were told they would have to pay the $20 to the council if they did not complete the second half of survey. Although the survey on Totoya has not yet been completed, to date, this practise has created a strong interest in form completion.

4 Conclusions

The PBF rocket stove program on Yanuca has proven to incur significant improvements in cooking fuel consumption and smoke reduction, and has been a great success for these reasons alone. But with an average payback period of only 6 months, rocket stoves are also an effective means for reducing dependence on expensive fossil fuels.

Further improvements in fuel consumption are possible by providing for adequate firewood storage and perhaps additional training on the best use of the stove.

5 References

Duncan, J., A. Hamm, et al. (2007). Understanding the Contribution of Direct Use of Gas to New Zealand's Energy Efficiency Objectives. Christchurch, CAENZ.

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Siwatibau, S. (1981). Rural Energy in Fiji: A survey of domestic rural energy use and potential. Ottawa, Canada, International Development Research Center.

World Bank (1985). Test Results on Kerosene and Other Stoves for Developing Countries, World Bank Energy Department, Paper 27.

6 Appendix A – Survey Form

Survey for rocket stove on Yanuca by Pacific Blue Foundation

$30 Rocket Stove which beats costs of kerosene and wood fire cooking

- super hot 600F smokeless stove runs on quarter of the wood, cooks faster, saves time and money spent on kerosene or wood collecting.
- cleaner burning, eyes are clear and breathing is good, owers CO2 emissions into atmosphere

Many of you pay up to $480 kerosene per year.
For only $30 you can start with a rocket stove in 3 months and save yourself a lot of money each year and save a lot of time spent collecting wood or cooking. More time to relax and do other things.

To get your rocket stove for $30 you MUST complete this survey form for 3 months before getting your rocket stove. You MUST write on this paper how much wood and kerosene you use each week for the next 3 months BEFORE getting your stove for half price of $30.

You can get all your $30 refunded, so your rocket stove will be FREE, if you continue to write on this paper all the wood and kerosene you use for the 3 months AFTER you start cooking with it.

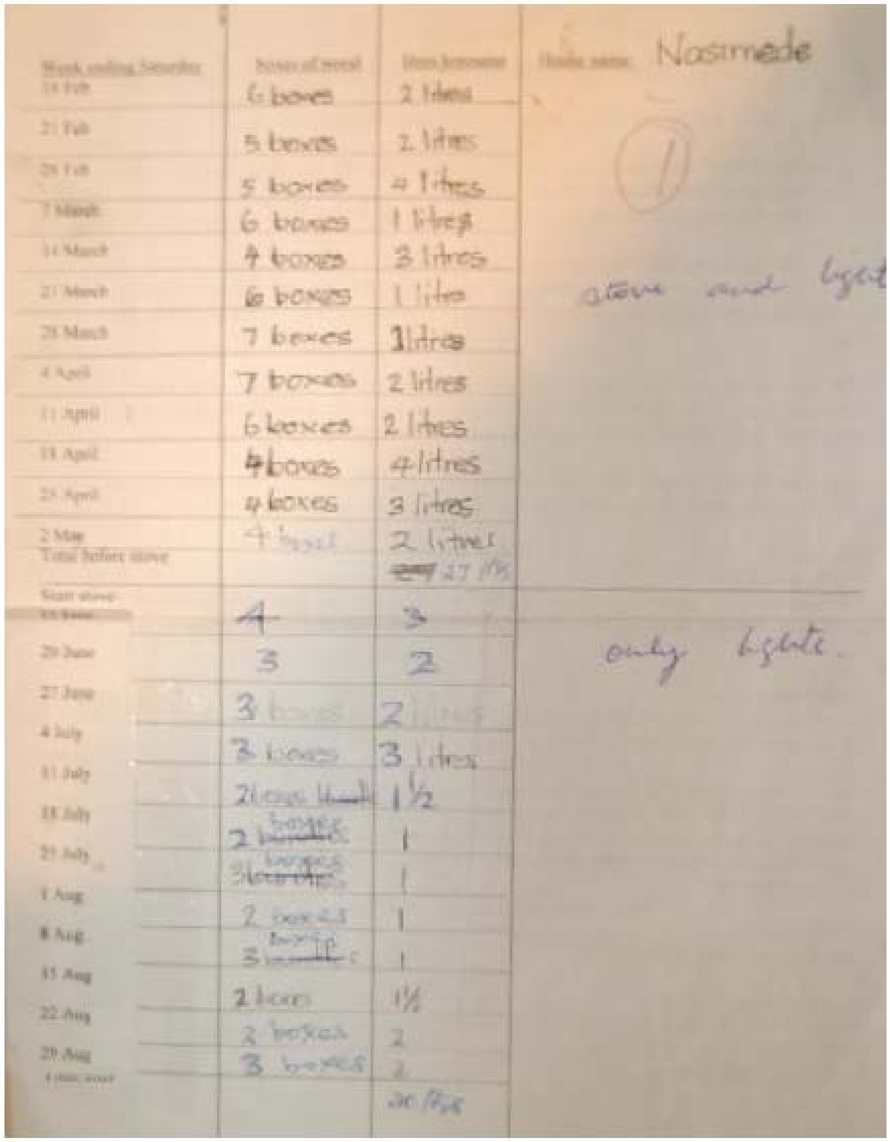
Testimonials
Bete, Yanuca Island
" Only have to buy kerosene for the lamp, all cooking done on the rocket stove, saves money, saves time collecting firewood. Even my small 4 year old grandson collects little pieces of wood now, its that easy"

Sireli, Yanuca Island
" Since having my stove the last four months I have not bought any more kerosene. Its easy to use and has saved me about $160 I would have spent on kerosene"

Inoke, Assistant Roko Tui, Navua Provincial Office.
"makes cooking delicious, different from cooking with kerosene, very tasty. We're not buying $10 kerosene a week so I'm saving $520 a year. Its easily carried and if it rains I can take it inside because there is no smoke and the fire is safe. I use about a quarter of the wood I do with an open fire I no longer use"

Sireli Kago
Turaga ni koro, Yanuca Island

Kerry Donovan
Pacific Islands Coordinator, Pacific Blue Foundation
ph+679 9924368
www.pacificbluefoundation.org



			Nasmede
	6 boxes	2 litres	①
	5 boxes	2 litres	
	5 boxes	4 litres	
	6 boxes	1 litres	
	4 boxes	3 litres	
	6 boxes	1 litre	stove and light
	7 boxes	1 litres	
	7 boxes	2 litres	
	6 boxes	2 litres	
	4 boxes	4 litres	
	4 boxes	3 litres	
	4 boxes	2 litres	
		27 litres	
	4	3	
	3	2	only lights.
	3 boxes	2 litres	
	3 boxes	3 litres	
	2 boxes	1½	
	2 boxes	1	
	3 boxes	1	
	2 boxes	1	
	3 boxes	1	
	2 boxes	1½	
	2 boxes	2	
	3 boxes	2	
		20 litres	

7 Appendix B – Survey results data

Table 2: Rocket stove survey raw data. Each row contains the firewood consumption in boxes (8.5kg per box on average) per week across the 19 participating households. The weeks up to the 2nd of May are prior to rocket stove introduction, and the subsequent weeks after.

Household >	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
14-Feb	6	5	3	6	1	2	8	7	3	3	4	3	2	6	2	1	2	2	5
21-Feb	5	6	3	6	1	2	6	6	2	3	6	3	3	6	2	1	2	2	5
28-Feb	5	5	3	5	2	2	4	5	3	2	5	2	4	7	2	1	4	2	4
7-Mar	6	5	3	4	2	4	10	8	3	4	4	3	3	6	2	1	4	2	5
14-Mar	4	6	3	4	3	1	12	7	4	6	5	3	4	6	2	1	2	2	4
21-Mar	6	7	3	6	4	2	15	9	4	2	5	2	4	6	2	1	1	2	3
28-Mar	7	5	3	7	2	2	5	8	3	3	4	2	5	8	2	1	1	2	5
4-Apr	7	5	3	5	3	1	7	7	3	6	5	2	3	9	2	1	1	3	5
11-Apr	6	6	3	6	3	2	9	6	3	4	5	3	5	9	2	1	2	2	4
18-Apr	4	6	3	6	4	2	13	4	2	3	6	3	4	3	2	1	2	2	5
25-Apr	4	7	3	5	3	2	8	7	2	5	5	3	3	6	2	1	1	3	5
2-May	4	4	3	4	3	3	10	5	3	4	4	2	4	2	2	1	1	3	
13-Jun	4	5	2	2	2	2	4	3	1	4	5			1	0.5	1	2	1	2
20-Jun	3	3	2	2	1	3	4	7	1	4	4	1		1	0.5	1	2	0.5	2
27-Jun	3	3	2	3	1	2	4	4	1	3	6	1	6.5	1	0.5	1	2	0.5	1.5
4-Jul	3	3	2	2	1	1	3	3	2	3	5	2	7	1	0.5	1	2	1	2
11-Jul	2	4	2	1	1	3	4	5	2	3	3	1	5	1	0.5	1	4	0.5	2
18-Jul	2	3	2	2	1	1	2	6	1	3	2	1	5	1	0.5	2	4	0.5	3
25-Jul	3	3	3	2	1	1	4	4	1	2	4	2	4	1	0.5	2	4	1	2
1-Aug	2	3	3	2	1	1	3	3	1	2	3	1	3	1	0.5	2	2	1	2.5
8-Aug	3	4	3	2	1	1	2	2	1	3	5	1	5	1	0.5	2	2	0.5	1.5
15-Aug	2	3	2	3	1	1	4	8	1	3	5	1	5	1	0.5	1	2	1	1
22-Aug	2	3	2	3	1	1	3	3	1	3	3	1	3	1	0.5	2	2	0.5	2
29-Aug	3	2	2	3	1	1	2	4	1	3	2	1	3	1	0.5	2	2	1	2

Table 3: Rocket stove survey raw data. Each row contains the weekly kerosene consumption in liters across the 19 participating households for cooking AND lighting. The weeks up to the 2nd of May are prior to rocket stove introduction, and the subsequent weeks after. Note all households were surveyed again after forms returned, and all except one household said they stopped using kerosene for cooking after 6 June, from when they had received their new stove. So all the figures (except for that one household) after 2nd May refer only to lighting kerosene.

Household >	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
14-Feb	2	2	4	3	1	2	4	1	3	3	5	1	4	3	1	2	2	2	3
21-Feb	2	3	4	3	1	2	2	1	5	3	2	1	4	3	0.5	0.5	2	2	3
28-Feb	5	3	4	3	1	2	5	1	5	3	4	1	3	2	0.5	0.5	2	2	5
7-Mar	1	2	4	2	1	3	1	1	5	4		1	4	3	0.5	2	2	2	4
14-Mar	3	3	4	2	2	2	5	2	3	3	3	1	2	3	0.5	0.5	2	2	3
21-Mar	1	3	4	4	2	2	1	2	5	3	1	2	4	3	0.5	2	2	1	3
28-Mar	1	3	4	2	1	1	6	1	5	2		2	2	2	0.5	1	2	1	4
4-Apr	2	3	4	3	1	2	2	1	3	3	3	2	4	1	0.5	2	2	2	3
11-Apr	2	2	4	4	2	2	6	1	5	3		1	2	1	0.5	2	3	2	5
18-Apr	4	3	4	2	2	2	4	1	3	4	5	1	2	2	0.5	1	3	1	3
25-Apr	3	2	4	4	2	2	2	1	4	3	4	1	2	1	0.5	1	2	2	3
2-May	2	3	4	2	2	2	4	1	3	2	2	1	2	5	6.5		2	2	
13-Jun	3	1	1	2	1.5	1	5	1.4	3	2	1	1	2	0.5		1	2	1	2
20-Jun	2	1	1	1	1.4	1	2	1.4	3	3		1	1	0.5		1	2	0.5	
27-Jun	2	1	1	2	1.4	1	4	1.4	2	4		1	1	0.5		1	2	0.5	
4-Jul	3	1	1	2	1.4	1		1.5	2	3	2	1	1	0.5		1	2	1	
11-Jul	1.5	1	1	1	1.4	1	3	1.5	2	4	2	1	2	1		1	2	0.5	
18-Jul	1	1	1	2	1.4	1	1	1.4	2	3	2	1	1	1			2	0.5	
25-Jul	1	1.5	1	2	1.4	1		1.4	2	3	5	1	2	0.5			2	1	2
1-Aug	1	1	1	2	1.4	1	3	1.4	2	3	1	1	1	0.5			2	0.5	
8-Aug	1	1	1	2	1.4	1		1.4	2	3	2	1	2	0.5			2	1	
15-Aug	1.5	1	1	1	1.4	1	5	1.4	2	4		1	1	0.5		1	2	0.5	
22-Aug	2	1	1	2	1.4	1	4	1.4	2	3	4	1	2	6		1	2	1	1
29-Aug	2	1	1	2	1.4	1	2	1.4	2	3	2	1	1			1	2		

NIWA
Taihoro Nukurangi

Specifications

Solar system for Yanuca Island

Client: The Pacific Blue Foundation

Prepared by: A Hamm

Date: December 2009

Background

Yanuca is a small island, 10 km south of the main island of Viti Levu. The island has a population of less than 300, all staying in Yanuca village. At present, Yanuca has no electricity supply. The Fiji government had installed an inefficient diesel generator system, however, residents found the fuel bills unaffordable. As an alternative to diesel electricity, the Pacific Blue Foundation is investigating options for supplying solar electricity to Yanuca. This document specifies a package solution for simple solar energy systems.

Requirements

1. The solar system shall supply enough electricity for:
    a. Basic lighting
    b. Radio
    c. Mobile recharging
    d. Small appliance battery recharging
2. The solar system shall be robust and tolerable of modest abuse.
3. The solar system shall use standard components which are easy to source and replace

4. The solar system shall be easy to self-assemble with a simple assembly manual and minimal guidance, and easily disassembled before extreme weather conditions such as high winds, hail, heavy rain, tsunami.
5. The solar system shall be expandable to accommodate more energy intensive appliances such as television and DVD players
6. The solar system shall accomodate mobile charging

System components and costs

System components were priced from a range of suppliers. The most helpful supplier with the best range of products and reasonable prices was CBS Power Solutions. Other standard system components are sourced from Dick Smith Electronics (DSE) and Clay Engineering. The list of recommended components and cheapest suppliers (prices as of November 2009) is shown in the table below.

Item	Supplier	Qty	Cost	Extended
Solar panel 20W	CBS	1	$250.00	$250.00
Mounting frame	CBS	1	$60.00	$60.00
Charge controller, 10A	Clay Eng	1	$100.00	$100.00
Battery, sealed LA, 25 AH	CBS	2	$140.00	$280.00
12V fluorescent lights	CBS	4	$30.00	$120.00
Double cig socket	DSE	2	$20.00	$40.00
Car cell phone charger	DSE	1	$35.00	$35.00
Light duty cable, 1.5mm2	DSE	60	$2.00	$120.00
Fittings and switches	DSE	1	$50.00	$50.00
Total				$1,055.00

System service

The performance of the above system was simulated for Yanuca conditions. An example of electricity services achievable are shown in the Table below. If any households require additional hours of lighting, they may purchase an additional solar panel and an additional battery, with advice on introducing new battery to used battery system.

	Use	Energy per use	Average energy per day
Mobile recharge	3 charges per week	4 Wh	2

Recharge AA cells	3 charges per week	8 Wh	3
Radio	13 hours/day	1 Wh	13
Light 5W	5 hours/day	5 Wh	25
Light 10W	2 hours/day	10 Wh	20
Total			63

System delivery

We recommend negotiating the supply of complete package solutions with one of the solar system suppliers in Fiji. The suppliers may also be able to send a technician to the island for setup instructions and training.

NIWA
Taihoro Nukurangi

Technical overview

Energy options for Yanuca Island

Client: The Pacific Blue Foundation

Prepared by: A Hamm

Date: December 2009

Introduction

Yanuca Island is a small community of approximately 52 households and 350 residents. Yanuca has had a diesel generator electricity supply system, but the generator broke down in 2009. This overview compares three options for reinstating electricity to Yanuca. All costs are in Fiji dollars.

Option 1 - Accept DOE offer – 35kVA generator

Description

DoE offered to install a brand new 35kVA replacement diesel generator. The electricity supply would be almost identical to the previous generator system.

Previously, Yanuca's village generator was irregularly run for about 2 hours per night. Typically, village generators run for four hours per night, but this was never possible on Yanuca due to exceptionally high fuel costs.

Advantages for Yanuca

- Low initial investment ($2800)
- No change to household wiring and installed lights
- Can run a wide range of appliances

Disadvantages for Yanuca

- High operating costs
- Noise and air pollution
- Low generator life expectancy[1]
- Diesel needs to be shipped to the island
- Unfair distribution of costs (low and high users are paying the same rates)
- Diesel prices are expected to increase significantly within generator lifetime
- No redundancy – if the generator breaks down, no one has power
- Dependency – if some households are unable to pay the bill, everyone is affected
- Intermittent electricity supply – typically four hours per day (Yanuca could previously only afford to pay diesel for 2 hours of operation per day)

Costs

A summary of lifetime costs for the generator is given in the Table below. Costs are based on generator operation for four hours per night. The "Low use" case means that people will use little electricity, i.e. as much as was used with the previous generator. The "High use" case is if the new generator is used to its full capacity. All costs are in Fiji dollars.

Initial investment	$	2,800.00			one of
Maintenance and repair costs	$	500.00			per year
	Low use (5kVA)		High use (35kVA)		
Fuel costs	$	6,657.60	$	23,301.60	per year
Total life cycle costs over 20 years	$	145,952.00	$	478,832.00	20 years
Average cost per connection	$	11.69	$	38.37	per month

Option 2 – Purchase smaller generator - 15kVA

Description

Accepting the DoE offer of a large generator is tempting due to the low initial costs (high government subsidy). However, employing a generator much bigger than required can cause a range of problems, including high fuel consumption and early generator failure.

Hence option 2 investigates a smaller generator system, acquired by the village without government subsidy. The cost for the village is higher but there are significant pay-offs in the long run.

[1] Unless Yanuca increases its electricity demand by 400% or more, the generator will fail prematurely due to under utilization.

Advantages for Yanuca

- Moderate initial investment ($20,000)
- No change to household wiring and installed lights
- Can run a wide range of appliances (sufficient capacity to double previous electricity use)

Disadvantages for Yanuca

- High operating costs
- Noise and Air pollution
- Diesel needs to be shipped to island
- Unfair distribution of costs (low and high users are paying the same rates)
- Diesel prices are expected to increase significantly within generator lifetime
- No redundancy – if generator breaks down, no one has light
- Dependency – if some households are unable t o pay the bill, everyone is affected
- Intermittent electricity supply – typically four hours per day

Costs

A summary of lifetime costs for the generator is given in the Table below. Costs are based on generator operation for four hours per night. The "Low use" case means that people will use little electricity, i.e. as much as was used with the previous generator. The "High use" case is if the new generator is used to its full capacity, in this case 10kVA on average.

Initial investment	$	20,000.00			one of
Maintenance and repair costs	$	200.00			per year
	Low use (5kVA)		High use (10kVA)		
Fuel costs	$	4,438.40	$	7,767.20	per year
Total life cycle costs over 20 years	$	112,768.00	$	179,344.00	20 years
Average cost per connection	$	9.04	$	14.37	per month

Option 3 – Solar system alternative

Description

Every household receives individual solar electricity systems. The initial costs are a little higher than a village diesel generator but there are no ongoing fuel costs. In order to make the initial expense easier to afford, the Pacific Blue Foundation may offer loans which can be repaid over time.

Advantages for Yanuca

- Low ongoing costs
- Electricity 24 hours a day
- No dependence on fundraising difficulties of other villagers
- High system flexibility and expandability
- Reduced diesel shipping

- No noise and diesel fumes
- High reliability

Disadvantages for Yanuca

- High initial cost
- No high use electric appliances possible
- Repayment of loans may be difficult in practice

Costs

A summary of costs is shown below. Due to the different nature of solar and diesel electricity systems, a direct comparison is not practical. The two low use and high use options below are quite different than above. The low use option is a small simple solar system which provides for lighting, radios and cell phone charging. The high use option is for the basic solar option plus an extension to allow for operating TVs. The initial investment figures in the table below include solar systems for every household. This works out to $1055 or $1583 per household for the low and high use options respectively. Maintenance and repair costs include a provision for periodic replacement of batteries (life expectancy: approx. five to ten years)

Initial investment	$ 54,860.00		one of
Maintenance and repair costs	$ 2,000.00		per year
	Low use (basic)	High use (TV option)	
Fuel costs	$ -	$ -	per year
Total life cycle costs over 20 years	$ 94,860.00	$ 122,290.00	20 years
Average cost per connection	$ 7.60	$ 9.80	per month

Taihoro Nukurangi

Energy Use and Future Potential of Totoya Island, Fiji

NIWA Client Report AKL2010-009
January 2010

NIWA Project: NEEA0101

Energy Use and Future Potential of Totoya Island, Fiji

Authors

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Prepared for

Pacific Blue Foundation

NIWA Client Report: AKL2010-009
January 2010

NIWA Project: PBF10101

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Rilke de Vos Energy Research Engineer Auckland	Ken Becker Regional Manager Auckland

Executive summary

The Pacific Blue Foundation (PBF) is a non-profit, public benefit, charitable trust which provides basic research, education, encouragement and dissemination of sustainable technologies and industries in the region of the island nations of the South Pacific. PBF have long recognised that access to energy has a significant influence on the economic, social and cultural well-being on the residents of the more remote islands of the South Pacific, but there has been little research to support this understanding.

In order to identify how energy infrastructure impacts the citizens of outer Fijian islands, PBF commissioned the National Institute of Water and Atmospheric Research Limited (NIWA) to survey how energy is currently being used, and the potential for sustainable energy solutions of four islands in the Yasayasa Moala Group, Fiji.

The study involved Andreas Hamm (NIWA) undertaking a survey with several PBF staff (Kerry Donovan, Roko Sau Roko Josefa Cinavilakeba, Sireli Kago) during October 2009, followed by a desktop analysis. As often happens with surveys of these remote islands, difficulties with boat services meant that it was only possible to survey Totoya Island. This report summarises the findings of the field survey, and presents preliminary assessments of the energy opportunities that are applicable to Totoya Island, the surroundings islands in the Lau Group, and wider Fiji. Some of the key findings from the field survey were:

The population of Totoya is declining, despite a high birth rate. The residents of Totoya Island live a traditional lifestyle, where most necessities of life are sourced from the land. The predominant income earning activities are cutting copra and weaving mats. Much of this income (approximately 2/3) is spent on fuel purchases. These fuels are inefficiently used for outboard engines, cooking and lighting.

The Fijian government has installed three diesel generator village power supplies but none are operational. All generators are significantly oversized, and 25% to 75% of generator fuel costs could be saved with appropriately sized generators. Despite the inefficiency, it appears that generator systems did not fail because of high fuel costs, but because of an inability to organize fund raising.

Simple per household solar electricity systems could fulfil Totoya's most important electricity needs in a cost effective way.

Totoya Island has an estimated potential coconut resource of up to ten times the current production of 224 tons per year. But coconut exports are not constrained by plantations but by shipping services. People on Totoya are not extracting the full value of copra exports because most people are using middle men such as shop-keepers or the church.

Producing coconut oil on Totoya for fuel is possible, but there may also be an even better business opportunity in exporting high grade coconut oil products within a cooperative framework.

Contents

Introduction

1.1 Background

The Pacific Blue Foundation (PBF) is a non-profit, public benefit, charitable trust which provides basic research, education, encouragement and dissemination of sustainable technologies and industries in the region of the island nations of the South Pacific. PBF have long recognised that access to energy has a significant influence on the economic, social and cultural well-being on the residents of the more remote islands of the South Pacific, but there has been little research to support this understanding.

In order to identify how energy infrastructure impacts the citizens of outer Fijian islands, PBF commissioned the National Institute of Water and Atmospheric Research Limited (NIWA) to survey how energy is currently being used, and the potential for sustainable energy solutions of four islands in the Yasayasa Moala Group[1], Fiji.

The study involved Andreas Hamm (NIWA) undertaking a survey with several PBF staff (Kerry Donovan, Roko Sau Roko Josefa Cinavilakeba, Sireli Kago) during October 2009, followed by a desktop analysis. As often happens, with surveys of these remote islands, difficulties with boat services meant that it was only possible to survey Totoya Island. This report summarises the findings of the field survey, and presents preliminary assessments of the energy opportunities that are applicable to Totoya Island, the surroundings islands in the Lau Group, and wider Fiji.

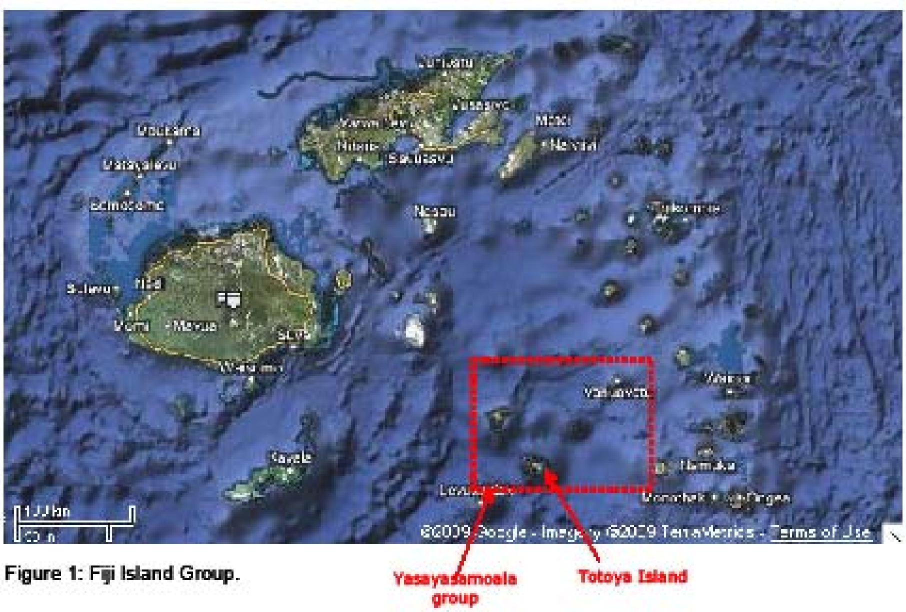

Figure 1: Fiji Island Group.

[1] The islands that were to be studied included: Totoya, Moala, Matuku, and Vanuavatu.

1.2 Totoya Island

Totoya, Moala and Matuku islands are peaks of oceanic central volcanoes on the Indo-Australian Plate (Clark, Cole et al. 1999), and form part of the Yasayasa Moala group. Totoya Island, which was the subject of this study, lies 200 km South East of Viti Levu, the main island of Fiji. Figure 1 shows the location of Totoya Island within the Fiji Islands Group. Totoya Island is situated at 18.9°S, 179.8°E.

The topography of Totoya Island is characterised by a ring of volcanic hills surrounding a large lagoon, which strongly influence the location of villages (see Figure 2). The island was created by volcanic eruptions 4.9 million years ago (Coulson 1976). The island describes a horseshoe rim with a ridge spine of multiple steep peaks 180 to 360 meters in elevation. The rim extends to an outside diameter of 10 km. The central lagoon is approximately 50 meters deep. The volcanic island shows diverse topography, with many valleys and creeks. The coastline is comprised of volcanic cliffs dotted with many small and some longer beaches.

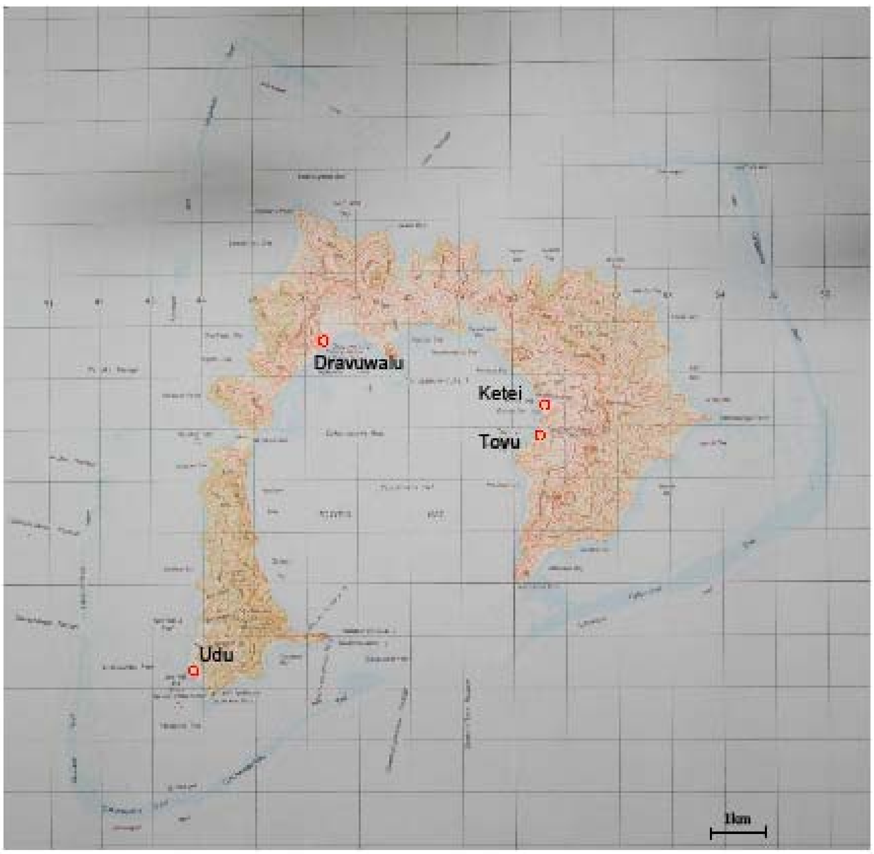

Figure 2: The topography of Totoya Island.

There are four villages on the island:

1. Tovu is the capital village of Totoya Island. The chief of Tovu village in olden days was the Paramount Chief of all the Yasayasa Moala group of islands.
2. Ketei village is only 600 meters away from Tovu. The only pier on Totoya is located between these two villages.
3. Dravuwalu village is located on the opposite side of the lagoon from Tovu. All goods moving between the ferry pier and Dravuwalu and Udu villages have to be carried by fibreglass boats with outboard engines.
4. As the only settlement outside the lagoon, Udu is the most remote village on Totoya.

As is typical of islands in the Yasayasa Moala group, the connection of Totoya Island with greater Fiji is via an irregular (mostly monthly) inter-island ferry service (see Figure 3). There is no fixed schedule: Typically, people call the ferry company every few days to find out the most likely date and time for ferry departure. The shipping vessels and companies change as much as the schedules. The boat trip takes between one and two full days, depending on the route chosen by the captain on the day.

Figure 3: Monthly ferry at Yaroi wharf, Matuku, enroute to Totoya.

The villages on Totoya Island are built in accord with traditional order - the houses are generally clustered fairly close together on the grassy village grounds. There are no fences. A significant portion of daily chores, such as washing laundry, takes place outside and residents interact freely and frequently. A special house site is reserved for the village chief.

Totoya Island's vegetation is largely deforested and overgrown by the invasive giant grass Miscanthus floridulus. Some areas of native Cibicibi (Maniltoa brevipes) and Cau (Casuarina nodiflora) forests remain (Cole 1996), particularly in less accessible parts of the island. Most of the land along the coastline is planted in coconut. Many patches of vegetable and root crop plantations can be found in the hills near the villages. The village grounds are generally kept in short grass, with single trees interspersed for shade.

Totoya Island has a tropical climate with monthly average temperatures always above 25°C. There is no weather station on Totoya, but the Matuku[2] station - less than 50 km away - is considered to be representative of Totoya's climate.

There is a small seasonal variation in temperature on Totoya, with average temperatures of 27°C in summer, dropping to 25°C in winter (Figure 4)

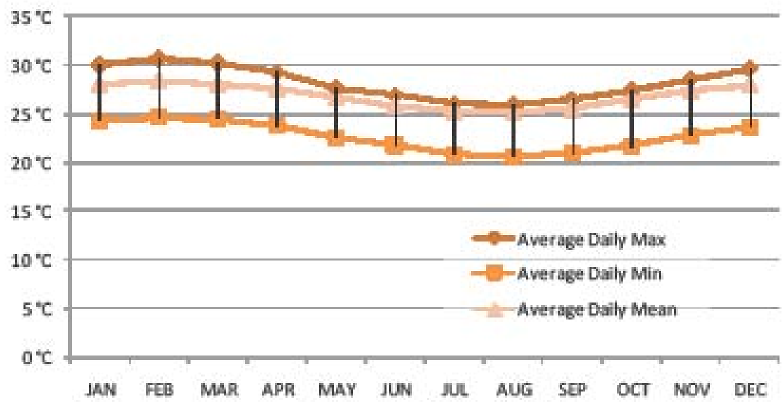

Figure 4: Seasonal air temperature profile recorded at the Matuku weather station. The chart is based on Fiji Meteorological Office data from 1951 to 1999.

The average rainfall is 1815 mm per year. The average year shows a build-up of rainfall levels towards 250 mm per month in mid-summer. Rainfall levels then drop to 100 mm in autumn (Figure 5).

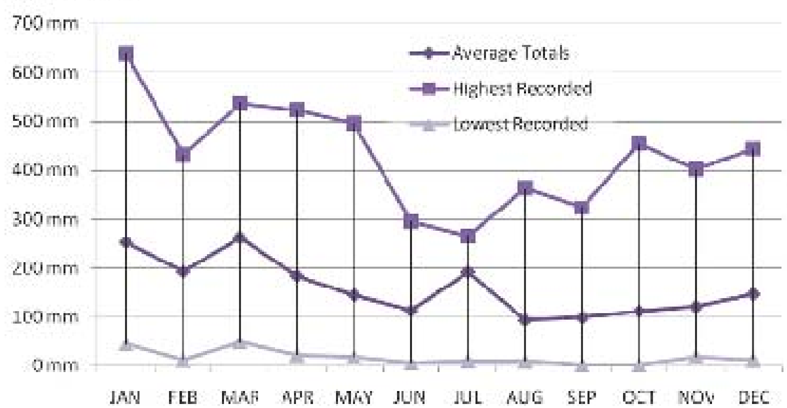

Figure 5: Seasonal rainfall profile (mm per month) recorded at the Matuku weather station. The chart is based on Fiji Meteorological Office data from 1951 to 1999.

[2] The Matuku weather station (ID W69600) is located 19°08'S, 179°44'E. The station is read out manually every 3 hours and has a 3m mast. In 1999, the station was unsuccessfully converted to an AWS, and has now been reverted back to a manual station. Data beyond 1999 was not available from the Fiji Meteorological Office at this stage.

While the wind data has been recorded on Matuku, the data is of limited use due to low elevation of monitoring mast and poor exposure to the prevailing winds. The mast position is shown in Figure 6, with the arrow indicating the prevailing wind direction. The wind data in Figure 7 shows no significant seasonal variation, but there is a 20% to 30% drop in wind speeds in summer compared to the rest of the year. This drop is to be expected due to the southward shift of the inter-tropical conversion zone in summer.

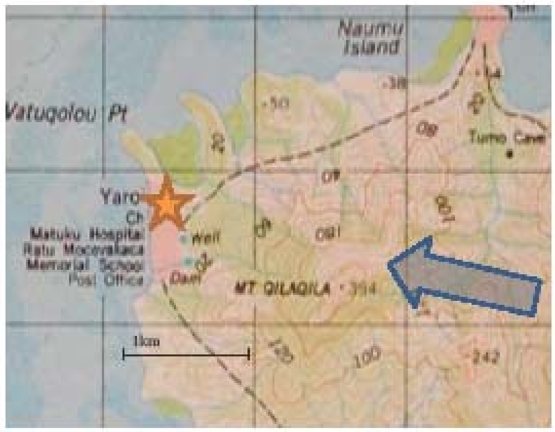

Figure 6: Location of the weather station on Matuku Island (star). The arrow represents the predominant wind direction.

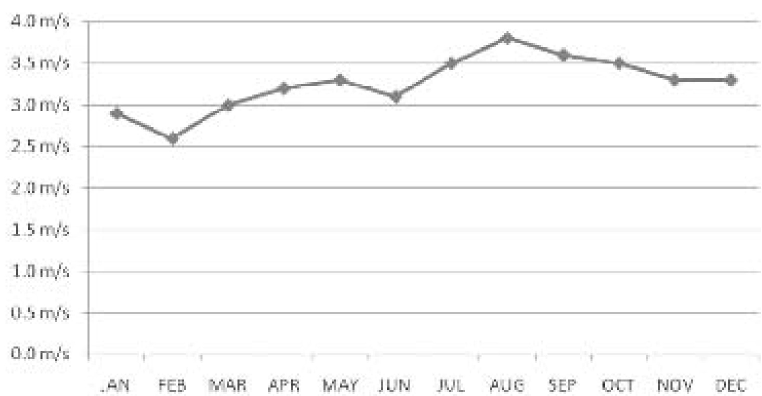

Figure 7: Seasonal wind speed profile (3 meter mast) recorded at the Matuku weather station. The chart is based on Fiji Meteorological Office data from 1979 to 1999.

2 Results of field survey

In order to understand the energy challenges and opportunities of the residents of Totoya Island, a field survey was undertaken between 7th September and 14th October 2009. The survey design and template was based on previous surveys undertaken by Andreas Hamm. The survey form (see appendix A) covers the following topics:

- Demographics
- Lighting
- Household electric appliances
- Cooking facilities
- Fuel use
- Energy issues
- Electricity supply options
- Community needs
- Island development options

The survey captured data from more than 60% of the residents on Totoya Island and is summarised below.

2.1 Demographics

Archaeologists suggest that humans settled Totoya at least 2,500 years ago, and possibly several centuries earlier (Clark, Cole et al. 1999). We are not aware of a historic population profile for Totoya, but residents suggest that numbers have dropped from more than 2,000 over the last 50 years. Today's population of 480[3] consists almost exclusively of ethnic Fijians.

NIWA collected demographic data from 61 households, and asked participants to list the age and gender of all household members. The resulting population pyramid is shown in Figure 8. The shape of a population pyramid contains clues about population trends. The Totoya Island pyramid indicates a population exhibiting extreme growth with high levels of migration from age bins "10 to 14" to "15 to 19". This observation was confirmed through discussion – the residents indicated that a lot of the young leave the island in order to attend a high school on Moala Island or mainland Fiji, and often never return.

A high level of migration was also evident from Kerry Donovan's 2008 survey, that observed that between 15% and over 50% of houses were abandoned and uninhabited in various villages.

[3] Estimate of island chief – Roko Sau

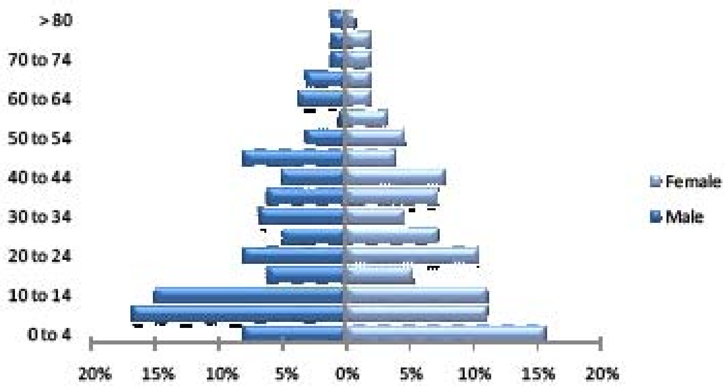

Figure 8: Population pyramid of Totoya, based on the NIWA 2009 survey.

Economic activity dominated by traditional copra

The people of Totoya live a traditional lifestyle with strong Western influences. Land rights are passed down from generation to generation, and there is no shortage of food during normal climatic conditions. Cyclone damage can seriously affect staple food crops short term because plantations are not well protected. Every household has gardens and plantations for producing their own agricultural products. The sea is another principal source of food, and the citizens of Totoya Island enjoy relatively rich fishing grounds. The monetary economy on Totoya is small. The NIWA survey found the average household income to be $135 per month while the median income was only $60 per month[4]. This indicates a relatively uneven distribution of income with few high earners and a majority of low earners. Figure 9 shows how many households engage in different economic activities. By far the most common way of earning income was copra production and weaving mats. The production and sale of coconut oil and other farm products is common, but volumes of production are extremely low. Kava is listed separately since it produces very high returns when compared to other crops.

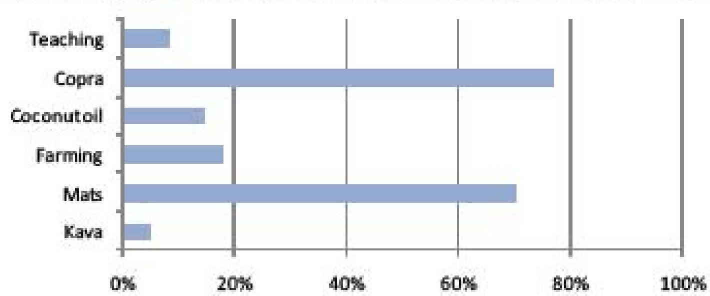

Figure 9: Level of engagement in commercial activities as percentage of households, based on the NIWA 2009 survey.

[4] Households were asked to record their average monthly household income (see survey form in the appendix).

The reported cumulative annual income of all households on Totoya combined is approximately $160,000 (interpolated from surveyed to total population[5]).

2.2 Lighting

Lighting is particularly important to the residents of Totoya Island since light is required for all domestic activities after sunset. Figure 10 gives an overview of penetration of different lighting technologies on Totoya Island. Short and long tubes refer to standard fluorescent light tubes of 18 watt (short 2 feet tube), and 40 watt (long 4 feet tube). When the Department of Energy installs electricity grids, they typically supply 2 or 3 short fluorescent tube lights to every household. The appliance penetration of 200% for Tovu and Ketei means that on average two tube lights are installed in each household. Since Udu never had a communal generator, only very few tubes are installed in this village. These are occasionally powered by private generators.

Non electric lighting is dominated by kerosene lanterns: On average, every household owns more than two lanterns. Kerosene lanterns are used for general lighting, but also as night lights. Benzene lanterns produce significantly more light than kerosene ones, but are more expensive to run and thus only used sparsely. To illustrate: our survey found that kerosene lanterns were used for an average of 10.5 hours per day, while benzene lanterns were used for 1.5 hours per day.

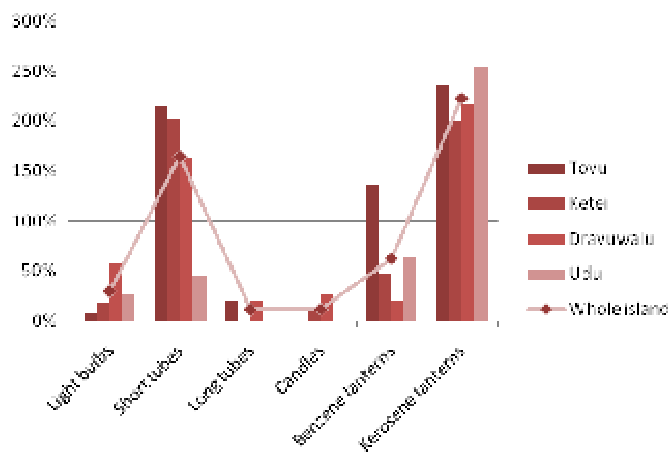

Figure 10: Penetration of different lighting technologies on Totoya.

2.3 Household electric appliances

People on Totoya own a range of electric appliances, although many of those are hardly ever used due to the lack of electricity supply. The penetration of a range of typical household

[5] Based on the NIWA survey.

appliances is shown in Figure 11. The most popular appliances are small radios. These are typically operated with D-cell batteries which are available from some local shops. About 25% of households own televisions or DVD players. While the village generators are not operating, some people run their own small generators to watch a movie once in a while. In general, Figure 11 shows a clear drop in appliance penetration from Tovu to Ketei, to Dravuwalu and then Udu. Since Udu never had a village generator to date, people own very few electric appliances.

To our surprise we noticed that several people on Totoya were using cell phones even though there is no cell phone coverage on the island. Cell phones were used for playing games and listening to music.

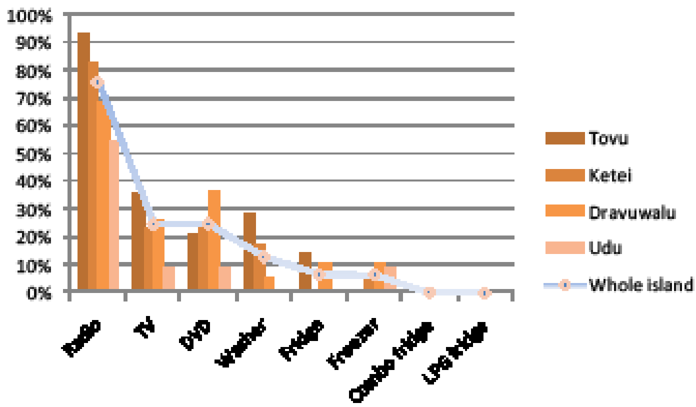

Figure 11: Appliance penetration on Totoya.

2.4 Cooking energy

The people of Totoya Island currently use four types of cooking facility:

1. LPG stoves,
2. Kerosene stoves,
3. Open fires, and
4. Traditional lovo (earth cooking) fires.

The distribution of ownership of these facilities across Totoya Island is shown in Figure 12. LPG stoves are popular in Tovu village and non-existent in Udu. LPG bottles are bulky and need to be imported from the mainland. They are therefore an expensive and unpractical choice for Totoya Island. This is particularly true for Udu and Dravuwalu, where all goods have to be brought from the ferry to the villages by small fibreglass boats with outboard engines.

Ninety percent of households own kerosene stoves in Tovu, with much lesser ownership in Ketei and Dravuwalu. Figure 12 shows clearly that the most popular cooking facilities on the island are open fires and traditional lovo fires.

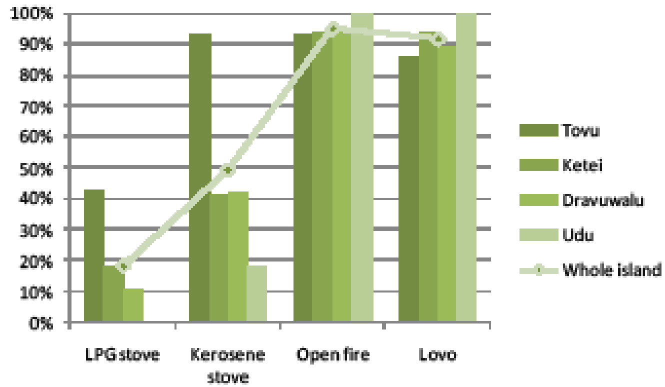

Figure 12: Penetration of different cooking facilities on Totoya.

LPG stoves on Totoya Island are typically LPG ranges with a baking oven. LPG ranges offer the only conventional type of baking oven on the island, and this may be the main attraction of LPG ranges over other types of stoves. LPG stoves are cleaner than other the other cooking facilities on Totoya Island. The efficiency of an LPG stove averages around 45% (Duncan, Hamm et al. 2007). LPG bottles are only sporadically available on Totoya Island at a price around $50 per 13 kg bottle.

Kerosene stoves on Totoya Island are of the multi-wick type. The cooking efficiency of simple multi-wick kerosene stoves was measured to be around 43% (World Bank 1985) which is in the same range as modern gas stoves. Multi-wick kerosene stoves are popular across Fiji because they are cheap to buy, easy to use and easy to maintain. The biggest disadvantages of these stoves are that kerosene releases toxic fumes[6] into the kitchen, and kerosene is increasingly expensive to buy. People on Totoya Island are currently paying $1.70 to $2.00 per litre of kerosene when bought at the local shop on the island.

Open wood fires are by far the most popular cooking facilities on Totoya Island. Firewood on Totoya Island is plentiful and most households are able to collect theirs from within a few minutes' walk of their homes. Typically the firewood is a mix of branches and other dead wood of various ages, and is collected on demand for one or two weeks in advance. Firewood is not stockpiled, dried and seasoned as is common practice in the West. Particularly during rainy periods this translates into poor wood combustion which leads to smoke and increased wood consumption. Firewood moisture on Totoya is estimated to range from 20% to 40%[7], it is likely to average at around 30%. Open cooking fires achieve an efficiency of roughly 10% (Siwatibau 1981). The efficiency of heat transfer from fire to cooking pot can vary greatly depending on how exposed the fire pit is to open winds or drafts.

[6] Kerosene has significantly higher emissions than LPG gas.
[7] This estimate is based on random samples of firewood which we measured on Totoya (2009).

As all across Polynesia, food is traditionally prepared in lovos, i.e. earth holes on hot rocks. Rocks are heated by fire until glowing red. After the remaining embers are removed, wrapped food is placed on the rocks and everything is covered with banana leaves and dirt until cooked. This method of cooking is no longer practiced for everyday meals because of long setup times and labour intensity. Today people on Totoya typically prepare lovos every Sunday as well as on festive occasions.

Rocket stoves are a new arrival on Totoya Island. At present there are ninety rocket stoves on the island, which were introduced by the Pacific Blue Foundation. Rocket stoves are efficient wood burning stoves which reduce smoke as well as fuel consumption compared with open fire cooking. Rocket stove efficiencies vary widely, but similar models to the one introduced on Totoya Island have efficiencies around 25% (Hamm 2009).

2.5 Fuel use

Fossil fuels are the main import to Totoya Island - diesel, kerosene, benzene and premix gasoline are all imported. On average, households spend about 61% of their income on fossil fuels.

Table 1 summaries the annual fuel imports to Totoya Island. The largest quantities of imported fuel are for premix, which is mainly used in outboard engines. This is followed by kerosene and benzene, which is used for lighting and cooking.

Table 1: Annual imports of fossil fuels to Totoya.

	Unit	Tovu	Ketei	Dravuwalu	Udu	Total
Gas	bottle	91	66	41	82	279
Benzene	Litre	2565	869	374	655	4464
Kerosene	Litre	4576	3224	1309	3372	12482
Diesel	Litre	0	0	0	0	0
Premix	Litre	9291	5361	1796	5566	22013

Table 2 shows the range of retail prices for fossil fuels as delivered to Totoya Island which were captured as part of the survey. To our surprise prices vary significantly between different suppliers on Totoya. The table also shows annual expenditure on fossil fuels on an island-wide and on a per-household basis.

Table 2: Annual expenditure on fossil fuel imports on Totoya.

	Unit	Min	Max	Total annual spend	Annual average household spend
Gas bottles	bottle	$48.00	$54.00	$14,216.34	$152.86
Benzene	Litre	$3.00	$4.00	$15,622.68	$167.99
Kerosene	Litre	$1.70	$2.00	$23,090.93	$248.29
Diesel	Litre	-	-	-	-
Premix	Litre	$1.95	$2.60	$50,080.58	$538.50
Total				$103,010.53	$1,107.64

2.6 Energy issues

As part of the energy survey, NIWA asked residents about their preferences on several common issues relating to energy and development. This survey captures a snapshot of peoples' opinions and attitudes towards a range of issues. We asked people to rank the significance of these on a scale from 1 to 3.

Figure 13 shows that all three, fuel cost, electricity reliability and electricity prices are perceived as very urgent issues.

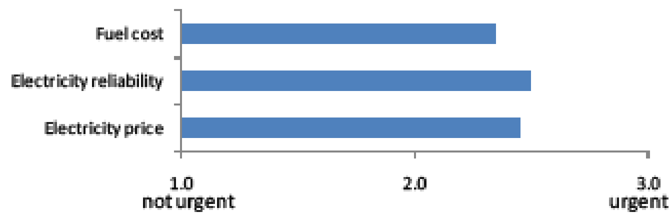

Figure 13: Survey results of most urgent energy issues on Totoya.

Preferences on three different energy generation technologies are shown in Figure 14. The results show that diesel generators are the least preferred option of electricity generation, and people appear to have extremely high confidence in solar power.

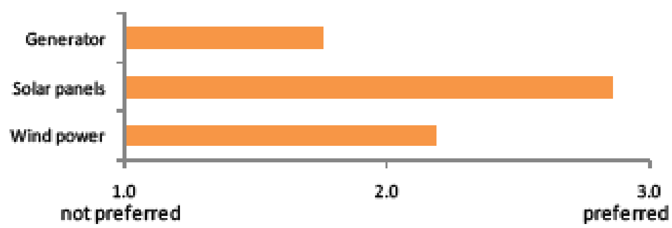

Figure 14: Survey results of preferences in generation technology on Totoya.

When asked about community needs, health was rated an urgent need by all respondents. As seen in Figure 15, very high urgency is also placed on lighting services. Refrigeration is rated as urgent, but appears to be a significantly lower priority than lighting.

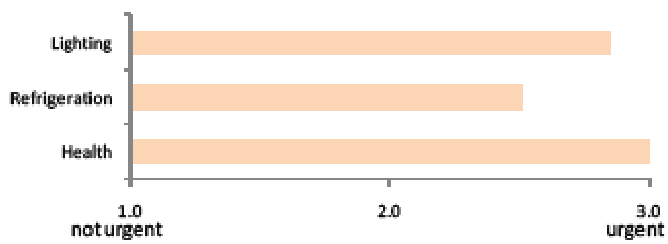

Figure 15: Survey results of urgency of key community needs on Totoya.

As shown in Figure 16, most future development ideas would seem to be well supported on Totoya. Better education, improved ferry services and ice for fishing stand out as valued developments. As new business opportunities, cottage industries and tourism are reasonably well supported.

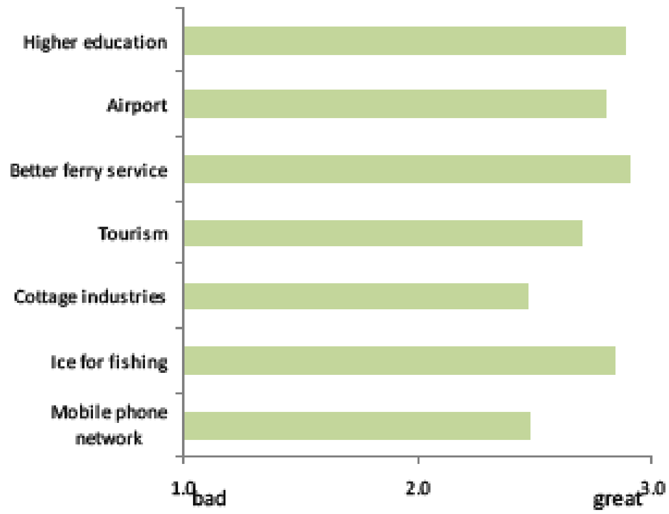

Figure 16: Survey results of attitude towards potential new developments for Totoya.

3 Living conditions and cultural context

Before focusing the attention on energy opportunities, this section explores general living conditions and some broader issues around daily life on Totoya.

3.1 Traditional village structure

The village infrastructure appears to be practical and mostly functional. Households generally have access to running water. Black water is captured in septic tanks or water sealed pits. Houses are in liveable condition, although visually in poor state of repair. While houses are small by Western standards, they appear to serve the traditional lifestyle well. A typical house has at least two areas, separated by curtains or light walls: one or more bedrooms and a large lounge. Bathrooms and kitchens are attached or free standing out-buildings. Bathrooms accommodate cold showers and toilets. Kitchens typically contain a sink, a food preparation area on the floor with kerosene or LPG stoves, as well as an open fire pit and a lovo fire pit (these are often outside under a roof). Frequent open fire cooking leads to toxic concentration of smoke in many food preparation areas and generally poor air quality in the village at cooking times.

Electricity is currently not available to a majority of houses in the villages. While electricity grids have been installed in 3 of the 4 Toyota island villages, the diesel generators powering these grids were in disrepair at the time of survey. This appears to be a typical situation on Totoya. Some small electric generators are used at high fuel cost but when electric lighting from these is unavailable, residents revert to kerosene and benzene lanterns. These produce a warm friendly light, but are also expensive to fuel and the total light output is rather limited.

Figure 17: Open grey water trench in Ketei Village.

3.2 Public health issues

While the villages on Totoya Island are largely functional, there are some observations that are important to note.

Dogs, cats, and chickens roam freely, domestic pigs are penned near houses for easy feeding. Collectively their faeces attract a high intensity of flies. Flies are so numerous that it is impossible to keep them entirely away from food. In this way, flies regularly transmit bacteria from animal faeces to human food and stomach upsets are not uncommon.

Black and grey water is channelled downhill to the beach in hand dug open trenches, sometimes reinforced with concrete. These trenches are a breeding ground for pathogens. In all four villages on Totoya Island, grey water enters the village beaches without treatment. On visual inspection, the beaches adjacent to the villages showed significant growth of sea grass and poor water quality.

The liquid portion of black water usually does not go into appropriate leach fields (as required for safe septic tank systems), but either straight into the ground or into the grey water collection trenches. This is an avenue of distributing existing harmful pathogens to other residents who directly or indirectly come in contact with the contaminated water.

Generally speaking, reticulated water supply systems in Fijian villages are a mixed blessing: reticulated water makes personal hygiene much easier, and greatly increases convenience. However, reticulated water supplies also supply a superb infrastructure for the transmission of germs. The disposal of human faeces was not a major issue on Fiji until flushing toilets were introduced.

Figure 18: Installation of Paramount Chief Roko Sau Roko Josefa Cinavilakeba on Totoya.

3.3 Strong governance

The traditional Fijian way of life has a strong hierarchical village structure and wider provincial structure. Residents highly respect their village chiefs and their Paramount Chiefs and give them full sovereignty to make strategic decisions. The traditional way of life is set to rely on a leader, and this leader is the chief of the village, who also relies on his Paramount Chief.

In the Fijian tradition, chiefly titles stay in the same families, the chiefly clans. Normally the first born son of a chief or Paramount Chief becomes his successor. Sometimes another son can be chosen if the first born is not able. When the previous Paramount Chief of Yasayasa Moala Islands passed away the communities were without an island-chief for several years because his successor was too young to take up the position until, on 29 December, 2009, he was installed on Totoya Island as Paramount Chief Roko Sau Roko Josefa Cinavilakeba.

Roko Sau, as he is correctly called by his followers since his installation, was born and raised on Totoya Island until he went to secondary and tertiary education in Suva and he is now an architect. He married his wife Makareta on Totoya Island and she also is from Totoya Island, and they now have five children.

There is positive support from government towards communities who have an installed chief or Paramount Chief because they recognise the people have sworn an allegiance to him during the Installation Ceremony and it instils a confidence in the people but also the government to support development in those communities. This leads on to a greater chance of success for development programs.

4 Utilizing Totoya's indigenous energy resources

4.1 Firewood

The residents of Totoya Island have a relatively plentiful firewood resource, which is used for cooking food and drying copra. The large firewood resource shows no signs of scarcity, with people generally collecting firewood in the form of dead branches and undergrowth trees from forests around the villages.

Firewood is collected on demand, perhaps up to one or two weeks prior to use. During particularly rainy periods, this practice results in combustion of significantly wet wood, which results in very low combustion efficiency, much smoke, and increased wood consumption. The smoke resulting from cooking over smouldering fires in confined spaces is a significant cause of health problems for residents, particularly women.

Some simple measures could mitigate this problem:

1. The construction of inexpensive firewood storage sheds – this would significantly improve the dryness of wood and thus reduce both smoke exposure and wood consumption.
2. Keeping cooking sheds open and well ventilated.
3. Introduce efficient well proven cleaner–burning rocket stoves, such as those in the October 2009 to March 2010 survey.

Figure 19: Typical method of cooking on Totoya Island. Open fire cooking areas are typically located in open sheds or outside.

4.2 Coconut oil

Coconut oil may be produced on Totoya from existing copra resources, and used as fuel for diesel generators or sold as a quality export product. This section explores current uses of the coconut resource, describes current copra production and discusses the future potential for local oil production.

Coconuts use on Totoya Island

On Totoya, coconut trees played as significant a role in traditional life as it does today. The coconut palm is easily the most versatile plant on the island. Figure 20 shows the different useable parts of a coconut in cross section view:

The coconut flesh is consumed as a snack at all stages of maturation, and coconut milk is an energy drink. Mature coconut flesh, the so called copra, is the feedstock for coconut cream and oil.

Coconut cream is an important ingredient in everyday cooking. It is easy to produce cream by grating the flesh, and squeezing out the liquid portion through muslin cloth. Totoyans also extract coconut oil from coconut cream. They often infuse this oil with flowers in order to scent it for later use as massage oil or body lotion.

Coconut shells serve as drinking and eating bowls, and the husks contain valuable fibres. These fibres have traditionally been used for making string and rope. Today people are using coconut husks only as cooking fuel in addition to firewood.

Coconut leaves are used for weaving baskets and occasionally for thatching the roofs and walls of houses. Coconut timber is being used in high quality furniture manufacture.

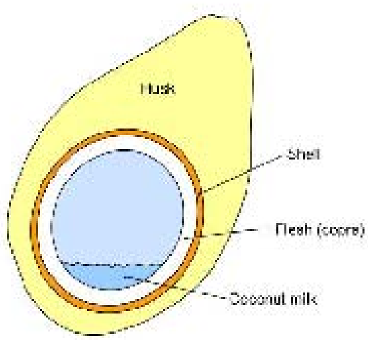

Figure 20: Cross section of a coconut.

Coconut potential much higher than current production

In an unpublished previous survey (early 2009) Fiji Coordinator Kerry Donovan (PBF) estimated a typical planting density of 140 trees per ha, a planted area of approximately 540 ha (15% of Totoya Islands total land area), and therefore a total tree count of between

76,000 and 80,000. Comparing this to the topographic map and public satellite imagery[8], this estimate seems possible but is on the high side. Without the benefit of a detailed survey on Totoya's coconut plantations, we conservatively estimate the resource to be around 60,000 trees on a planted area of 400 to 500 ha.

Well serviced coconut plantations yield between 3 and 5 tons of dried copra per ha per year, depending on the coconut tree variety. As a rough guideline, Totoya Island could be producing between 1,200 and 2,500 tons per annum without extending the area of current plantations. Kerry Donovan of PBF recently estimated Totoya's current production to be around 224 tons per year. Production could thus be increased by a factor of eight.

At present, the main limitation for extending copra production on Totoya is a constraint in shipping services: According to the shipping company currently servicing Totoya, Seaview Shipping Ltd., they are only able to carry 400 to 450 bags (20 to 22 tons) of copra from Totoya per trip. Thus, the theoretical limit for Totoya Island's copra export is around 240 tons per annum.

Unless Totoya Island arranges for alternative shipping services, there is limited scope for expanding the copra exports.

Value of copra

All copra from Totoya is sold to Punjas Ltd., Fiji's main coconut oil producer. The Coconut Industry Development Authority regulates and adjusts the copra buying price daily.

As illustrated in Figure 21, copra price can vary significantly, but has generally been increasing in price over the last 15 years. The world price reached record highs in the first half of 2008, but dropped back down to nearly $500 per ton in the last quarter of 2008. Following another price hike earlier this year, the Fiji copra price was back at $500 per ton in November 2009.

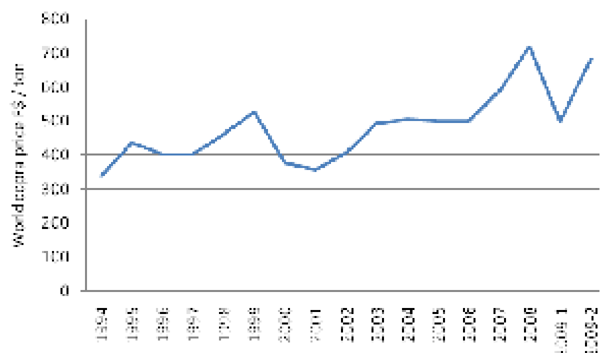

Figure 21: World price for F1 grade dry copra (Source: Fiji Islands Bureau of Statistics - Key Statistics: September 2009). The price paid for low grade (F2) copra are 10% lower (Punjas Ltd). On average, about 70% of all copra received by Punjas is F1 grade.

[8] Counting coconut trees from satellite images is normally an accurate method; however, publicly available satellite images from Google Earth® had too much cloud cover for an accurate count. Since these images are periodically updated, an accurate tree count is likely to be possible with the next image update in place.

Selling copra from Totoya Island

In 1980, the people of Totoya Island started operating a cooperative in order to handle copra sales to Punjas Ltd collectively. The cooperative went bankrupt because of a suspension of shipping service to Totoya following the 1987 political coup.

Punjas Ltd informed us that there are 10 to 15 different copra sellers on Totoya Island, these include private individuals, shop owners and church committees.

Private direct sale to Punjas Ltd yields the highest price for the producer and is easy: The bags are marked with the owners initials, and Punjas Ltd remits the balance to the owner on receipt of the product. The limitation for Totoyans lies in shipping: often the ships arrive late, and regularly there are more bags of copra waiting than the ship can carry. Thus, two months and more can pass between bagging the copra and receiving a payment.

Church committees and some shop owners offer an alternative solution: they buy the copra on the island at a lower price – currently $200 per ton for fresh or $300 per ton for dried copra - and export it to Punjas Ltd collectively. While the price difference to Punjas Ltd is considerable at 40% to over 100%, most residents on Totoya prefer this option. This may be because of immediate payments or because of the drying service the church or shop owners typically offer.

Anyone exporting from Totoya Island is liable for shipping charges of $1 per bag (approx. $20 / ton). Because shipping is charged per bag, Punjas Ltd advises that it is important to fill the copra bags up to their full capacity of 50 to 55 kg.

According to Punjas Ltd, Totoya generally produces a mix of high and low grade copra. Copra can be of lower grade for various reasons, including:

- It is not dried well enough
- It is rancid from prolonged storage
- It is dried unevenly and partly burned from fire drying.

Apart from downgrading, losses sometimes occur during shipping, for instance bags opening up through rough treatment onboard.

Collecting copra on the island

The coconut plantations on Totoya Island are located all around the island, and often far from the villages (see Figure 22). Coconuts must be transported to the villages and ultimately to the wharf between Ketei and Tovu. Presently the only means of transport is by inefficient and costly outboard fibreglass boats. As illustrated in Table 3, the cost of this transport is a significant portion of copra prices. Coconuts are transported to the village either whole or as cut copra. Economically, transporting cut copra is four times as efficient as transporting whole nuts.

It would be highly beneficial for Totoya Island's coconut producers to dry and bag copra prior to transport and to gain access to cheaper and more economical transport. This could be a small sailing cargo boat or small fuel efficient freighter.

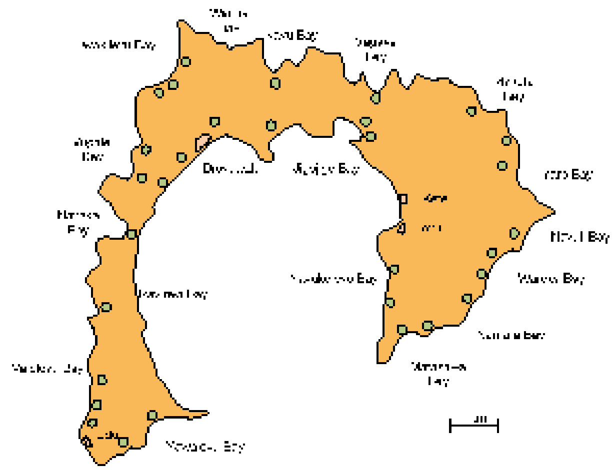

Figure 22: Map showing major coconut plantations (green dots) on Totoya.

Table 3: Fuel cost for transporting copra from plantations to the villages by outboard boat.

Roundtrip distance	F$ per ton of dried copra Whole nuts	F$ per ton of dried copra Dried & bagged
2 km	$ 40.00	$ 10.00
5 km	$ 100.00	$ 25.00
10 km	$ 200.00	$ 50.00
20 km	$ 400.00	$ 100.00
30 km	$ 600.00	$ 150.00

Producing coconut oil the traditional way

Coconut oil has been traditionally produced on Totoya Island in household quantities. The traditional processing chain from coconut to oil is shown in Figure 23. The steps involve the following: the coconut is freed of its husk, split in half, and grated on a special coconut grater by hand. The grated flesh is then squeezed by hand through a cloth. The result is relatively dry press cake and coconut cream. In a next step the coconut cream is boiled until all water is evaporated.

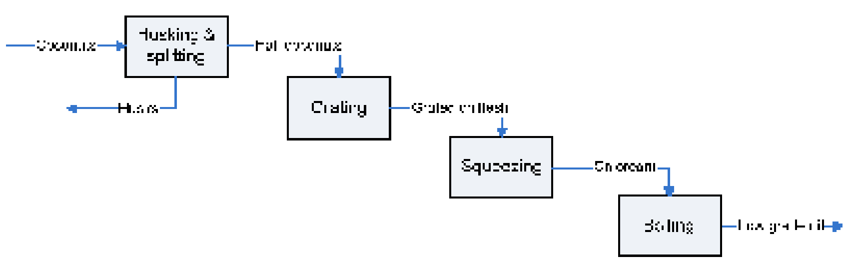

Figure 23: Processing chain for producing coconut oil on household scale the traditional way.

This method is time consuming but suitable for household or small cottage industry scale production, typically 5 to 10 litres at a time. This method tends to produce low grade oils, mainly due to the prolonged harsh heat treatment. Sampling different oils on Totoya Island, we found the quality to vary significantly and observed off flavours in many samples, as well as solid particles in others. The oils tend to be yellow to dark yellow in colour, whereas pure coconut oil is almost transparent, with no shade of yellow.

Totoyans often scent this type of coconut oil with flowers to make an attractive body oil.

Many households sell this traditional coconut oil to family members in Suva for around $10 per litre. This is a relatively high price, but volumes are low. It is unlikely that any wider markets could be accessed with this product.

Avenues for commercial coconut oil production

The processing chain of coconut oil for commercial production is shown in Figure 24Figure 25. The copra is generally cut out of the nuts on the plantations and transported to local storage and drying facilities. Copra is dried from 60% initial moisture content to a maximum of 30% residual moisture before it is stored in bags, often for weeks, and periodically delivered to the press. At the plant, copra may be dried further as required, and is then crushed and pressed under high pressure. The coconut presscake or pomace is sold and may be used as animal feed. Due to the low quality copra feedstock, oil quality tends to be very low and needs to be refined prior to consumption. The large companies use chemical refining processes to dissolve flavours out of the oil, remove acidity, bleach it, and deodorize it.

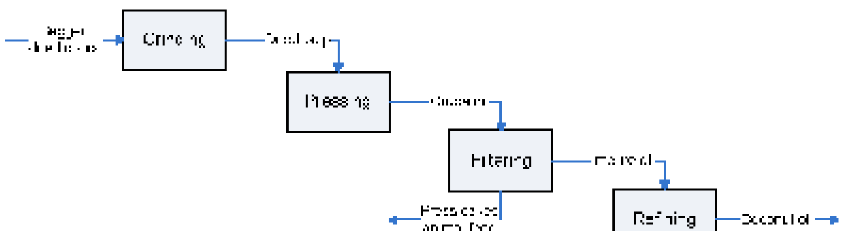

Figure 24: Large scale commercial coconut oil production.

Industrial scale coconut oil production is not suitable for Totoya Island because: the value of the oil is low, quantities have to be large, and the production equipment is complex.

With small scale coconut oil extraction technology, Totoya Island could produce small quantities of high grade oil, and thus combine the advantages of fresh processing of a high value product, and overcome the disadvantage of unreliable shipping services to the island. A typical production process for small scale coconut oil production is shown in Figure 25. The feedstock is fresh copra which is ground up and dried. The dried coconut pulp is squeezed in manual presses in order to separate fibres from oil. A filtering system removes impurities; depending on the end use, gravity filters may suffice. The economics of a small coconut oil production facility are discussed in the next section.

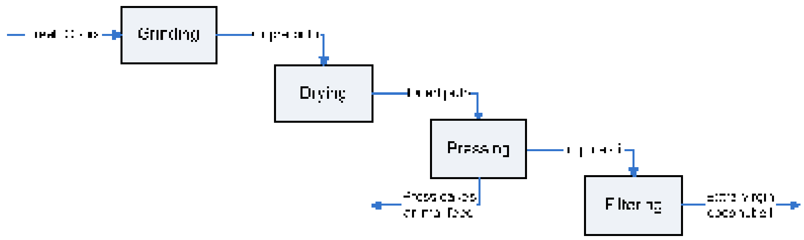

Figure 25: Small scale high quality coconut oil production.

Coconut oil production systems and costs

Coconut oil production systems can be very simple, and the initial capital outlay does not have to be high. Figure 26 shows indicative capital and operating costs of a very simple coconut oil production system. Actual costs may vary significantly depending on the local situation. For example, Totoya Island may decide to adapt the vacant old cooperative building for initial coconut oil production and save on factory construction materials. The heart of the plant is the oil press. We propose a simple manual hydraulic press such as the ones locally manufactured by John Bennett (Figure 27). This particular model presses at a high 20 metric ton pressure, produces a few litres of oil with each filling and costs F$2,500. Similar models are on the market, and the most well known is the Australian press by DME®. However, the DME press is significantly more expensive (F$7,000 + import duties + shipping).

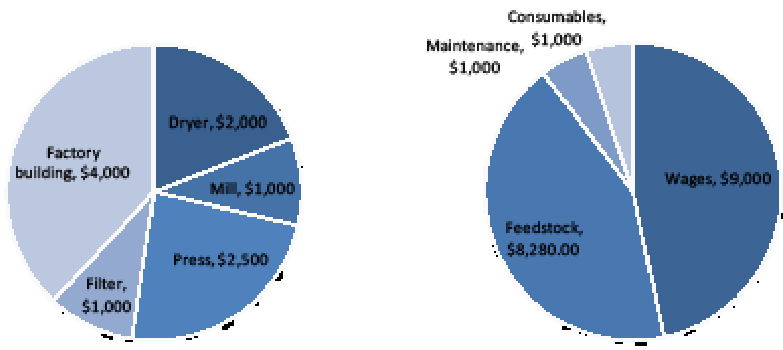

Figure 26: Indicative capital outlay (left) and operating costs (right) of a very simple coconut oil production system.

Figure 27: Hydraulic coconut oil press locally manufactured in Fiji by John Bennett (Photo courtesy of John Bennett).

From the author's personal experience the DME® press is not very robust, with mechanical parts in the lever mechanism prone to wearing out. Hydraulic presses do not exhibit this weakness.

The mill we recommend for grinding the copra before pressing is a heavy duty garden shredder. A cheaper alternative would be electric coconut graters, although these are more labour intensive to use and require external electricity.

A simple solar dryer may be constructed from stainless steel sheets, covered with glass or Plexiglass®. Wood fired dryers also work well and might be particularly useful as a backup for rainy days. Wood fired dryers currently used on Totoya Island are not suitable, because the ground copra would be exposed to smoke and uneven heating. A simple design such as the one shown in Figure 28 effectively removes the smoke through a chimney, and is easy to keep clean and hygienic.

Assuming the above system was operating as a business with two full time staff paid at $3 per hour, an annual output of 4,500 litres could be produced at a cost of $2.20 per litre. This assumes that coconuts are purchased from Totoya farmers at a price of $300 per ton for fresh copra. This is equivalent to a price of $500 per ton for dried copra, and is in the range of what Punjas Ltd would pay. This small scheme would use the equivalent of 8 tons of dried copra, or 3.5% of Totoya Island's annual production.

Figure 28: Simple wood fired copra dryer (Photo: A. Hamm).

Using coconut oil as a bio-fuel

The resulting coconut oil can be used as bio-fuel for various applications, such as:

- kerosene hurricane lanterns if mixed in a ratio of 30% kerosene to 70% coconut oil
- traditional lanterns, direct
- diesel generators if these are adapted to coconut oil
- diesel outboard engines.

Coconut oil may be used directly in modified diesel engines. Many engines can be converted and conversion kits are available from specialised suppliers. Fiji's Department of Energy issues new diesel generator installations with a coconut oil option by default.

It is also possible to process coconut oil into biodiesel, however, this requires a 10% addition of imported methanol, a toxic fossil fuel derived alcohol. Biodiesel can be produced on a garage scale with improvised equipment, but it is important to work accurately. The technical term for the chemical reaction between alcohol and coconut oil is esterification. The end products of this chemical reaction are biodiesel and glycerine which need to be separated through "washing".

While the use of biodiesel in engines requires no engine modification, the production of biodiesel brings its own complications and requires addition of imported methanol. We therefore recommend considering direct use of coconut oil before attempting biodiesel production.

Considering the relatively high costs due to the small scale of production, coconut oil could be marginally competitive with fossil fuel products. However, it keeps money and labour on Totoya, and rising fossil fuel prices could further improve the economics in favour of coconut oil in future.

Value added coconut oil products

Presently, coconut oil production is a very attractive small business opportunity for the residents of Totoya Island. High quality extra virgin coconut oil is a highly priced commodity overseas, and can retail for in excess of F$50 per litre Other coconut oil products could be produced locally without need for expensive equipment. The list of potential non fuel products includes[9]:

- Natural health food
- Cooking oil
- Raw and fresh bread spread
- Stable carrier oil for other dietary supplements
- Skin moisturiser
- Massage Oil
- Baby Oil
- Hair Oil
- Pet Health food
- Base ingredient for organic cosmetics
- Best oil for premium soap and shampoo - with natural glycerine - it even lathers in salt water.
- Head lice and hair nit control
- Tooth Paste.

A bigger picture perspective on the potential benefits of local coconut oil production for own use is illustrated in Figure 29. Importing the goods to the islands gets more and more expensive the more remote the place, while exporting products generates less value than from locations near trading hubs.

[9] We took this list from www.kokonutpacific.com.au . This inspiring website contains a wealth of information on coconut oil business opportunities for developing nations.

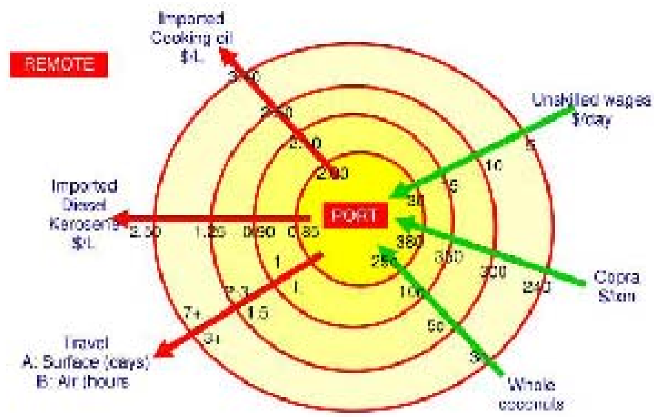

Figure 29: Coconut product trade: price (US$) vs distance from site of production to port, and port to consumer. The Figure is reproduced from (Etherington 2006) with the author's permission.

4.3 Solar

A reliable energy resource

Totoya Island has a reliable solar resource year-round. There is no weather station with irradiation sensors near Totoya, and the closest such station appears to be in Suva (200km North-West).

When solar irradiation data records are not available at one location, climate models are often used to generate solar irradiation from cloud cover data.

Both, observed (Suva) and modelled (Suva and Totoya) irradiation are shown in Figure 30. The modelled data is about 10% higher than observed levels in summer, but up to 40% higher in winter. This could indicate physical obstructions in the vicinity of the weather station, which have a much more profound blocking effect on irradiation from a lower-angle winter sun than in summer.

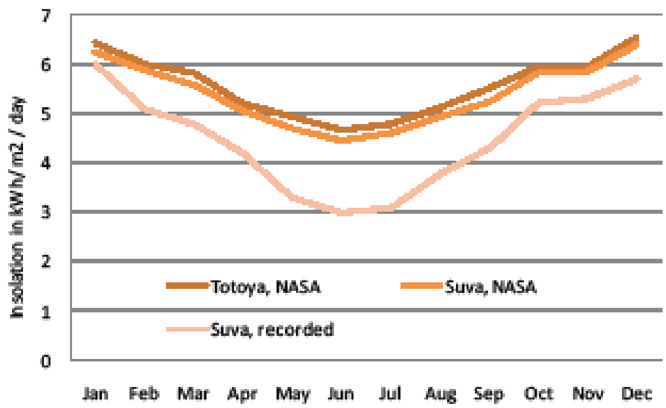

Figure 30: Solar irradiation on a horizontal surface (sources: SOPAC, Weather Underground[10])

As a conservative approach, we propose to use the observed solar irradiation data from Suva for laying out solar systems in Totoya's villages (values provided in Table 4). The observed data appears to account for local physical obstructions, which reflects a realistic situation for solar installations within a village.

Table 4: Solar irradiation data for Suva (kWh/m²/day) based on long term records (source: SOPAC). We propose to use this data for sizing village solar installations on Totoya Island.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
6.0	5.1	4.8	4.2	3.3	3.0	3.1	3.8	4.3	5.2	5.3	5.7

How much electricity will the sun generate on Totoya Island?

Generating household scale electricity from the sun is straightforward: a simple system only requires a solar PV panel, a charge controller, and a battery. The basic system layout is shown in Figure 31.

Solar panels are rated by their output power at standard irradiation conditions, e.g. 100W. We simulated a generic solar system in Homer® and calculated the average output of end use electricity per day for the conditions on Totoya. Table 5 shows how much consumable energy a solar system would produce on a daily basis for the conditions on Totoya. This table helps sizing of a solar system to match the required energy demand.

[10] The data was produced using an online model available at: http://www.wunderground.com/calculators/solar.html. This model superimposes NASA cloud cover data on global irradiation in order to calculate irradiation on the earth surface for any location.

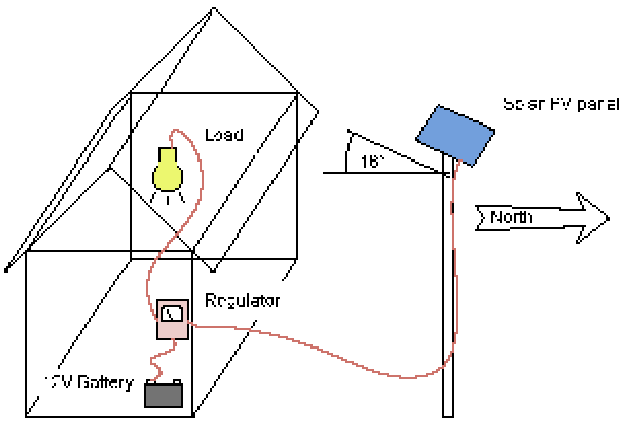

Figure 31: Layout diagram of a simple household solar system.

Table 5: Consumable solar electricity generated by different size solar panels. The values are given in Wh / day. The values are monthly averages. Day to day fluctuations are compensated for with batteries.

Panel size	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1 W	5	4	4	4	3	3	3	3	4	4	4	4
10 W	45	38	38	36	30	27	28	33	35	40	39	40
40 W	181	153	152	143	119	109	114	134	141	160	154	162
100 W	452	383	381	356	299	272	284	334	352	400	386	405

A basic solar system design for Totoya Island

Based on the figures above, we have specified a simple solar system design for Totoya, which would provide enough electric energy for basic lighting, radio, and charging rechargeable battery appliances such as cell phones or flashlights. The electricity services are summarized in Table 6. The total service adds up to 63Wh per day. According to Table 5 a 10 Watt solar panel would provide approximately 30Wh per day in winter (June). For the 63Wh service, we therefore require approximately twice that amount of electricity, i.e. we require a 20W panel.

A typical load curve for the proposed solar system is shown in Figure 32. The load curve visualizes the amounts of electricity required for different services at different time.

Table 6: Example list of electric appliances to be operated on the proposed small solar system on Totoya.

	Use	Energy per use	Average energy per day
Mobile recharge	3 charges per week	4 Wh	2
Recharge AA cells	3 charges per week	8 Wh	3
Radio	13 hours/day	1 Wh	13
Light 5W	5 hours/day	5 Wh	25
Light 10W	2 hours/day	10 Wh	20
Total			63

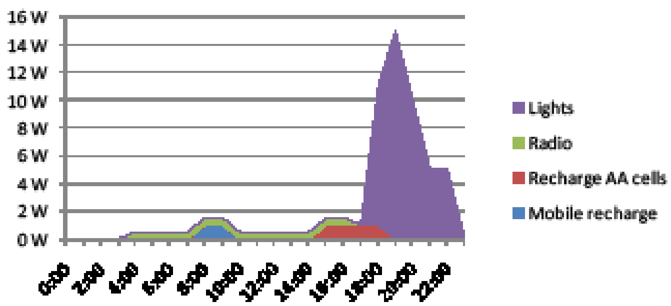

Figure 32: Typical (potential) load curve for a small solar system on Totoya Island.

Costs for the proposed systems have been determined from quotes from major local suppliers for available components. The cost list in Table 7 contains costs for all components required. Apart from the solar system itself, also included are lights with fixtures, universal standard 12V cigarette lighter sockets, and universal 12V cell phone chargers.

Table 7: Parts list for a small standard solar system for Totoya.

Item	Supplier	Qty	Cost	Extended
Solar panel 20W	CBS	1	$250.00	$250.00
Mounting frame	CBS	1	$60.00	$60.00
Charge controller, 10A	Clay Eng	1	$100.00	$100.00
Battery, sealed LA, 25 AH	CBS	2	$140.00	$280.00
12V fluorescent lights	CBS	4	$30.00	$120.00
Double cig socket	DSE	2	$20.00	$40.00
Car cell phone charger	DSE	1	$35.00	$35.00
Light duty cable, 1.5mm2	DSE	60	$2.00	$120.00
Fittings and switches	DSE	1	$50.00	$50.00
Total				$1,055.00

Using the sun for drying high quality copra

As mentioned in the following chapter, Totoya has scope for improving quality and efficiency of copra drying. Solar dryers offer the following advantages over customary drying methods used on Totoya:

- Protection of copra from UV light (e.g., glass or Plexiglass® block out 99% of UV radiation)
- Protection from birds and animals
- Shorter drying times
- Protection from rain.

These factors will ultimately lead to increased copra quality. If communal copra dryers where installed in every village on the island, residents could greatly reduce production of low grade copra, and ensure products would receive the full price from Punjas Ltd.

Solar dryers would offer even greater benefits if Totoya Island farmers decided to produce their own coconut oil. In this case, solar dryers would be the most cost effective way of producing copra for oils of the highest quality. Examples of successful solar copra dryers are shown in Figure 33 and Figure 34.

Figure 33: Large solar copra dryer on Rotuma Island, designed by John Bennett of Fiji (Photo: A. Hamm)

Figure 34: Small scale solar dryer on Rotuma Island, designed by John Bennett of Fiji (Photo: A. Hamm)

Such dryers can easily be locally produced from relatively inexpensive materials. Many dryer designs are available in the public domain.

4.4 Wind

The wind power potential of Totoya is difficult to assess without deploying a sensor mast on the island. The wind data presented in Section 1 is not useable to evaluate the wind power resource due to the sheltered location and low height (3 meters) of the monitoring equipment. It may be worthwhile monitoring the resource in future, particularly if electricity demand should increase. At the current demand level, it is unlikely that wind would be a cost effective way of generating electricity even if the resource was fairly good.

4.5 Waste water

Waste water contains energy which can be recovered in different ways. Depending on the technologies used, the economic viability of energy recovery from waste water streams generally depends strongly on specific circumstances, and normally requires additional project benefits other than energy itself. Typical side benefits are to mitigate water pollution problems.

Grey water

Almost all households on Totoya have access to running water. In return, this means that almost all households are generating significant streams of waste water. Grey water either just soaks into the ground, or flows into collection channels. Whatever does not soak into the ground on the way to the ocean is released to the beaches and creates a local water pollution problem. Increased nutrient levels typically foster the growth of sea grass, algae, and damage coral.

Grey water is low in energy content and high in nutrients. Grey water could indirectly contribute to energy production by conducting it to artificial wetlands or ponds for the farming of energy crops. This option is generally more practical in communities with a significant elevation gradient because grey water may be gravity fed instead of pumped. If any, Ketei would be a good candidate village for such a scheme.

Black water

We did not locate any old style pit toilets on Totoya. It appears that the vast majority of Totoyans are using flush toilets. The less common type of flush toilet is the so-called water sealed toilet - a flushing toilet mounted over a large collection pit. The more common toilet is a standard flush toilet mounted above a septic tank. Septic tanks are locally constructed, but typically miss the dissipation field component; i.e. the liquid portion of the black water does not trickle-soak into dissipation fields where it would be assimilated by micro organisms and plants. Instead the liquid portion seeps into grey water channels, collects in puddles or soaks into sandy soil outside the house.

A relatively simple way of recovering energy from black water in septic tanks is to modify these to capture methane gas. An energy balance suggests that the energy recovered from human waste alone is small, but with biogas storage could supplement gas for cooking.

One person typically produces a daily 0.25 kg of volatile solid waste, which equates to a production of 0.075 m^3 of methane per person per day or an energy equivalent of 2.55 MJ. Thus, at 80% extraction efficiency a four-adult household would have the potential to produce 8 MJ per day, roughly equivalent to a small 300 g piece of firewood, or 0.2 litres of kerosene.

Following septic tank treatment the nutrients in black water could be beneficially used to grow wetland plants or algae as energy crops or for use as fertiliser or animal feed.

4.6 Other renewable resources

Hydro

Hydro electricity schemes can be a cost effective way of harnessing renewable energy, but there are no large streams on Totoya. We decided not to further investigate flow rates of existing creeks further because visual inspection found no significant flow rates.

Marine power

While it may appear that marine energy would be a natural solution for producing energy on an island, no mature technologies are available to tap this resource. Existing prototype tidal energy plants are in locations with tidal changes of more than 10 meters, and very specific geological formations. Wave power generators are still far from commercialization.

5 Current energy use and more efficient alternatives

Energy on Totoya Island is used for

- Access to the island
- Domestic transport by outboard vessels
- Cooking
- Lighting
- Minor electricity services (cell phones, faxes, few computers).

This section presents results from the NIWA 2009 energy survey and discusses how energy can be used more effectively to provide the services.

5.1 Existing electricity infrastructure

Between 1980 and 1986, the Fiji Department of Energy installed diesel generator village energy systems in three of Totoya Island's four villages. Key data of those systems are summarised in Table 8. Two of the three generator systems have broken down. Tovu's generator system is still working but is not being used due to the high cost of diesel. Once in use, the generator systems have been used for 3 to 4 hours per day, typically from 18:00 to 22:00. The former operators in all villages reported that the systems have not been used much, and it has always been extremely difficult to raise funds for the diesel bills.

Table 8: Diesel generators on Totoya (The data stems from inspections and interviews in September 2009).

	Year installed	Make	Capacity	Est. load	Phases	Status	Fuel use
Tovu	1986	Lister	25 kVA	5.3 kVA	3	Ok, unused	2.3 l/h
Ketei	1980	Lister	40 kVA	3.9 kVA	3	Broke 2007	2.5 l/h
Dravuwalu	1981	Lister	17 kVA	4.0 kVA	1	Broke 2004	1.7 l/h

The village generator systems inherently provide a very limited energy service because of the limited running time per day. It would be unaffordable to run generators for longer than the typical four hours per day, and this time limitation equally limits the usefulness of this service: for example, refrigerators would barely cool down to operating temperature before they warm up again as the generators switch off. Daytime activities, e.g. using food processors, electric drills, or fax machines are out of the question. We estimated the average loads on the individual village systems based on the numbers of appliances[11] recorded in individual households and public facilities, and interpolated to the village populations (see Table 9). The fuel consumption figures in Table 8 are actual values reported by the village representatives. According to these fuel consumptions and the numbers of connected households, the annual fuel bill per household would be

- $169 per household per year for Tovu
- $289 per household per year for Ketei

[11] Actual loads could not be measured because none of the grids was operational at the time of survey. However, the load figures are roughly in line with fuel consumption figures provided to us by the former generator operators.

- $171 per household per year for Dravuwalu.[12]

The service per households is equal for all villages, but the generator in Ketei is significantly oversized making it more expensive to run for the same electricity output.

Table 9: Energy use on Totoya's electricity grids.

	Avg. load	Tovu	load	Ketei	load	Dravuwalu	load
Active house connections	111 W	Qty 37	4092 W	Qty 24	2654 W	Qty 27	2986 W
Street lights	18 W	Qty 6	108 W	Qty 10	180 W	Qty 8	144 W
Church lights	36 W	Qty 2	72 W	Qty 8	288 W	Qty 2	72 W
Total			4272 W		3122 W		3202 W

Figure 35: Diesel generator in Dravuwalu.

If Totoya was to consider running diesel generators in future, all villages could save significantly by installing smaller generators, which more closely match actual electricity consumption. Generally, village generator systems in Fiji see very flat load curves without high peaks. We recommend sizing generators to match actual village loads plus a 30% contingency margin: On this basis the following generator sizes are recommended for Totoya's villages:

- Tovu: 7kVA
- Ketei: 5kVA
- Dravuwalu: 5kVA.

[12] These figures are based on a diesel price of $1.90 per litre, and a runtime of 4 hours / day.

Savings in fuel consumption compared to the installed systems would be in the order of 50% for Tovu and Dravuwalu, and 75% for Ketei.

It is important to note that the recommended smaller generators would supply existing loads well, but would not leave much room for future expansion in electricity appliance use. With small generators, the people of Totoya would probably find it affordable to supply four hours of electricity daily.

While the existing diesel generator systems are extremely inefficient and expensive to run for the service they provide, they only cost between $170 and $290 per household per year, which is not unaffordable. For example, households spend an average of $160 per year for lighting benzene, a cost that could be replaced by paying for generator fuel. Perhaps the biggest problem with current village generator systems is the way they are financed - the village typically raises funds to pay for diesel fuel. If some households cannot afford their share at a time, diesel cannot be purchased and electricity becomes unavailable for everyone.

For a successful generator fundraising system, there needs to be

1. An accepted and enforced way of temporarily disconnecting non-paying households, perhaps on a pre-pay basis,
2. A savings account to put money aside for repairs.

5.2 Lighting

Lighting technology and running costs

The different light sources used on Totoya span a very large range of efficiencies and running costs. An overview of light output power and efficacies is given in Table 10. The light total output capacity of a source is measured in lumen (lm). Lighting efficiency is measured in lumen of light output per watt of energy input (lm / W). The correct technical term for measuring efficiency of lighting sources is efficacy.

The least efficient lighting sources are candles and simple kerosene lanterns where light is emitted from an actual combustion flame. Benzene lanterns are ten times more efficient. Here, the light is emitted from a glowing gas rather than a flame. Electric light sources are at least another ten times more efficient than benzene lanterns. The traditional incandescent light bulb emits light through a brightly glowing wire, while fluorescent tubes emit light from electrically excited gases.

A relatively new lighting technology is the light emitting diode (LED). LEDs effectively convert electric energy to photons by exciting electrons of a semi conductor material.

The most efficient light sources for domestic purposes are fluorescent tube lights. Efficiencies of LED lights vary widely, and some are as efficient as fluorescent lights.

Table 10: Light output and efficacy ranges for different types of lighting (Data sources: (Mills 2003), (Benya, Heschong et al. 2003)).

	Light output (lm)	Efficacy (lm/w)
Candle	10 to 15	0.1 to 0.3
Kerosene lantern	10 to 70	0.1 to 0.2
Benzene lantern	1000 to 1500	1.2 to 2
White LED bulbs	20 to 300	10 to 40
Incandescent bulbs	200 to 1500	5 to 15
Compact fluorescent lights (5 to 26 W)	200 to 1200	40 to 55
Compact fluorescent lights (27 to 55 W)	1000 to 4000	50 to 80
Fluorescent tubes	1500 to 4000	70 to 95

While it is important to understand lighting efficiency ranges of different technologies, it is equally important to understand that each light source is used in different and unique ways. For example, a kerosene lantern is ten times less efficient than a benzene lantern; however, the benzene lantern will use twice the amount of fuel since its light output is more than 20 times higher. Whether a kerosene lantern or a benzene lantern is the best choice for a task depends on the amount of light required.

Table 11 shows fuel use, hourly running costs for one typical source, and costs per unit of light output. All numbers are calculated with current fuel prices on Totoya. Fuel consumption for electric lighting is represented as diesel consumption for running a generator to produce electricity.

Interestingly, running costs per source are in a relatively narrow range from $0.002 to $0.18 per hour, with most sources costing between 2 and 10 cents per hour. Costs per unit of light output show much greater variation: it is 4000 times more expensive to produce the same quantity of light with candle than with fluorescent tubes. However, one may not require the full light output of a fluorescent tube and one candle may be enough for the task. One candle is only four times as expensive to run as a fluorescent tube and an electricity source is required.

Table 11: Running costs of different light sources.

	Fuel use (l / hour)	Running costs ($ / hour)	Cost per light output ($ / [million lm h])
Candle	0.005	$0.08	$8,333.33
Kerosene lantern	0.030	$0.06	$910.83
Benzene lantern	0.060	$0.18	$206.36
White LED bulb (2 W)	0.001	$0.002	$4.71
Incandescent bulb (60W)	0.024	$0.05	$18.84
Compact fluorescent light (27W)	0.011	$0.02	$3.43
Fluorescent tube (20W)	0.008	$0.02	$2.35

Apart from lighting efficiency and running costs there are other considerations which are often neglected: different light sources produce different "types" of light. For example, incandescent light bulbs produce a relatively warm light and render colors truly (comparable to sun light). Classic fluorescent lights produce cold light, and have a cold feel. Fluorescent tubes do not render colors very well and thus have limited use for applications where this is important: for example photo laboratories. The extreme end of the spectrum is the low pressure sodium lamp, which is three times as efficient as a fluorescent tube but has almost no color rendition: low pressure sodium lamps are often used for lighting streets or parking lots.Under low pressure sodium lamps the world looks nearly black and white with an intense orange hue.

Kerosene lanterns and candles produce little, but very warm light with true color rendition. A house lit with kerosene lanterns produces a warm and welcoming feeling.

LED lights can be produced in any color temperature and typically render colors as well as fluorescent lights[13].

More efficient lighting options for Totoya

The discussion above showed what sources of light are currently used on Totoya, how efficient they are at generating light, how much light they emit and how much they cost to run on the island.

As they do now, people on Totoya will continue to have different preferences for their choices of light. But here we can make recommendations for what we consider the best choices for typical applications, considering our observations and the information above. A list of these choices is given in Table 12. We recommend compact fluorescent lights for almost all applications. These are commonly available in Fiji, come with standard Edison fittings and in a wide variety of power ranges. Compact fluorescents are commonly available in warm light versions which do not have the same cold feel fluorescent tubes do. Compact fluorescent lights could be supplied as part of a standard solar package solution.

Table 12: Lights for tasks on Totoya.

	Typically used	Light output (lm)	Running costs ($ / hour)	Recommended replacement	Light output (lm)
Lounge	Benzene lantern	1200	$0.18	Solar compact fluorescent, 10W	400
Bedroom	Kerosene lantern	60	$0.06	Solar compact fluorescent, 5W	200
Kitchen	Benzene lantern	1200	$0.18	Solar compact fluorescent, 10W	400
Bathroom	Kerosene lantern	60	$0.06	Solar compact fluorescent, 5W	200
Night light	Kerosene lantern	60	$0.06	Solar LED night light	10

5.3 Cooking energy

A comparative overview of energy and running costs of different cooking facilities on Totoya is shown in Table 13. Rocket stoves are included in the table; although not yet in use, there

[13] LEDs with almost true color rendition are possible but more expensive than standard ones.

are 90 rocket stoves being trialled on the island and there is an initiative to establish them on the island.

Fuel efficiency values in the table are averages and may vary greatly from house to house depending on how people use them. Lovos are not included because there we are not aware of any studies on fuel efficiency of these stoves.

Table 13: Comparing different cooking facilities on Totoya Island: Primary energy requirements, fuel quantity, and costs are given for heating one litre of water from 20°C to the boiling point.

	Efficiency	Primary energy	Fuel quantity	Cost
LPG stove	45%	0.74 MJ	0.015 KG	6 cents
Kerosene multi-wick stove	43%	0.78 MJ	0.021 L	4 cents
Open fire	10%	3.35 MJ	0.258 KG	0 cents
Rocket stove	25%	1.34 MJ	0.103 KG	0 cents

Which stove is used for what?

The cooking facilities discussed above are often not used exclusively but complimentarily to each other. In our household survey we asked which stove people used to prepare different types of meals. Figure 36 shows the percentages of households who regularly use each type of appliance for different meals. The data shows a slight preference of LPG and kerosene stoves for preparation of smaller meals, e.g. breakfast. Personal observation also showed that people almost exclusively use wood fires for extended and larger energy cooking tasks, such as boiling large pots of water. Lovos are almost exclusively used to prepare lunches on Sundays.

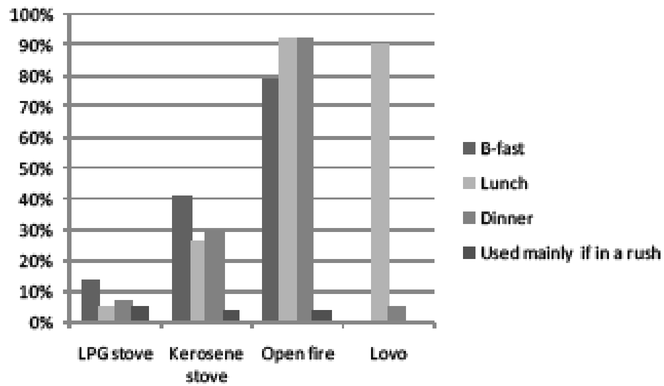

Figure 36: Different types of cooking facilities households typically for preparing different meals.

A qualitative overview of the suitability of the common cooking facilities on Totoya and their relative energy consumption levels is given in Figure 37. Rocket stoves are more efficient than open fires, but open fires are more scalable to larger meals if required. We estimate the cooking efficiency of lovos to be slightly lower than wood fires, but one single lovo fire is scalable to feed a huge range of guests, from a single family meal to hundreds of people. On a different island, the author was part of a funeral function were one large lovo was used to simultaneously cook one full grown cow, seven pigs, and 14 large baskets of root crops.

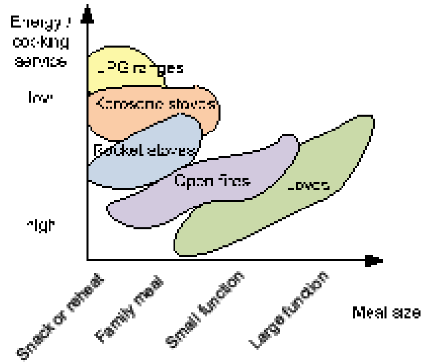

Figure 37: Qualitative overview of cooking stove efficiency ranges for different types of meals. The chart is not based on actual data and ranges are indicative only.

Introducing new cooking technologies

Totoya would benefit from new and more efficient cooking technologies in order to reduce smoke in the villages and firewood consumption, but more importantly to reduce the need for imported LPG and kerosene. The rocket stove mentioned above could have the potential to satisfy these requirements and could bring significant benefits to Totoya. In this section we do not want to suggest any particular design or approach, but instead contribute some general considerations for introducing advanced cooking stoves. Many stove programs have been implemented around the world, some were failures and some had lasting success. A world bank study (Barnes, Openshaw et al. 1994) assessed numerous stove introduction programs. Results from this study could be of tremendous value for introducing new technologies on Totoya. The key findings are summarized in Table 14: the table contains criteria for success and failure of programs, based on long term experience: for example, the study found that stove programs are more successful if locals are involved in designing the new stoves.

Table 14: Reasons for success or failure of improved cooking stove programs.

	Reasons for success	Reasons for failure
1	Program targets region where traditional fuel and stove are purchased or fuel is hard to collect.	Program targets region where traditional fuel and stove are purchased or fuel is easy to collect.
2	People cook in areas where smoke causes health problems and is annoying	People cook in the open and smoke is not really a problem.
3	Market surveys are undertaken to assess potential market for improved stoves.	Outside "experts" determine that improved stoves are required.
4	Stoves are designed according to consumer preferences, including testing under actual use.	Stove is designed as a technical package in the laboratory, ignoring customer's preferences.
5	Stoves are designed with the assistance of local artisans.	Local artisans are told or even contracted to build stoves according to specifications.
6	Local scrap materials are used in production of the stove, making it relatively inexpensive.	Imported materials are used in the production of the stove, making it expensive.
7	The production of the stove by artisans or manufacturers is not subsidized.	The production of the stove by artisans or manufacturers is subsidized.
8	Stove or critical components are mass produced.	Critical stove components are custom built.
9	Similar to traditional stove.	Dissimilar to traditional stove.
10	The stove is easy to light and accepts different-sized wood.	The stove is difficult to light and requires the use of small pieces of wood.
11	Power output of stove can be adjusted.	Power output cannot be easily controlled.
12	The government assists only in dissemination, technical advice, and quality control.	The government is involved in production.
13	The stove saves fuel, time, and effort.	The stove does not live up to promised economy or convenience under real cooking conditions.
14	Donor or government support extended over at least 5 years and designed to build local institutions and develop local expertise.	Major achievements expected in less than 3 years, all analysis, planning, and management done by outsiders.
15	Monitoring and evaluation criteria and responsibilities chosen during planning stages according to specific goals in the project.	Monitoring and evaluation needs are not planned and budgeted, or criteria are taken uncritically from other projects or not explicitly addressed.
16	Consumer payback of 1 to 3 months.	Consumer payback of more than 1 year.

Source: (Barnes, Openshaw et al. 1994)

In another well founded study, (Smith and Ramakrishna 1991) developed a matrix for assessing favourable and unfavourable conditions for introducing new stoves (Figure 38). The matrix is valuable, since it includes recommendations for approaching stove introductions under different conditions.

Source of fue / Source of stove	**Unfavorable** Fuel gathered	**Favorable** Fuel purchased
Constructed by family **Unfavorable**	**Most unfavorable (unless fuel deficit is perceived)** *Strategy* • Subsidies for stove purchase may be necessary • Long-term effort and extended external involvement is necessary • Favourable short term results should not be expected	**Somewhat favorable** *Strategy* • Offer incentives or partial subsidies • Fuel price should reflect full value of biomass resources • Assess potential for fuel substitution
Purchased **Favorable**	**Somewhat favorable** *Strategy* • Encourage conservation of biofuels through education about environmental benefits • Determine alternative uses of biofuel resources	**Most favorable** *Strategy* • Commercialization of improved stove should be possible • No subsidies should be considered for stoves or fuels • Assess potential for fuel substituion

Figure 38: Matrix of favorable and unfavorable conditions for improved cookstove acceptance and recommended project strategies. Source: (Smith and Ramakrishna 1991).

We applied the matrix of Figure 38 to Totoya Island (Figure 39). Naturally, if applying this matrix to Totoya we have to consider different types of cooking facilities separately.
As illustrated in Figure 39, the easiest way to introduce new cooking stoves would be to replace expensive kerosene and LPG cooking facilities. This means, if a new stove was introduced, it would be most acceptable if it could deliver the benefits of LPG and Kerosene stoves, e.g. fast heat up time and instant heat.

A very suitable stove for saving on LPG and kerosene costs without compromising the ability for fast cooking are rocket stoves. We recommend introducing low cost rocket stoves to the island combined with education on firewood drying.

In the longer term, it is recommended to use local artisans to adapt the rocket stove principle to a local design, in order to best suit Totoya's local construction materials as well as the peoples' cooking habits. An example of a rocket stove constructed solely from materials together with people from the island is shown in Figure 40. This is by no means a final design, but illustrates the fact that wood burning stoves can be built locally.

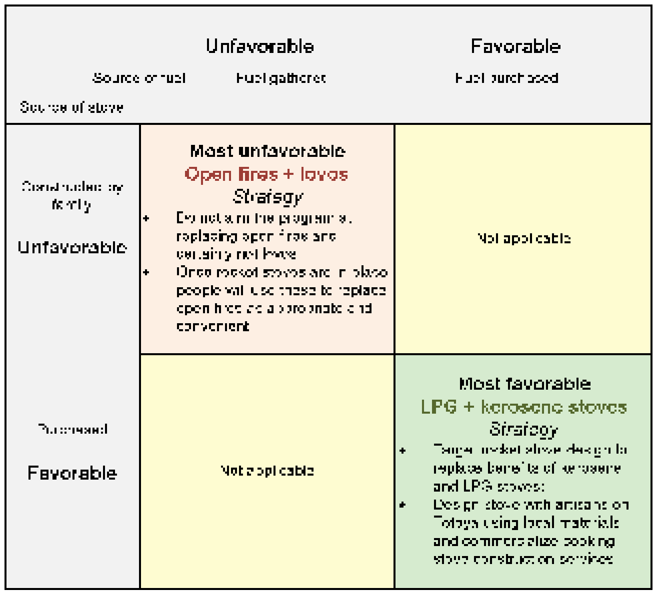

Figure 39: Recommended strategic considerations for introducing rocket stoves to Totoya.

Figure 40: Example of an experimental rocket stove build together with local artisans on Totoya in 2009, made from local materials.

5.4 Totoya community activities

We decided to include a section about community lawn mowing activities in this report because of the significant use of resources.

All able adult men on Totoya are traditionally obligated to participate in community work activities. As shown in Table 15, able adult men spend approximately one to two weeks per month on communal lawn mowing and weeding, i.e. 25% to 50% of all potential male working hours on the island. For example in Tovu, the roughly 40 participants work for approximately 6 hours per day for 7 to 14 days, the first and second week of each month. Imagine the enormous potential this "free" work force could have to make a positive change on Totota: e.g. building roads and tracks, cleaning up coconut plantations, rebuilding the cooperative etc.

Table 15. Energy use and labour for lawn mowing activities.

	Workforce			Fuel/month		Days/m	Work		Mowing speed	Monthly mowing cost	
Village	Mowers	Manual	Total	Village	School	onth	hours/month	Mow area	m2/hour	Fuel	Labour
Tovu	10	30	40	65 l	25 l	14	3360	4 ha	12	$189	$10,080
Ketei	6	24	30	25 l	10 l	7	1260	4 ha	32	$74	$3,780
Dravualu	8	7	15	30 l	20 l	14	1260	4 ha	32	$105	$3,780
Udo	3	7	10	13 l	10 l	7	420	4 ha	95	$48	$1,260

Fuel costs for lawn mowing are paid for by the village committee for village grounds, and by the government for the school area.

Annual costs for lawn mowing and weeding are shown in Table 16. An opportunity cost for the labour spent is included for reference of scale for this missed opportunity.

Table 16. Annual opportunity cost of lawnmowing and weeding in Tovu.

Item	Description	Quantity	Cost	Extended
Machinery	Petrol powered weed eaters	10	$ -	$ -
Labour	Opportunity cost - work hours	23040	$ 3.00	$ 69,120.00
Fuel school	Premix supplied by government	300	$ -	$ -
Fuel village	Premix bought in drums from Suva	780	$ 1.75	$ 1,365.00
Total				$ 70,485.00

We made no investigation on new lawn mowing approaches for Totoya, but would like to encourage the community to consider more economical solutions.

5.5 Domestic transport by boat

There are no roads on Totoya and the only motorized domestic goods and people transport is by outboard fibreglass vessels. Village by village fuel consumption and annual household fuel expenditures are shown in Table 17.

Table 17: Outboard fuel consumption on Totoya.

	Fuel use	Average use per household	Average annual household expenditure
Tovu	9291 l/year	249 l/year	$566.15
Ketei	5361 l/year	168 l/year	$381.15
Dravuwalu	1796 l/year	66 l/year	$149.43
Udu	5566 l/year	402 l/year	$914.14

Totoya Island depends on domestic sea transport for visiting the neighbouring villages, fishing journeys, and access to coconut plantations. Totoya Island could significantly reduce outboard fuel expenditure by acquiring sailing yachts for most of the non-urgent transport requirements.

5.6 Summary of energy flows

For comparison, we calculated total energy flows on Totoya from the numbers we developed in this report and charted these in Figure 41. Energy flows are approximate only, but represent orders of magnitude. Diesel generated electricity does not appear in the chart since communal electricity was not generated at the time of the survey. The estimated energy use of the ferry between Totoya and the mainland is shown in the chart for reference. Since the ferry services three islands on each trip from the mainland, fuel use for the ferry has been scaled down by a factor of 1/3 in order to only account for the people from Totoya. The chart shows that the ferry uses almost as much fuel as all imported fossil fuels combined.

Domestic energy use is clearly dominated by firewood for cooking. As discussed, firewood is not used very efficiently and not dried appropriately. Cooking firewood consumption could be reduced by seasoning the wood well before burning it, and by introducing more efficient cook stoves such as rocket stoves.

Premix is dominating the scale of imported fossil fuels. Next to some special applications like lawn mowing, most premix is used to run outboard engines. Almost everyone is using kerosene for lighting or cooking.

The copra resource on Totoya is large compared to all other energy uses on the island; the unused copra resource alone could theoretically produce enough coconut oil to cover double Totoya's needs.

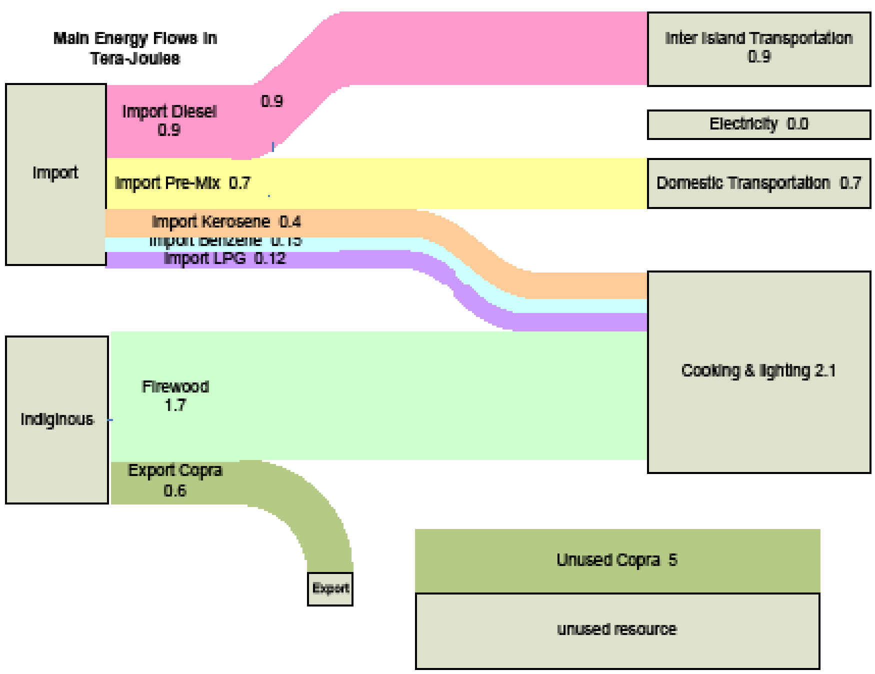

Figure 41: Energy flows on Totoya Island.

6 Conclusions

This study reviewed a range of energy sources and end-uses on Totoya Island and considered the potential for introduction of more efficient alternatives.

The island's current electricity supply system is largely dysfunctional. This is due to a combination of high diesel prices, inability to raise funds communally, and difficulties with generator maintenance. We recommend to abandon diesel generated electricity and install very simple but reliable per dwelling solar systems.

We identified lighting as one of the most important energy services on the island. The most common form of lighting, kerosene lanterns, is costly to run and not very efficient. We recommend running efficient lighting systems from the small solar systems mentioned above. Cooking is the largest single energy end use on Totoya Island. While firewood is plentiful and free of charge to anyone on the island, much effort could be saved by using wood more effectively. We recommend providing simple shelters for storing and seasoning firewood before use. Significant money is spent on imported LPG and kerosene for cooking. We recommend to trial rocket wood burning stoves, which can burn "free" firewood with the convenience and speed of LPG or kerosene cooking.

Domestic transport is a significant energy user. Imported premix is used in convenient but inefficient outboard engines. Since Totoya depends on cheap sea transport for contact with other villages as well as access to most coconut plantations, we recommend that Totoya investigates more efficient small boats or sailing yachts.

Totoya Island has a copra resource which is estimated to be almost ten times higher than current production. The limitation for expanding production is the monthly ferry service to Totoya and is therefore not easy to change. On the other hand, it is possible to produce coconut oil on Totoya with simple technology. It is possible to produce a range of high quality coconut oil products. Coconut oil can be used directly as fuel for modified diesel engines.

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Appendix – Survey form

Rural Energy Survey - Pacific Blue Foundation						*p 1*
INTRO						
	Village					
	House No					
	Intervier					
	Date					
DEMOGRAPHICS						
	People in household	**M/F**	**Age**	**Present**	**Profession**	
	Member 1					
	Member 2					
	Member 3					
	Member 4					
	Member 5					
	Member 6					
	Member 7					
	Member 8					
	Average monthly household income			**$**		
LIGHTING		**No**	**Hrs/d**	**Comments**		
	Light bulbs					
	Short tubes					
	Long tubes					
	Candles					
	Benzene lanterns					
	Kerosene lanterns					
APPLIANCES		**No**	**Hrs/d**	**Comments**		
	Radio					
	TV					
	DVD					
	Washer					
	Fridge					
	Freezer					
	Combo fridge					
	LPG fridge					
COOKING FACLITIES		**B-fast**	**Lunch**	**Dinner**	**Used mainly if in a rush**	
	LPG stove					
	Kerosene stove					
	Open fire					
	Lovo					

Rural Energy Survey - Pacific Blue Foundation							***p 2***
FUEL USE							
	Gas bottle last X months						
	Benzene liters / week						
	Kerosene liters / week						
	Firewood bundles / week						
	Candles / week						
	Batteries / week						
	Lovos / week						
	Cooking fires / week						
	Vehicle fuel l / week						
	Outboard fuel l / week						
ENERGY ISSUES - rank from 1 (not urgent) to 3 (very urgent)							
		Rank	**Comments**				
	Electricity price						
	Electricity reliability						
	Fuel cost						
POWER SUPPLY OPTIONS - rank from 1 (not preferred) to 3 (preferred)							
		Rank	**Comments**				
	Wind power						
	Solar panels						
	Generator						
COMMUNITY NEEDS - rank from 1 (not urgent) to 3 (very urgent)							
	Health						
	Refrigeration						
	Lighting						
DEVELOPMENTS ON YOUR ISLAND - rank from 1 (bad) to 3 (great)							
		Rank	**Comments**				
	Mobile phone network						
	Ice for fishing						
	Cottage industires						
	Tourism						
	Better ferry service						

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