Status of Fanga'uta Lagoon 2015

Ridge to Reef Project, Kingdom of Tonga

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DEPARTMENT OF ENVIRONMENT
GOVERNMENT OF TONGA

STATUS OF FANGA'UTA LAGOON 2015

Contributors:

Ms. Sela Fa'u
Mr. Tevita Fotu
Ms. Talita M. Helu
Ms. Ta'hirih H. Hokafonu
Dr. Ursula Kaly
Ms. Pelanatita Kara
Mr. Viliami Kato
Mr. Richard Atelea Kautoke
Mr. Taaniela Kula
Mr. Inoke F. Kupu
Dr. Siola'a Malimali
Dr. Viliami T. Manu
Ms. Atelaite Lupe Matoto
M. Paula P. Ma'u
Ms. Andrea Talia'uli
Dr. Salome T. Taufa

Editors:

Ms. Ta'hirih F.Hokafonu
Dr. Ursula Kaly
Ms. Atelaite Lupe Matoto

R2R Project Management Unit

Ms. Ta'hirih Hokafonu	Project Coordinator
Ms. Seini Fotu	Technical Officer
Ms. Patiola Mapukava	Financial Officer
Ms. Muli Hurrel	Administrative Assistant
Mr. Vivieni Sika	Programme Support Officer/Driver

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I. Hokafonu, Ta'hirih F. II. Kaly, Ursula III. Matoto, Lupe A. IV. Department of Environment, Tonga Ministry of Meteorology, Environment, Information, Disaster Management, Energy, Climate Change and Communications.

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Message from the CEO

It is a pleasure, as the Chair of the Technical Working Group for managing the Fanga'uta Lagoon Catchment area, to present its status report for the year 2015. This is part of an output to the Ridge to Reef (R2R) project funded by the Global Environment Facility (GEF) and implemented by the United Nations Development Programme (UNDP).

This report is one product of the work executed by a number of stakeholders, from communities, Non-government and government organisations, and the private sector. Taking an integrated approach, these groups gathered vital information required to inform policy and decision makers on the status of the Faga'uta Lagoon Catchment, and recommend viable options on how best to manage the area.

The importance of understanding and rehabilitating the lagoon's ecosystem health is central to sustaining its ecosystem services for community wellbeing and livelihoods. It is also one of the priorities for government. Therefore, a programme of monitoring of the Lagoon's ecosystem health, followed by targeted interventions and on-going monitoring will provide us with both the path, and indications, for interventions to minimise impacts and restore the lagoon. In addition, planning holistically is very much required, as one cannot manage the lagoon in isolation; hence the Ridge to Reef management concept is central. This is an integrated approach of managing our activities from the highest point on land, down to the reef and out to our ocean spaces.

Considering the multidisciplinary nature of Fanga'uta Lagoon, it was vital that a collaborative approach was undertaken through the involvement of various stakeholders, experts and concerned organisations, Ministries and Departments when developing this work and report.

May I congratulate all those who were involved with the preparation of this report. I am confident that the sharing of experiences with other Parties through this report would enormously help in addressing the challenges we face today and tomorrow.

Special thanks are extended to the Deputy Prime Minister, Minister for MEIDECC and Chair of the National Environment Coordinating Committee (NECC); and to the members of the NECC, for their direction and continued support with the implementation of the Ridge to Reef Programme.

I would also like to thank the R2R Technical Working Group (TWG) and the Scientific Technical Advisor, for their valuable contributions and support during the development and completion of this report.

Finally, a thank you is also extended to the communities for their valued input and participation during the consultation process; and to the staff of the Department of Environment, and the R2R Project Management Unit, for their continued assistance and coordination in completing this very important task.

Malo 'aupito

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Paula Ma'u
Chief Executive Officer for MEIDECC

MINISTRY OF METEOROLOGY, ENERGY, INFORMATION DISASTER MANAGEMENT, ENVIRONMENT CLIMATE CHANGE & COMMUNICATIONS
MEIDECC TONGA

Summary

The UNDP/GEF regional Ridge-to-Reef (R2R) programme[1] in Tonga focused on understanding, improving and maintaining the Fanga'uta Lagoon ecosystem, including its catchment (the ridge) through to the lagoon itself and nearshore areas beyond (the reef). Its purpose was to improve the ecosystem goods (such as forests, farming, fishing) and services (such as cycling of wastes, carbon storage) on which the surrounding communities of Nuku'alofa depend. This was part of a broader Pacific initiative focusing on integrated water, land, forest and coastal management to preserve biodiversity, ecosystem services, store carbon, improve climate resilience and sustain livelihoods under Global Environment Facility (GEF) projects.

The Fanga'uta Lagoon Catchment includes much of the capital of Tonga, Nuku'alofa, and is home to over 55% of Tongatapu's population (over 40,000 people and 8,000 households). The importance of this area and its value to people is not always considered on a day to day basis, by national planners or residents. Many of the communities within the lagoon area are dependent for their livelihoods and wellbeing on the ecosystem services the lagoon provides. Therefore it is in our best interests to restore and rehabilitate the lagoon to a state where it can sustain and provide the goods and services required.

In recent years ecosystem services and yields of goods have dropped and some exploitation of species is no-longer sustainable. For example, significant areas of mangroves have been exploited and areas reclaimed. This has been accompanied by increasing community concern about contamination and loss of productivity of the lagoon. In order for us to continue receiving benefits from the lagoon in the future, we need to look at ways of protecting and improving its health. Ecosystem goods, services and resilience are dependent on healthy ecosystems.

This survey and report were designed to inform all stakeholders, including communities, government and users of the catchment area, of the current status of Fanga'uta Lagoon. By providing up-to-date facts of current condition, it is expected that the report will provide direction and motivation for people to work together in a united front to improve the status of the area. This status report will serve to provide answers to peoples' concerns on the environment that they are living in and assist them with information relevant to its protection and improvement.

This report is divided into three sections covering:

1. Marine environment: Lagoon water quality, bottom-dwelling organisms such as seagrasses and invertebrates, and fisheries;
2. Coastlines and catchment land: Springs and wells, mangroves, land cover and vegetation, soils, agriculture, waste management, reclamations and developments; and
3. The human dimension: Focusing on attitudes and behaviours that describe how communities and people interact with and use the lagoon.

A series of scientific surveys was undertaken between August and November 2015 using field surveys, laboratory assays, community meetings and household surveys to characterise the current state of the Fanga'uta Lagoon catchment area. The work was carried out by staff from 12 ministries, 2 NGOs and 1 Private Sector who worked together under the Ridge to Reef Project, each bringing their specific expertise so that linkages between traditionally separate disciplines could be made (e.g. links between fisheries and infrastructure).

Details of the findings are presented in each chapter, but across the disciplines a wide range of issues was identified for the lagoon, its catchment and human populations:

1. The lagoon water quality is deteriorating very quickly. The Pea and Fangakakau Sections have the most water quality concerns, with high faecal coliform counts (indicators of sewage pollution) as well as high Phosphate concentrations (over international standards). In contrast the Mouth and Mu'a Sections are the cleanest parts of the lagoon.
2. Seagrass cover has declined in the lagoon since 1998 and is heavily covered by epiphytes (usually an indicator of nutrient enrichment such as form sewage and agriculture) mostly in the Fangakakau and Mu'a sections.
3. Fisheries resources (finfish) and catches appear lower in the lagoon than at other landings elsewhere in Tonga. During the pilot creel survey a total of 35 species from 23 families was observed and the resources are significant to communities living within the catchment. However, these results are based on insufficient data which should span years.
4. In the coastal environments 73 fresh water springs and bore holes were tested providing baseline information. A range of water quality issues was found that should be addressed as part of lagoon recovery.

[1] Actually termed the Integrated Environmental Management Plan of Fanga'uta Lagoon Catchment Project (IEMP-FLC)

5. Rates of natural water discharge suggest the Vaini Sector has the highest velocity flow of over 8,000 m^3/hr. This high water flow may be related to beautification work which meant that springs were cleaned at many of the freshwater springs there. Moderate water flows were found in the Mu'a Section, and low flows in the Pea and Nuku'alofa sections of the lagoon (0-600 m^3/hr).
6. Land cover: About 19% of the Fanaga'uta Lagoon Catchment comprises built-up areas, 30% is coconut cropland, 14% is scrubland, 8% of the cover is by mangroves, 7% by grassland and coconut-grassland, 6% by cropland, 4% by woodland, 2% by saline wetland, and 1% each for coconut-scrub, estuarine mudflats, rock and wetland. Less than 1% of the catchment is landfill and sand. Land reclamations were mostly at Nuku'alofa beachfront and Fanga'uta Lagoon section covering about 28ha. These have mostly been used for residential developments, public purposes or Township extensions.
7. The soils within the catchment are mainly of younger volcanic ash soils which are thinner at Lapaha and up to 1 meter thick in the Vaini area. These soils are heavily relied on for subsistence farming, and commercial growing.
8. Coastal vegetation covered about 120 ha and was characterised by relatively low diversity, with 129 species of trees found. The area has important economic resources of edible fruit trees (mango, kuava), nuts (ifi, niu), medicines (lala, laufale), pine trees (paini, kauli) and ornamental trees (mangroves, ovava). The vegetation has a low density of adult trees. Two-thirds of the vegetation is dominated by young age-class shade-tolerant canopy trees. Two main issues were identified for any future replanting schemes: the dumping and accumulation of rubbish along the coast and the uncontrolled roaming pigs at villages. Hotspots of damaged coastal vegetation were found at Hoi, Malapo, Alaki, Vaini, Kauvai, Halaleva, Umusi and Popua.
9. Mangroves covered about 419ha, which is 29% of Tongatapu's mangroves. Species richness comprised 6 major species (one unidentified), 5 minor species and 14 mangrove associates. Special attention is needed for Tongota'ane *Bruiquiera gymnorhiza* (white), Hangale *Lumnitzera littorea*, Lekileki *Xylocarpus granatum* and Mamea *Heritiera littoralis* as they are becoming endanagered in the lagoon. Seven mangrove hotspots in order of decreasing damage were identified at Talasiu, Vaini/Longoteme, Nukunukumotu, Popua, Nukuhetulu, Patangata and Fanga.
10. The waste collected over two weeks during this survey for characterisation recovered about 46.7 tonnes of waste mainly from coastal areas and residential areas. Most garbage was of plastics and cans of different types. A clean up of the coastal areas has yet to take place in most places around Fanga'uta Lagoon.
11. There were significant issues for which we found poor understanding at a grassroots level during the socio-economic survey. This included topics concerned with the sustainable use of mangroves, impacts of chemical use on farms, the Special Management Area (SMA) program, fisheries management measures for, impacts of sewage on the lagoon and information on opportunities for ecotourism. At least half of the people interviewed were uninformed about the government rubbish collection service and very few households were engaged in conservation programmes. The survey highlighted problems with poor or non-existent drainage systems (usually on roadways) and issues for the transport of garbage.

As a result of the identified issues, a range of recommendations for improving the ecosystems of the lagoon and its catchment were developed. These are wide-ranging in their scope, focus on the most important issues for the area and identify synergies. Improvements in one or more areas were recognised as being central to improvements in others leading to a roadmap for integrated management:

A. Poor lagoon water quality, overgrowth of seagrasses by algae (epiphytes) and poor spring and borehole water quality are all, at least in a large part, likely to be related to sewage leaking out of septic tanks and agricultural chemicals that are finding their way to the lagoon. Ongoing monitoring, further investigations and solutions for reducing nutrient enrichment and pollution of the lagoon need to be sought.

B. Ecotourism and the flow of spring waters could be enhanced by beautification projects aimed at cleaning out coastal and spring areas. Other benefits could include increased clean water flows through the lagoon if the nutrient loads from sewage and agriculture are also reduced.

C. Further surveys and monitoring are needed to better understand the lagoon and catchment area, provide data for determining whether interventions are working and identifying new issues as they arise. This could include:

- Hydrographic/benthic survey of the lagoon needed before any dredging or reclamations are done;
- Detailed mapping of mangroves and land cover;

- Monitoring of lagoon fisheries beyond this pilot survey to be carried out for several years;
- Investigations of areas of the lagoon with high pollution loads to identify sources and solutions, focusing on sewage, solid wastes and agricultural chemicals;
- Socio-economic surveys should be repeated periodically to determine if the level of community awareness and patterns of behaviour have changed against this baseline.

D. Legal instruments needed already in place for protecting lagoon and catchment values should be improved and/or enforced. For example, Environmental Impact Assessments (EIA) should accompany any developments and improvements in the lagoon to ensure vulnerable resources and services are protected. Enforcement of policies on reclamations and lagoon developments is also needed.

E. Modifications to lagoon depth and reclamations should be minimised and accompanied by careful investigations and analysis with the aim of promoting the best outcomes for the entire catchment and its people. Dredging machines should be used with caution as they can make significant modifications and should be accompanied by EIAs. Suction pumps should be used in the case of cleaning out springs to minimise damage to surrounding areas. In addition a community group 'Land Reclamation Watch' could be formed to protect against illegal developments. Communities could be encouraged to report unexpected developments.

F. Restoration of habitats and vegetation should be undertaken where necessary to improve the function of the lagoon. This could include:

- Restoration of coastal plants through: planting natural crawling plants along the lagoon coast to trap silts and minimise flow of materials into the lagoon; encouraging replanting of protective undergrowth;
- Minimising clearing of trees which is damaging natural cycles of regeneration;
- Minimising soil erosion;
- Investigating mechanisms for legal protection of areas to be rehabilitated so that regeneration is successful;
- Safeguarding bird, mammals and agents that disburse seedlings;
- Controlling roaming pigs that threaten vegetation;
- Mangrove replanting of seedlings and propagules where there has been damage in the past. A nursery should be established for replenishment projects.

G. Pollution in the lagoon is severe and coming from sewage, rubbish disposal, agriculture and chemical use. These find their way into the groundwater, through direct dumping or are washed into the lagoon by surface run-off or through stormwater drains. Low cost technologies for controlling, diverting or minimising these need to be investigated. Regular clean-ups by communities are needed.

H. Sewage pollution is a special case and is probably responsible for most of the nutrient enrichment in the lagoon (even more than agriculture). Current sewage systems if working well digest raw sewage and convert it to a microbiologically safe, but nutrient-rich material more suited to fertilizer. The overflows and sludge even from good septic systems act as lagoon enrichers, leading to damage. A feasibility study is needed to investigate mechanisms of efficiently removing the sewage from within the catchment to allow the lagoon to recover.

I. Drainage systems should be investigated for their contribution to polluting the lagoon and solutions found to prevent further pollution.

J. Public awareness and participation needs to be encouraged to improve attitudes and the ways that people interact with the lagoon. These should focus on waste disposal, littering, agriculture, organic methods, encouraging regrowth of plants in towns and allotments and on the role of mangroves for providing ecosystem good s and services. Pilot activities should be developed to complement the public awareness campaigns.

K. Hydrology and geomorphological features of the lagoon should be changed with extreme caution and thorough environmental assessments. This includes seawalls, dredging and other developments that can alter water movements into and through the lagoon, and change its depth and shape.

L. Mangroves need to be managed and protected. Uses for fuel, wood, medicines, traditional products and seafoods need to be kept to sustainable levels. Mangrove green belts should be maintained for protecting human settlements located behind them, especially in Popua and Patangata. Rare species should be protected, especially in Nukuhetulu and Folaha with the oldest and most diverse mangroves in the region. Further destruction of mangroves at Nukunukumotu should be prevented.

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Chapter 1: Introduction

1.1 Project Objectives

The Integrated Environmental Management Plan (IEMP) of the Fanga'uta Lagoon Catchment Project (FLC) (or IEMP-FLC) is part of the Program on "Pacific Islands Ridge-to-Reef National Priorities—Integrated Water, Land, Forest and Coastal Management to Preserve Biodiversity, Ecosystem Services, Store carbon, Improve Climate Resilience and Sustain Livelihoods" under the Global Environment Facility (GEF) projects. It focuses on support, maintaining and enhancing the ecosystem goods and services of Tonga's main lagoon catchment and marine reserve areas through integrated approaches to land, water, forest, biodiversity and coastal resource management. These in turn, contribute to poverty reduction, sustainable livelihoods and climate resilience.

The Fanga'uta Lagoon Catchment area is home to over 55% of Tongatapu's population (over 40,000 people and 8,000 households) (*1*). The importance of this area and its value to people is not always considered on a day to day basis, by national planners or residents. Many of the communities within the lagoon area are dependent for their livelihoods and wellbeing on the ecosystem services the lagoon provides. Therefore it is in our best interests to restore and rehabilitate the lagoon to a state where it can sustain and provide the goods and services required.

The lagoon is a life-support system for communities, providing a wide range of marine and intertidal values. The lagoon has provided goods such as mangrove wood, medicines, fishes, seaweed, and shellfish for generations (*2*). However, in recent years yields have dropped and some species are no longer sustainably exploited. For example, mangroves have been exploited and areas reclaimed (*3*).

The lagoon also provides services such as habitats to support our fisheries, attenuate our pollution, carbon sequestration, recreational opportunities (*4*) and coastal protection. In order for us to continue receiving benefits from the lagoon in the future, we need to look at ways of protecting and improving its health. Ecosystem goods, services and resilience are dependent on healthy ecosystems.

In recent years, considerable community concern has been expressed about possible contamination and loss of productivity of the lagoon due to the effects of urbanisation, changing land use, pollution and overfishing. Therefore, the main objective of the project was to identify the current issues and establish appropriate governance of the catchment area to guide efforts being made to improve the environmental conditions. This was to be done through detailed monitoring and implementing an integrated environmental management plan for Fanga'uta Lagoon to protect livelihoods and food production, and through enhancing climate resilience of its people.

1.2 Environmental & Physical Context

Fanga'uta Lagoon is a shallow, almost enclosed embayment, covering an area of 28.4km^2 in the heart of Tongatapu Island, Tonga. The lagoon has a depth of between 1.4 and 6m and a total water volume of around 38,000 mega litres. The Lagoon has two shallow entrances: the narrow passage of Ava Tongo, opening towards Nuku'alofa Harbour to the west, and the wider passage of Manavanga which opens towards Piha Passage (Figure 1). The Lagoon has a natural cleaning habitats and systems that include mangroves, lagoon floor sediments, the tidal system, and fresh water springs (FWS). Fanga'uta Lagoon has two branches, the Nuku'alofa (western) branch and the Mu'a branch in the south-east. These consist of four sectors which are Pea, Folaha, Mu'a and Vaini (Figure 1).

Water interchange between the coastal waters to the north and the lagoon itself is limited. The average length of residence time of water in the lagoon is about 29 days in the western branch and 9 days in the south-eastern branch. It has oceanic tropical humid climate with high variability of rainfall annually. It supports several types of diverse and productive ecosystems such as mangroves, mudflats, seagrass beds and a few coral patch reefs which originally included a relatively diverse fauna and flora.

Already under stress in 2001, the lagoon water quality has declined in the 15 years since monitoring was carried out as part of the Tonga Environmental Management and Planning Project (TEMPP) project (*5*). Increased nutrients and sedimentation have been affecting the marine biodiversity accommodated by the lagoon's ecosystems. This is partly due to large changes in the human environment within the catchment associated with increasing population in Tongatapu. In turn, this has led to increased demands and pressure on available ecological services and resources, increased pollution entering the lagoon and other forms of unsustainable use. In particular, the mobilisation of wastes has been hard to avoid as the catchment of 80km^2 is sloped towards the lagoon (*6*) and encompasses over 30 urban areas and villages.

Freshwater enters the lagoon through rain, ground water seepage, surface runoff and storm water drains. It was estimated that 26,000m^3 freshwater per day flowed into the lagoon from diffuse subsurface sources (*6*) five decades ago, but with increased human developments at the coastal areas of the lagoon it is expected that freshwater flow has changed as well.

1.3 Purpose of this Survey & Report

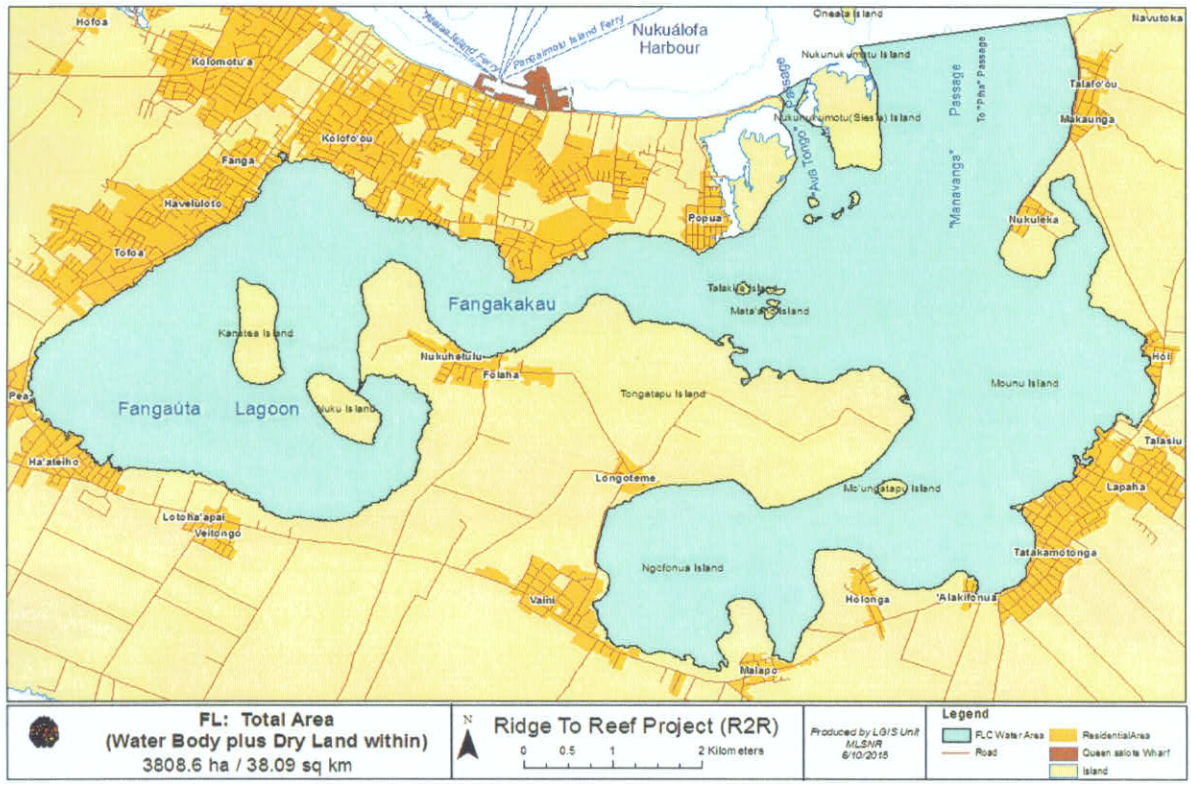
The purpose of this survey and report was to inform all stakeholders, including communities, government and users of the catchment area, of the current status of Fanga'uta Lagoon. By providing up-to-date facts of current condition, it is expected that this report will provide direction and motivation for people to work together in a united front to improve its status. Long term sustainability of the lagoon's ecological services is needed in order to ensure security of people's

livelihoods, poverty reduction and better climate resilience.

This status report will serve to provide answers to peoples' concerns on the environment that they are living in and assist them with information relevant to its protection and improvement. The project will help to create strong linkages between sustainable development of freshwater catchment and coastal areas and it will enhance synergy at the grassroots level, community and national level in management of natural resources at the catchment area.

Figure 1: The Fanga'uta Lagoon Catchment Area

(Source: GIS Unit – MLSNR, 2015)



Chapter 2: Fanga'uta Lagoon's Marine Environment

2.1 Introduction

The main factors affecting the marine environment in the lagoon are pollution, habitat destruction and overfishing. Healthy ecosystems can absorb and attenuate quite a lot of pollution and cope reasonably well. However, in 1993 Fanga'uta Lagoon changed from a healthy lagoon with clear waters and some patch reefs to one with murky waters, with fish kills, and green algae growing on the seagrasses and corals in a process we call 'eutrophication' (*7*). In this state the lagoon cannot manage the current pollution levels.

To reverse the damage, it is important to monitor the lagoon's water quality and biological conditions and to identify interventions that can improve the health of the lagoon. Monitoring can also inform the public and regulators of whether the lagoon is considered safe for seafood consumption, recreation and boating.

Coastal fisheries provide an important source of protein, livelihood and cultural identity to the people of Tonga. As is common in many areas of Tonga, a wide range of species is harvested for consumption in Fanga'uta lagoon, utilizing a variety of fishing methods. They include netting, handlining, spearfishing and gleaning (i.e. walking and picking).

There are management systems for fisheries in Tonga, including Fanga'uta Lagoon, and these are mix of input and output controls, regulated under the Fisheries Management Act 2002. They include closed seasons for mullet, minimum net mesh sizes, a ban on many sea cucumbers, and the use of poisons or underwater breathing apparatus (SCUBA) for fishing. There is also a number of proposed Special Management Areas for the lagoon.

Despite these measures, fishers in the Fanga'uta Lagoon Catchment have expressed concern over diminishing fish stocks since at least the mid-1970s. Most fishers said catches today are less than half in number of what they were 20 years ago (*8*). They also said that reef fish in general are much smaller now, and some species cannot found anymore. With little existing information on fisher's catches gathered for Fanga'uta Lagoon, it has been hard to assess the status of lagoon fisheries and develop actions that might reverse declines. This status report represents the first fishers survey for the FLC. Focus was on documenting some demographics of the fishers, providing a snapshot of catch composition (species) and to cdocument fishers' perceptions of the status of the lagoon's resources.

2.2 Methods & approach

Water quality and benthic surveys (seagrasses, algae, corals etc) were carried out 10-22 August 2015 in six sections of Fanga'uta Lagoon. The sites used were the same as those established during the TEMPP Project in 1998-2000 (*9*) to allow for status now and comparisons with data collected up to 17 years ago. The areas of the lagoon surveyed were Pea, Fanga'uta and Fangakakau in the western arm, Vaini and Mu'a in the east, and the Mouth of the lagoon, with 5 sites within each Section and a total of 30 sites throughout the lagoon (Figure 2).

Figure 2: Location of marine survey sections and sites

Water quality measures were made of physical water characters (pH, salinity, dissolved oxygen (DO), temperature, water clarity and depth) in addition to nutrients (Phosphate, ammonia and nitrate) and faecal coliforms that indicate sewage pollution. Physical water quality measures were taken using electronic water quality meters near the surface (10cm depth) and approximately 20cm up off the bottom. Where depths could not be reached directly by probes, a diver collected a water sample for immediate testing at the surface. Water clarity was measured using both a turbidity tube and a secchi disk, and depth was measured using a dropline.

Water samples of 100ml were collected for faecal coliform testing, stored on ice and analysed in the Geology Laboratory using a membrane filtration technique. For nutrient tests a single 1 litre sample was collected at each site and analysed in the same laboratory using the Hach/Palintest methods.

For benthic marine communities, the percent cover by seagrasses, their epiphytes2 and algae were estimated using a grab method. This differed from the quadrat method used in the 1998-2000 TEMPP surveys because poor visibility made visual methods impossible (see (*9*) for more details on methods). Ten grab samples were therefore used to estimate the percentage cover by seagrasses and algae as well as the presence of other organisms. Quadrats divided as 81 sampling points to estimate percent cover were used in areas that were less turbid around the mouth of the lagoon.

Fisheries in the lagoon were investigated using a 'creel' survey of fisher's catches. Landings were intercepted mostly between 8:00-15:00 at Makaunga, Talafo'ou, Niutao, Nukuleka, Ma'ufanga, Popua, Patangata, Tukutonga, and 'Umusi areas between 10-16 November

[2] Epiphytes are defined as any algae or other organisms covering the blades of the seagrass >5mm

2015. All landed seafoods (fish, shellfish) were identified to species level, counted and their fork length and weight measured. The lead fisher for each landing was interviewed to determine other fishers who took part, fishing methods used, locations fished, the distance travelled, and the costs involved. Their historical fishing patterns, and perceptions of the state of resources, were also documented.

Data for the marine surveys, and all other surveys undertaken as part of this work were entered into a purpose-built R2R survey database for storage of information and analysis. Summary statistics on measures relevant to each dataset were produced by the database and compiled for interpretation. For example, for the creel survey, this included averages of number of fishers per trip, trip duration, catch and catch per unit of fishing effort (CPUE) based on the number of fish caught per fisher per hour spent fishing.

2.3 Status of the Marine Environment

Lagoon Water quality

Surface salinity ranged from 39[3] parts per thousand (ppt) around the Mouth, Mu'a and Vaini Sections and 20ppt on the western arm of the lagoon, whilst the bottom salinity was slightly lower than the surface in all areas.

The temperature of the lagoon water averaged around 23.5 degrees Celsius (C) around the Pea section, decreasing towards the mouth to about 21 . The western arm was about 1 degree warmer than the eastern arm of the lagoon. There was no significant difference in surface and bottom temperatures.

Dissolved oxygen (DO) level at the surface was very good throughout the lagoon at an average of 8.7mg/L. The lowest surface average was around 7.5mg/L at one site near Popua and highest in the Pea Section. Bottom dissolved oxygen was slightly higher than the surface DO.

The pH value, a measure of acidity/alkalinity averaged pH=8 around the lagoon. The lowest average pH of 6 was found at one site in the Mu'a Section.

Water clarity was best around the Mouth and Mu'a sections. Fanga'uta and Fangakakau Sections were found very turbid, with visibility as low as 20cm; and 40cm around the Vaini Section. The deepest depth surveyed was down to 6m around the Mouth Section of the lagoon.

Highest faecal counts were found at one site in the Pea Section, and one site in Fangakakau. These results exceeding the Australian / NZ standards (*10*) for recreational use at 150 faecal counts/100mL. Pea, Fanga'uta and Fangakakau Sections also exceeded the standard for edible seafood of 14 faecal counts/100mL.

[3] Average seawater is around 35 ppt

Nutrients in the Water

Nitrate levels were elevated at one site in Mu'a with 1.54mg/L and 0.68mg/L at one site in Pea. Lower levels were found at the mouth of the lagoon and in Fanga'uta and Fangakakau Sections. However, all water samples tested exceeded the Australian / NZ standards for Nitrate for recreational swimming and boating activities (*10*).

Ammonia levels were low in all Sections of the lagoon and levels did not exceed water quality guidelines.

Phosphate levels were higher than the Australia / NZ standards for recreational swimming and boating activities in all sections of the lagoon. The highest readings were found in Pea, Fanga'uta, and Vaini. The lowest levels were found at Fangakakau.

Bottom-dwelling animals and plants

Two species of seagrasses, *Halodule uninervis* and *Halophila ovalis* and several types of algae, including *Caulerpa spp* and *Halimeda spp* were recorded in the lagoon during the survey (Figure 3). Other minor species of seagrasses were recorded in the lagoon.

Halodule uninervis: There were significant differences in cover by this seagrass in the different sections of the lagoon. The highest density was found in the Pea Section (14-85% cover). There were no seagrasses of this type found, at Mu'a and Vaini, with intermediate cover being recorded at Fanga'uta, Fangakakau and the mouth.

Halophila ovalis: Cover by *Halophila* was 3-50% throughout the lagoon. There was very low cover by *Halophila* at the mouth of the lagoon, with intermediate cover being recorded in the remaining Sections of the lagoon.

Overall seagrass cover was relatively high at Pea (85%), with intermediate cover being recorded in Fanga'uta, Fangakakau, and Mu'a (30-70%). Cover by all seagrasses was near zero at Vaini. Overall, cover by seagrasses declined in the lagoon since 1998 (Figure 4).

Figure 3: Seagrass species common in the lagoon

Strap-like seagrass is Halodule uninervis, Oval leaf is Halophila ovalis.

Figure 4: Seagrass cover 1998-2015 at all sites

Bar graphs show changes in percent cover for 1998, 1999, 2000 and 2015

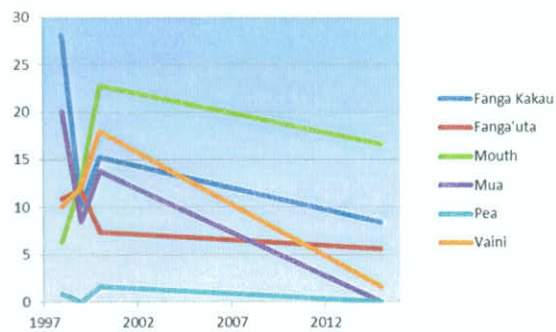
Epiphytes are an indicator of stress, with seagrasses heavily covered by algae often indicating nutrient enrichment (*11*). During this study, all seagrasses were 100% covered by epiphytes. However, the thickness of the cover was generally lowest at the mouth of the lagoon and at Mu'a.

Caulerpa species were not observed in Pea, but other sections of the lagoon had varying amounts of this alga. Low cover by *Caulerpa* was found at Fanga'uta, Fangakakau and Vaini, and greater densities found in the Mouth and Mu'a Sections. *Halimeda* species were not very common in the western arm of Fanga'uta lagoon. In the eastern three sections of the lagoon there was a slightly higher cover by Halimeda.

Algal mats were in large quantities in Pea, with smaller numbers in Fangakakau and the Mouth. Corals were not recorded in any part of the lagoon.

Figure 5: Percent cover of Caulerpa species

Data are from all surveys since 1998

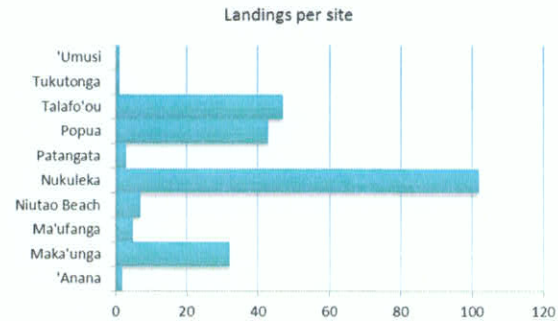


Fisheries

A total of 243 landings were intercepted during the creel survey, mostly of them around the mouth of the lagoon and close to around 10 villages (Figure 6). The largest number of landings was recorded at Nukuleka (42%), Talafo'ou (19%), Popua (18%) and Maka'unga (13%) (Figure 7).

Figure 6: Map showing landing sites (dark blue) and fishing areas (light blue)

Figure 7: Total number of landings by village



The average number of fishers per trip was 1, and varied between 1 and 1.6, with most trips comprised of just 1 or a very small group of fishers (Figure 8). Further, the fishers themselves were surveyed mostly 1 or 2 times during the survey, suggesting that the fishery involves a large number of people doing small scale, infrequent fishing (Figure 9).

Figure 8: Average number of fishers (+/-SE) per trip at landing sites

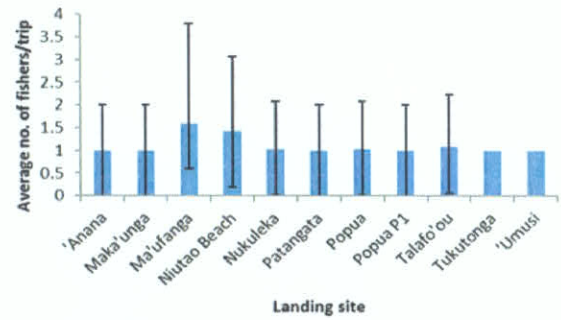


Figure 9: Number of times particular fishers were intercepted during the survey

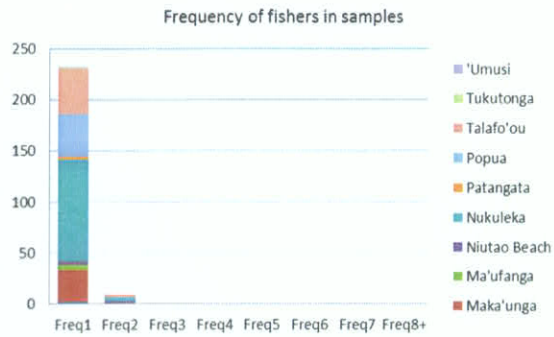


Figure 10 shows the average percentage of the catch by village which was destined for home use or sale. Overall the percentage of catch designated for home use was about the same as that for sale. Home use was most important in 'Anana, Niutao Beach, Tukutonga and Makaunga. The catches were mostly used for sale in 'Umusi and Ma'ufanga.

Figure 10: Percent of catch (average +/-SE) for home and sale at landing sites

In terms of catch composition, a total of 35 species from 23 families was recorded during the survey. The catch was dominated by finfishes such as snappers (Lutjanidae) and emperors (Lethrinidae), bivalve shellfishes, sea cucumbers (such as lolyfish and dragonfish), and shrimps (Penaeidae) (Figure 11). The most common species of Bivalves in the landing catch were the Kuku, Kaloa'a and To'o (representing 56% of the total landed catch by abundance). The most common species of finfish in the landing were Tanutanu (10%), Tokonifusi and Hoputu (10%), 'Unomoa (4%) and 'Ume kaki (2%). The Seacucumber (Loli and Lomu) contribute by 8% of the landing catch.

The most common fishing method was snorkelling, followed by handlining, castnetting and gleaning or collecting (Figure 12).

Figure 11: Percent contribution to the landed catch by species group

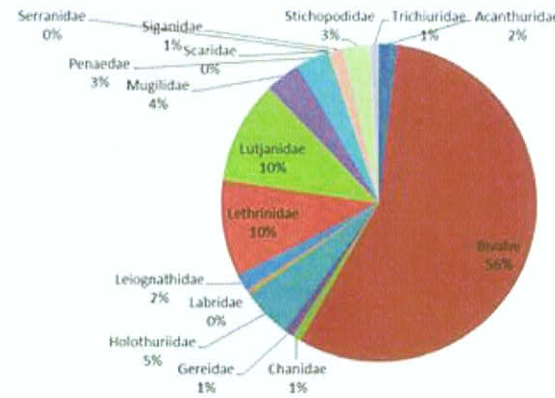
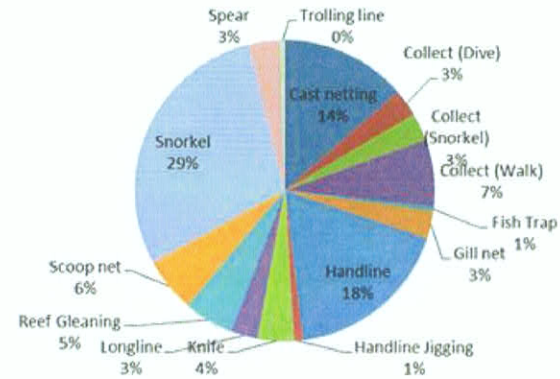


Figure 12: Percent contribution to the landed catch by fishing method



The average catch varied between 5-71 animals caught per fisher per hour of fishing, depending on the fishing method used and species targeted. In terms of weight of seafoods caught, this was between an average of 0.8-6.8 kg of seafood per fisher per hour. The fishing method with the greatest return by abundance of seafoods caught was 'knife' fishing, while in terms of weight caught, the greatest catch per fisher per hour was by reef gleaners.

2.4 Conclusions & Recommendations for Marine Areas

The status of the health of the lagoon was found to be poor in all sections. The areas of the lagoon closest to the mouth were, however, in better condition than the rest due to daily tidal water exchange. Although a healthy lagoon is able to clean itself, Funga'uta Lagoon is receiving levels of pollutants that far exceed what it can assimilate. The lagoon will require assistance from its stewards and users to facilitate a rehabilitation process.

Water Quality & Benthic Organisms

We found that the water quality of the lagoon has declined since the last survey carried out 15 years ago (

Table 1). This has occurred despite waste minimisation campaigns, public awareness and mangrove rehabilitation programmes. This suggests that we have not fully identified the stressors and/or that although we have programmes in place, they are not enough for the

lagoon to rehabilitate itself against the rate of development around it.

Table 1: Water quality events in each section of the lagoon

The bars show the number of sites out 5 for each section of the lagoon at which major impact events were recorded comparing 1998-2000 data with 2015

Problems in the lagoon can compound so that things could get worse in the future. Algal mats formed by alternating layers of blue-green algae, bacteria and sediments were found in several parts of the lagoon. In great quantities, these can be associated with Harmful Algal Blooms (HABs), known as green tides. Their accumulation can reduce the light penetration in the water column, reducing the suitability of the habitat for seagrasses. Exceedingly high biomass can also cause fish gills to clog, leading to suffocation and the development of "dead zones."

These results suggest that rehabilitation actions are now critical for ensuring longterm health and utility of the lagoon. The following activities are recommended:

- There should be a revision of the integrated management plan for the lagoon focused on improving conditions and ensuring sustainable use of the area. This includes a wholistic spatial plan.
- Major problems tended to be common in the western side of the lagoon in Pea, Fanga'uta and Fangakakau. This is also the area with the densest population. Further investigations are needed to identify all major reasons for the problems and interventions to be implemented. At this stage, this includes Pea, Mu'a, Fanga'uta and Vaini.
- Particularly high faecal coliform counts at Pea and Fangakakau require attention.
- Sewage pollution is probably the largest source of nutrients entering the lagoon, causing many of the problems we found. A Nuku'alofa sewage system able to export pollution away from the lagoon is urgently needed. The current building codes should also be reviewed to identify alternative and effective sewage systems for out-lying areas where a centralised system would not be able to reach.
- Monitoring should continue indefinitely to get long term data on change and seasonal patterns. In addition to identifying and then being able to address problem areas.
- Seafoods should be tested immediately to see if they are fit for human consumption. This should be followed with recommendations to be made to the public.
- The public needs to be informed about the importance of international standards for recreational use and seafood consumption, and the fact that conditions in the lagoon have exceeded the allowable levels.

Fisheries

The results for fisheries come from a single "snapshot" of data collected during a 10 day pilot in November 2015, and are unlikely to be representative of the catches across Fanga'uta lagoon in a full year. The results obtained do, however, suggest that finfish resources are under stress. The overall catch rates of key families were generally lower than at other landings elsewhere in Tonga. Ongoing creel surveys are therefore recommended for the lagoon variations in catches over time and from place to place. In addition to continuing creel monitoring, the following recommendations are proposed for fisheries:

- A 'core' monitoring team should be established within the Department of Fisheries and Environment that can carry out the surevys and work with regional organisations.
- Future creel surveys should be extended to other locations in the lagoon such as Lapaha, Hoi, Holonga, Malapo, Vaini, Folaha, Longoteme, Ha'ateiho, Veitongo, Pea and Havelu.
- Additional biological sampling should be added to the creel work to focus on sizes and/or ages at maturity.

Chapter 3: Coastlines & Catchment land

3.1 Introduction

Coasts are an interface between oceans and the land, including freshwater systems that mingle with salt water in estuaries. The transition between terrestrial and marine environments represents one of the vital changes in habitat for living organisms and Fanga'uta Lagoon is no different in the case of Tonga. The lagoon produced unique flora and fauna adapted to dealing with unique environmental challenges. One of those challenges is that the border between terrestrial and marine systems is constantly changing due to increased human population, an increase in groundwater extraction and increasing wastewater contributing to pollution. In the future groundwater and spring water quality will become measures of sustainable practices which determine the impact of terrestrial activities or land use practices. The fact that Fanga'uta is a booming residential area, because of its proximity to the Lagoon, singles it out as vulnerable to human impacts; which makes this project critical for the baseline data it has collected.

The most important indicators for the baseline data on the health of lagoon coasts included measures on coastal vegetation (including land cover within the catchment), fresh water springs, boreholes, land reclamation, mangroves (including hotspots), soils and land use. The baseline data collected for this chapter will provide a benchmark for the current status of the coastal environment around Fanga'uta and help us to identify interventions that might be needed to address issues for the coastline of the lagoon. These will be designed to

assist in the recovery of the once-abundant resources of the lagoon.

3.2 Methods & Approach

Water Quality of Bores and Springs: The geographic information systems (GIS) specialists within the Terrestrial and Coastal Monitoring Team of the R2R Project reviewed the existing Environment Management Plan (EMP) (*5*) for the Fangaúta Lagoon System (FLS). Surveys were then undertaken to assess the current conditions and status of the coastal areas of the lagoon as follows:

- Survey of Freshwater Springs: their locations, heritage values, and water discharge;
- Identification of Mangrove Hotspots: locations and mangrove loss
- Mapping of land cover within the Catchment
- Identification of reclamations and developments

The work was carried out using a combination of satellite imagery, historical maps and on the ground surveys at many sites around the lagoon.

Gathering information on the springs, mangrove areas, land cover types, reclamations and developments is critical to understanding the mechanisms for changes in the lagoon over time. For freshwater springs this included measuring discharge from them because it may contribute significantly to the water quality of the Lagoon. Improvements where discharges have been compromised could contribute significantly to lagoon water quality. At the same time measures on the quality of the spring water and wells was measured to establish a baseline for environmental health status and an indicator of sustainable practices. The quality of these waters can show the level of impact of terrestrial activities or land uses within the Fanga'uta Catchment Area.

It is also critical to identify and map the extent of the existing land reclamations and other developments around the Fangaúta coastal areas. These could be some of the main threats to the cleanliness of the lagoon, and causes of any decreases in mangroves.

Freshwater springs: The Lagoon was divided into four main Sectors for the survey of springs (Figure 13), adopting the approach from a previous study (*12*) on the hydrodynamics of the Lagoon to simplify the display of surveyed data. The four Sectors were Pea Sector, Nuku'alofa Branch, Mu'a Sector and Vaini Sector.

Figure 13: Fresh Water Springs surveyed at 4 Sectors of Fanga'uta Lagoon (Source GIS, MLSNR)

The location of every known freshwater Spring along the lagoon coastline was mapped by the team trekking along the Lagoon coastal areas beginning from Makaunga in the north-east, down to Maúfanga in the south. The names of the springs were provided by town officers, district officers and members from the communities. All locations of springs were recorded uysing a hand-held global positioning system (GPS) (GeoXH GNSS set) and the data were downloaded directly into ArcGIS software for processing and mapping.

The survey specifically targeted springs located in areas with (i) heritage values but located inland, (ii) heritage values and located in coastal areas, (iii) located at coastal areas but too deep to measure, and (iv) located at coastal areas but now covered over by new developments.

Figure 14: Vai ko Veifoa spring at Holonga

Figure 15: Vai o Lole spring at 'Alaki

The amount of discharge for 38 of the springs was measured during low tides to determine the amount of freshwater flowing from them to the lagoon every hour. A plastic measuring tape and stop-watch were used for measuring the velocity of the water flow. Measurements were also taken of the entrance area to the spring water cave. Field records were downloaded into an Excel Spread sheet for automated calculations of water discharge rates.

Figure 16: Trekking through Kauvai near Tupou Beach

Figure 17: Tufumahina main water spring

Figure 18: Diagram of how water discharge was measured

Heritage values of springs: The known historical and heritage values of the springs were documented during visits with town officers. This included the collection of copies of formal documentation where available.

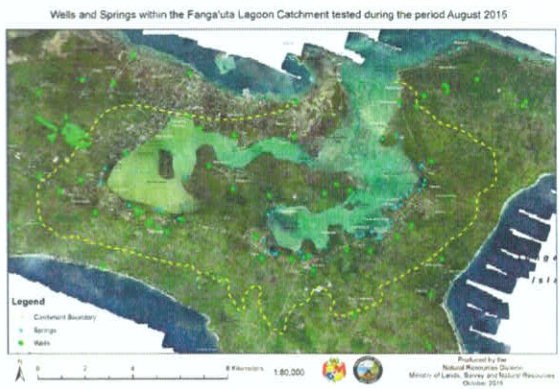
Figure 19: Developed and clean springs: Vai-a-Fafine/Vai-a-Tangata, Vaini (near Tupou Beach)

Figure 20: Pakilau, Vaini

Figure 21: Freshwater springs with heritage values: Fangakukuvalu, Nukuleka

Water quality in wells and springs: These were sampled and tested for physical properties, nutrient levels and bacterial contents in a manner similar to the marine surveys. Sample sites included 57 springs (not previously tested) and 16 wells (Figure 22). The springs, where groundwater seeps out of the ground on the surface, were more noticeable along the shoreline during low tide. The 16 wells sampled were either private or village water supply production wells.

Figure 22: Location of wells and springs sampled for water quality, October 2015 (Natural Resources)



The 16 wells had historical water quality data, so it was possible to cross referencing the new data with older baselines to detect changes. Two water samples were taken per site, one for bacteria in a 100ml glass container, and the other for nutrients in a 100ml plastic container. All sampling containers were sterilised prior to use and refrigerated the night sampling day. After collection samples were placed in a cooler with ice to prevent the samples from degrading and taken to a laboratory for testing.

Measurements of pH, temperature and conductivity (a measure for salinity) were taken on site using a Solonist water quality meter. Measurements of nutrients and faecal coliform bacteria (an indicator of sewage pollution) were made in the Geology Water laboratory. Bacteria were tested using a DelAgua kit using the membrane filtration method. Most of the water quality variables measured were compared to the standards recommend by the United Nations World Health Organisation (WHO) Drinking Water Guidelines (*13*).

All results of tests and measurements are recorded on a paper form sheet before entering into an excel spread sheet file. Results of water quality testing were transferred to the ArcGIS mapping program where spatial analysis tools were used to interpolate the results.

Coastal vegetation: The lagoon shoreline was divided into 2 sections for the survey:

Section 1	▪ Manuka – Makaunga (excluding Niutao) ▪ 3.5km (lineal distance) and 2.6ha (area) ▪ Survey method: full survey.
Section 2	▪ Nukuleka – Patangata (including Siesia and Niutao) ▪ 76km (lineal distance) and 105ha (area) ▪ Survey method: sample survey

Efforts were made to identify all vegetation types, with a particular focus on the vascular or higher tree species. We also measured other important variables such as diameter at breast height (dbh) and height of the tree or plant.

Mangrove Hotspots & Surveys: Mangrove Hotspots were identified using high resolution satellite images from different time frames, which were then used to detect changes over time. All areas showing significant change then digitised so that calculations of areas lost or that changed over the years could be made.

Mangrove cover was surveyed in 4 island areas of the lagoon at Nukunukumotu, Talakite, Mata'aho and Mo'ungatapu. These were areas not previously surveyed in an earlier study (*14*) which was referenced to describe mangrove cover in other parts of the lagoon.

The Nukehetulu-Folaha mangrove area has high diversity and is well-established. Palaeoecological studies have shown it to be the longest established mangrove area known in the Pacific islands, a refuge from which mangroves expanded as sea-level stabilized following the last de-glaciation (*15, 16*). The area is also a proposed Conservation site for the IUCN MESCAL Project.

Popua and Patangata are located in the Central District where the Government has the sole ownership of land. The area is mostly covered by *Rhizophora* species (tongo). Due to the proximity to the settlements of Popua

and Patangata these areas are among the worst degraded areas in Tongatapu.

Talakite, Mata'aho & Mo'ungatapu islands are located inside the lagoon near the mouth of the lagoon. Nukunukumotu is also known as Siesia next to Patangata village. These islands are similar in nature for their small size, and lower human intervention.

A GPS-based survey in the field involved identifying mangrove species and the following steps:

- Using Google Earth, the entire area of the target mangrove forest was defined.
- Google Earth was also used to help identify different vegetation types, mangrove associated species and water bodies or streams.
- After identifying the boundaries of mangrove area, the start and end coordinates of a representative transect were extracted, entered into a GPS and used to navigate to the field site and the transect line.
- At each point where boundaries of mangrove species occurred, the data were recorded.

Land cover and Vegetation: The catchment was divided into two sections for a survey of land cover. This included identification of all vegetation, stem counts (number of plants and trees), measurement of height and recording the state of the forest in each area.

A land cover map was developed using LIDAR data to digitise the various types of Land cover on terrestrial areas of the catchment. This information was added as a map layer in the GIS.

Soils: Sampling was designed to encompass all of the different land uses in the catchment area. This included undisturbed forest, secondary forest, land under traditional crops, semi-intensive/very intensive agriculture lands, industrial areas and rural and urban residential areas from the village of Manuka to the capital Nuku'alofa (Figure 23).

The chemicals likely to be present in the soils included fertilizers and pesticides (especially the herbicides paraquat and glyphosate for weed control in farming, offices, airports, infrastructure and residential homes). Industrial chemicals were also expected, such as Tonga Forest Products Ltd 'Tanalith C Oxide' for timber treatments, Tonga Power Ltd persistent organic pollutant (POPs) associated with transformer residues, oils and fuels and general household pesticides, bleach, detergents, paints and other domestic chemicals.

Using a GPS, tax allotment and soil-type map, sample sites were located and details such as vegetation, crops, and landuses recorded. The soil type in the area was identified and cores of 15-20cm depth dug to collect a vertical slice of the soil. At each location a criss-cross pattern was used to collect 20-30 cores within an area of about 2 acres. The cores were then pooled and mixed thoroughly in a big plastic bag and a sub sample of 1.5-2 kg extracted, labelled and taken to the soil laboratory for testing.

In the laboratory samples were placed in aluminium trays and plant and rock materials discarded. The samples were then air dried using a fan for 4 days before being ground with a mortar and pestle. The samples were then sieved to 2 mm, resulting in a 200g sample, representative for one location.

Figure 23: Location of soil sampling sites

A total of 20 soil samples were selected for chemical analysis of heavy metals and residues of organochlorines, organophosphates and carbamates (pesticides). Six of these were from residential areas (3 urban, 3 rural) and 5 from industrial sites. Nine of the samples were from agricultural and forest areas (1 primary forest site, 1 secondary forestry site, 1 brushwood vegetation, 1 traditional farming and 5 squash farms).

Agriculture: The Tonga Agricultural Extension Division of the Ministry of Agriculture, Food and Forests (MAFF) undertook a baseline survey to understand the current status of farming and use of chemicals within the catchment. A random selection of 10% of all tax allotments (farming plots) in the area Tofoa to Talafo'ou villages was surveyed. That was equivalent to 202 tax allotments selected from 20 villages. At the time of each visit the tax allotment number, land use, food crops grown, agricultural practices used and livestock kept were recorded.

Waste: This is considered one of the major environmental issues within the Fanga'uta Lagoon Catchment. Consultation meetings conducted in 26 villages showed that the public was very concerned about people illegally dumping waste around the lagoon. They were also concerned about the Waste Authority Ltd collection services to all villages. District and Town officers requested installation of anti-littering sign posts to educate and change people's attitudes and to use the waste collection services instead of littering the lagoon. They also requested a clean-up of the areas before installation of sign posts that would remind people to use weekly rubbish services and not to dump waste anywhere they liked.

A waste survey was carried out at all 26 villages around the lagoon. This involved inspections of beaches, coastlines, mangrove, forested and other areas around the lagoon to identify waste hotspots. The clean-up program, run for 2 weeks was also used to sample. All waste collected was characterised before being disposed of at Tapuhia Landfill. Separate vehicles were used for disposal materials and those to be recycled.

Reclamations & Developments: Land reclamation boundaries were similarly digitised using existing

cadastral town and tax allotment maps, as well as the latest available satellite images.

3.3 Status of Coasts and Catchment

Freshwater Springs and wells

A total of 54 freshwater springs was mapped within the lagoon catchment. There were 10 in Pea Sector; 2 in Nuku'alofa Branch; 12 in Vaini Sector; and 30 in Muá Sector (Figure 24). Most of the springs in Vaini Sector were well developed and cleaned by the community in their efforts to beautify their natural environment for ecotourism purposes.

As there were no water reservoirs in Tonga in ancient times, the freshwater springs were the main source for community drinking water, bathing, water sports and for watering animals.

Figure 24: Fresh Water Springs identified

(Source – GIS, MLSNR)

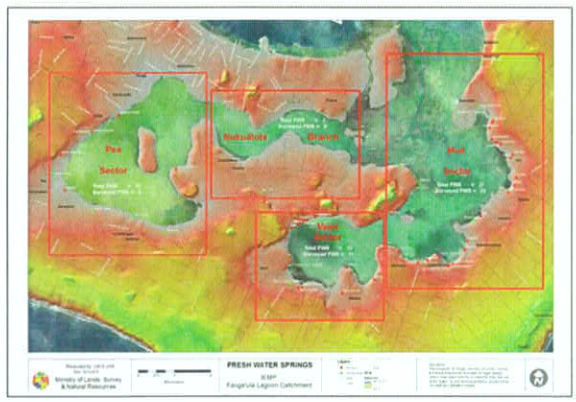


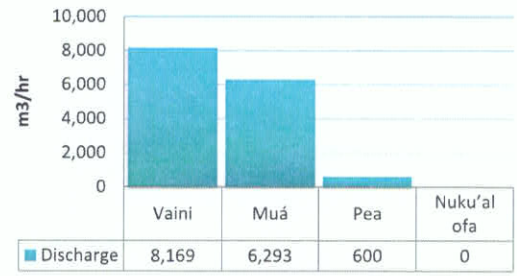
Table 2: Identified Fresh Water Springs with Heritage Values

The remaining FWS historical values is currently awaiting reports from Town and District Officers

Name	Location
Po'uli kae 'aho	Makaunga
Fanga Kukuvalu	Nukuleka
Mohuloto 'i Fungasia	Nukuleka
Vai 'o Lole	Alaki
Vai 'o Lulu Vai 'o Lupe	Alaki
Tu'imatamoana	Alaki
Vai ko Tolopona	Tatakamotonga
Vaini / Vai ko Felefonu	Vaini
Tufu mo Kale	Malapo
Ha'apuopuai	Tatakamotonga
Fangasiale	Longoteme
Vai ko Puna	Pea

Spring water discharge rates: The Vaini Sector had the highest rates of water discharge found during the study (Figure 25). It is possible that this is related to the observation that most of the springs in the area have been cleaned and cared for by the community. However, it is also possible that other factors are affecting flow rates and further investigations will be needed.

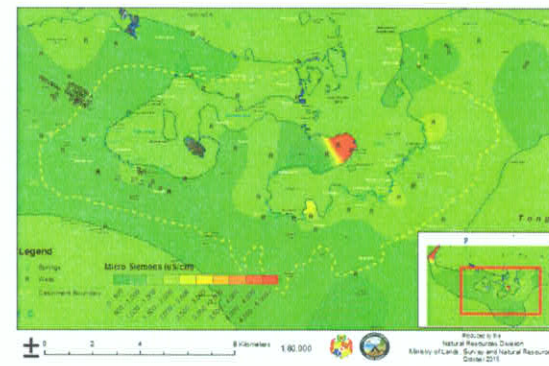
Figure 25: Total discharge of freshwater springs in each survey Sector



Water quality: Conductivity, a measure of water salinity was highest on the land area near the Mu'a section of the lagoon, opposite the mouth (Figure 26). Generally the land areas in the western and southern parts of the catchment, and on the eastern side of the mouth had the freshest well and spring waters.

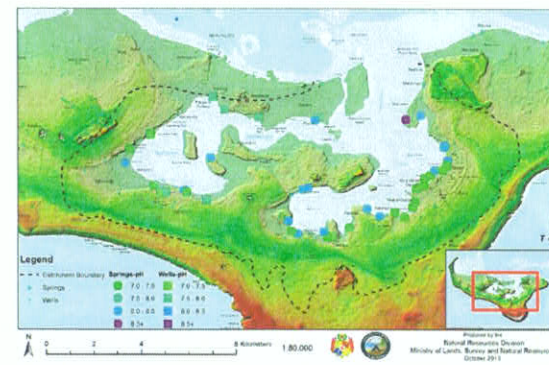
Figure 26: Conductivity (a measure for salinity) of wells and springs during August 2015

Conductivity values are accurate only for the area bound by the coastline (blue) and the catchment boundary (yellow dashed line).



The results of pH (water acidity/alkalinity) testing showed a relatively normal range between 7.03 (neutral) and 8.53 (slightly alkaline). The highest alkaline reading, from Nukuleka should be investigated further to determine its source. Readings of between 8.0-8.5 were also found in the eastern Fangakakau Area (Figure 27).

Figure 27: pH readings from springs and wells

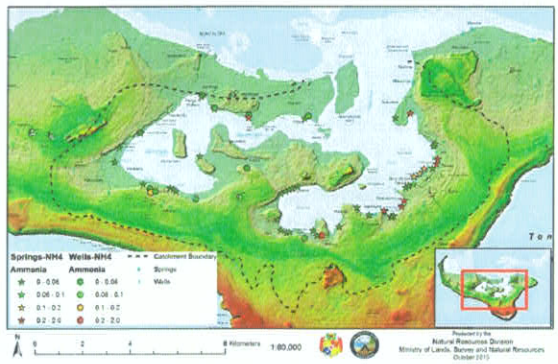


Nitrate levels in the lagoon were below 7.6 mg/L at Mataika village. These were well below the safe level of 50mg/L for drinking water (*13*). Other areas with a content of greater than 4.0 mg/L were Lavengamalie, Malapo, Veitongo and around Fungamanamo'ui Golf

Course. The remaining samples had either lower or zero levels of nitrate. Although all samples were considered safe from drinking water, the presence of nitrate indicates significant levels of organic matter decomposition (oxidised nitrogen).

The Ammonia level at Anana was found to be 1.2mg/L, which was higher than the safe level for drinking water of only 1mg/L. Other areas with noticeable contents were Nukuleka, Lahapa and Hoi with 0.46, 0.46 and 0.31mg/L respectively (Figure 28). The presence of Ammonia is indicative of waste decomposition through anaerobic processes. The natural level in groundwater and springs should be around 0.2 mg/L. Higher levels can occur due to application of nitrogen fertilizers, livestock operations, industrial processes, and sewage.

Figure 28: Ammonia readings (NH_3)



The phosphate levels observed during the survey were safely below the standards for drinking water. The highest concentration of 4 mg/L was observed at Lapaha (Figure 29). Other areas with concentrations above 2 mg/L were Malapo, 'Alakifonua and Tatakamotonga. The sources may be natural, but it is more likely they come from excessive use of fertilisers, pesticides and cleaning compounds in the area. These end up draining into the groundwater and springs through soaking into the soil. Human and animal wastes (sewage) are also likely to be a contributing factor.

While phosphates can encourage growth of plankton and water plants and this may be seen as beneficial for marine life, the opposite is true for Fanga'uta Lagoon. Surplus phosphates are known to cause algal blooms that may choke the lagoon life. Sources of phosphate within the catchment should be monitored closely and followed by mitigation plans.

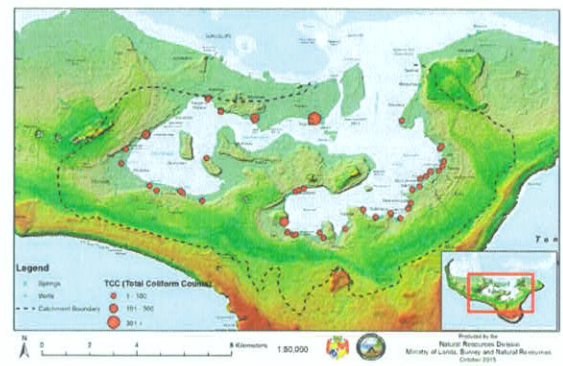
Figure 29: Phosphate readings (as PO_4)

Faecal coliforms (indicator of sewage pollution): Most of the bacterial counts were between 1-100 colonies (per 100ml of water sample). These were mostly from the springs around the lagoon. The bacterial counts from Vaini, Lavengamalie and Anana were the highest between 101-300 counts. Although this is not considered alarming, these values suggest that further investigations are needed to identify whether there are any point sources that could be mitigated, and/or whether the sewage pollution is more diffuse over the catchment.

The 300+ bacterial counts for the Popua Area is an indication of the contamination level from human and animal waste infiltrating to the groundwater. This is a serious concern, for it can be a catalyst to disease epidemics or outbreaks. Further investigations need to be undertaken to determine the spatial extent of the contamination. Mitigation options should be implemented soon.

Figure 30: Faecal coliform counts

Values are colonies per 100ml of water sample.



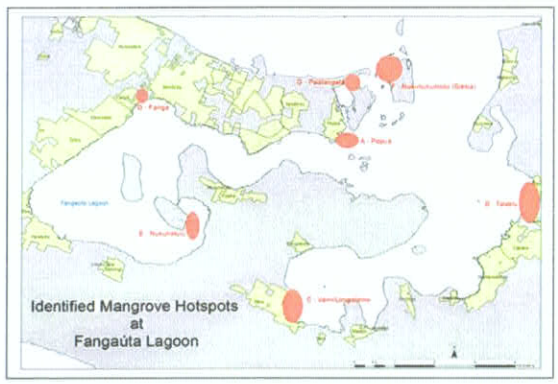
Mangroves

Mangrove hotspots: Mangroves hotspots were identified in the Lagoon, based on calculations of loss over the last 8 years. We identified 7 such areas (Figure 31). The loss of cover between 2004 and 2012 was 50% at Popua, 31% at Talasiu and 12% at Nukuhetulu.

We suspect that some mangrove loss is due to alterations of natural flow patterns of water into the lagoon as observed at Nukuhetulu. The raised road level and reclamation of a large area for recreational activities (sports field) have blocked or altered the natural flow of fresh and tidal waters between Folaha marshland and the lagoon. Other factors would include overharvesting of mangrove materials and outright cutting and reclaiming the areas for developments.

The three most critically affected hotspots were at Popua (Hotspot A), Talasiu (B), and Nukuhetulu (E) (Figure 31).

Figure 31: Identified mangrove hotspots



Yarita & 'Aholahi (*14, 17*) showed that most mangroves in the lagoon were found along muddy sheltered shorelines free from strong winds and currents. They thrived in areas with fine sediments and fresh water. The total area of mangroves in Tongatapu was 1,450 ha, occupying about 6% of the total land area of the island. Fanga'uta Lagoon has about 29% of the total mangroves for Tongatapu, estimated at about 419 ha. According to Yarita & Hoifua the area of mangroves is decreasing to cutting, over-use and coastal development.

Hoifua & Yarita (*18*) found 11 species of mangroves in Tongatapu, including 6 that are common (Table 3).

Table 3: List of mangrove species in Tongatapu

List from Hoifua & Yarita 2012; No. is total count of each species in this study

Tongo Group	Scientific name	Local name	No.
Major components	*Bruguiera gymnorhiza (Red)*	Fa'onelua	2
	Bruguiera gymnorhiza (White)	Tongota'ane	463
	Lumnitzera littorea	Hangale	212
	Rhizophora samoensis	Tongolei	323
	Rhizophora stylosa	Tongofeta'u	11826
	Rhizophora x selala (hybrid)	Tongo	32
Minor components	*Acrostichum speciosum*	Hakato	
	Excoecaria agallocha	Feta'anu	4
	Heritiera littorali s	Mamea	
	Pemphis acidula	Ngingie	
	Xylocarpus granatum	Lekileki	32
Mangrove associates	*Barringtonia asiatica*	Futu	
	Cerbra manghas	Totohina	
	Calophylum inophyllum	Feta'u	
	Clerodendrum inerme	Lalahina	
	Derris trifoliata	Kavahaha	
	Hibiscus tiliaceus	Fau	
	Morinda citrifolia	Nonu	
	Pandanus tectorius	Fafa	
	Thespesia populnea	Milo	
	Scaevola taccada	Ngahu	
	Spinifex littoreus		
	Stahytarpheta jamaicensis	Hiku'ikumaa	
	Xylocarpus rumphii	Lekileki	
	Vitex trifolia	Lalatahi	

In this survey of Fanga'uta Lagoon, the most abundant species was Tongofetau, with Tongota'ane as second most abundant (Table 3). Very low numbers of Hybrid Rhizophora, Lekileki, Feta'anu and Fa'onelua were recorded. Their low abundance could indicate a low survival rate or high rate of destruction. The results suggest that these 4 species should be protected and special attention should be paid to propagating their seedlings for replanting.

Hangale and Tongota'ane are occasional along the upper boundary of Fanga'uta lagoon. These species are rare, and the numbers are small. These species become interspersed with Feta'anu towards the land edge. Other species, especially mangrove associates, form an understorey in these areas, including Hakato, Feta'u, Kavahaha, Lalahina and Fau.

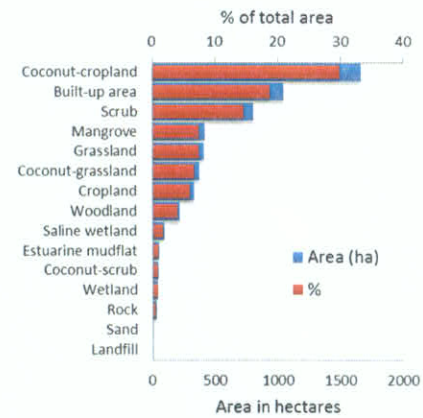
Popua, Patangata and Nukunukumotu are located in an area in which the Government has the sole ownership of land. The area is mostly covered by *Rhizophora* species and is the worst degraded mangrove area on Tongatapu. In contrast, the Nukehetulu area has high diversity and is probably the longest established mangrove area known in the Pacific islands (*15, 16*). This area is proposed as a Conservation site for the IUCN MESCAL[4] Project. The mangrove areas at Talakite, Mata'aho, and Moungatapu are all small islands that are not inhabited or exposed to much human traffic. Some of the largest mangroves were recorded in this area, and it is likely this would be a good area from which to source propagules and seeds. They are young geologically, so the diversity of mangrove species is not as high as in Nukuhetulu.

Land Cover & Coastal Vegetation

Land cover: The three most dominant land cover features shown in Figure 33 Table 4 are coconut-croplands (most outstanding), Built-up areas, and scrubs. It is important to recognize the various land cover features at the FLC as they also contribute to the health and cleanliness of the lagoon.

The three most dominant Land cover features shown (Figure 32, Figure 33) were found to be coconut-croplands (30% of the total area of the catchment) built-up areas (19%), and scrub (14%).

Figure 32: Land cover as total area (ha) and percentage



The three land covers with the lowest percentage of the catchment area were landfill, sand and rock. Wetlands and estuarine mudflats occupy about 1% of the area each, and saline wetlands (or 'wet deserts') around 2% of the area.

[4] International Union for Conservation of Nature

Figure 33: Land use and vegetation cover map for the catchment

(Source – GIS of MLSNR, 2015)

Coastal Vegetation:

In two sections of the coastal lands surveyed, 26 different woody and shrub species were identified. All of the trees are considered native except the dwarf palm species. Overall, in one of the sites we counted 1,041 stems (trees or plants), with Toa (*Casuarina equisetifolia*) the most common species (431 stems). The least common species were vavae, tuitui, 'olive, milo, masi and kalosipani.

In terms of forest structure, the forest age-class in Section 1 was dominated by medium trees, and in Section 2 by young trees (about 2/3 of the vegetation). Section 1 shows a forest structure consistent with discontinuous or periodic recruitment. The actual level of seedling establishment may be sufficient to maintain the population, but its infrequency causes notable discontinuities in the structure of the population as the newly established seedlings and saplings grow into the larger sizes, often depending on canopy gaps for regeneration. The larger number of small trees in Section 2 is a characteristic of shade–tolerant canopy trees that maintain a more or less constant rate of recruitment. The Section 2 forest structure is considered the ideal assemblage of a stable and self–maintaining plant population.

We identified 2 major issues for coastal vegetation, namely the present of rubbish dumping sites and roaming pigs. These issues are expected to present obstacles to the improvement of floral-diversity, whether by tree planting or natural regenerating initiatives.

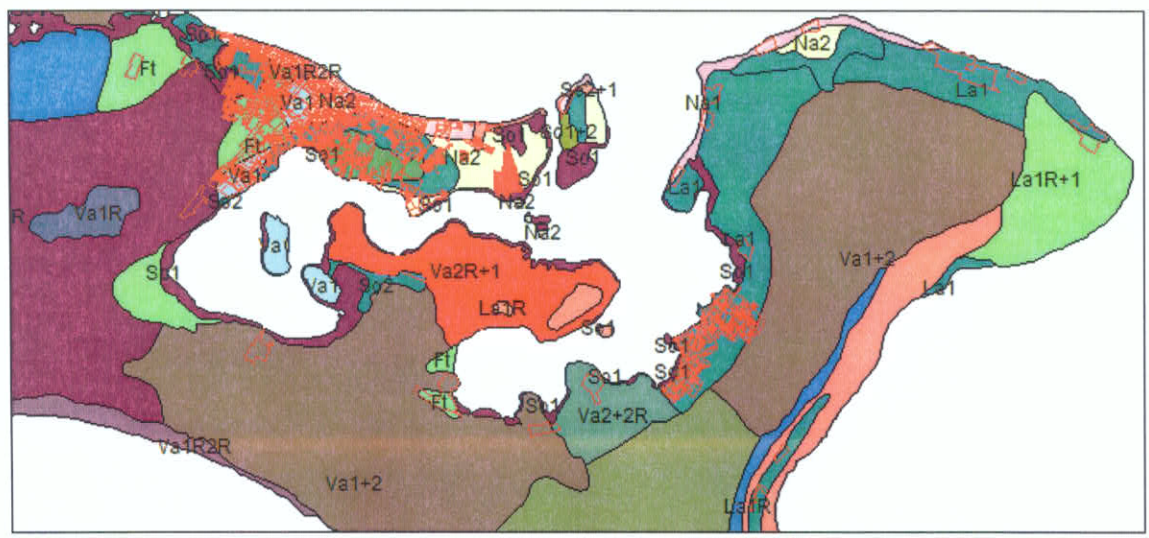
Soils

The major soils of Tongatapu are derived from several deposits of volcanic ash from volcanoes on the western side. There is a younger reddish brown volcanic ash (5,000 yrs. old) on top of an older volcanic ash soil of browner yellowish color (20,000 yrs. old) (*19*). The younger volcanic ash soils are much more fertile with a higher amount of nutrient levels for plant growth such as phosphates, calcium, magnesium, potassium, sodium, iron, aluminum and silicon than the older soils underneath. The younger volcanic ash soils are also thicker by more than 2 meters in the west, decreasing down to less than 0.5 metres in the east. The iron oxides in the soil aid in aggregation, but bind the phosphate fertilizer applied in agriculture, making it unavailable to plant roots.

The Fanga'uta catchment includes farming areas Manuka in the north-east Vaini and Ha'ateiho in the south, Havelu to the west and to the Nuku'alofa eastern suburb of 'Anana in the north. This area includes a range of different soil types (Figure 34), ranging from Nuku'alofa sandy loam soil, Lapaha clay loam soil, Vaini clay loam soil, Sopu peaty sandy loam soil, Fatai poor drained clay loam soil and the Fahefa clay loam soil. The properties of these soil types correlate well with the current land-use and existing vegetation with the exception of the urban expansion of the residential zones.

Figure 34: Soil types in the lagoon catchment

Nuku'alofa sandy loam soil (Na1+2), Lapaha clay loam soil (La1+R), Vaini clay loam soil (Va1+2+R), Sopu peaty sandy loam soil (So1), Fatai poor drained clay loam soil (Ft) and Fahefa cloam loam soil (Fh+R).



Agriculture

Tax allotments and landuse: Nukuleka had the fewest parcels of land, while Lapaha had the most at 39 parcels involved in agricultural activities. In Malapo land was used for 8 different types of farm production, the highest average diversity in landuse recorded. This was followed by Holonga and Lapaha with 4 different types of landuse each and Folaha at an average of 3.6. The rest of the villages had no farming allotments (Haveluloto, Maka-ki-'Eua, Pea and Tofoa). However, this only refers to the sites visited and there could be some agricultural landuse at some of these villages.

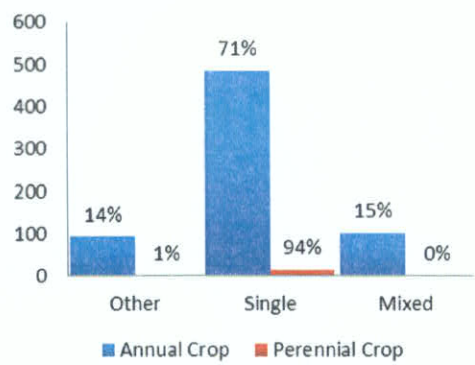
Crops: About 60% of the annual crops surveyed use the line method of planting of their crop. The compact method is used by 30% and the scatter method about 2% of allotments. About 8% of those surveyed used other methods.

Most of the crops recorded from 695 samples were annuals (98%) with only 2% as perennials (Figure 35). These were distributed as 72% single plantings, 15% mixed planting and 14% 'other'. Almost all of the perennial crops (94%) were present as single plantings. In contrast, for annual crops, although single plantings were dominant (74%) about 15% were as mixed plantings.

Agricultural practices: Of the 695 crop areas surveyed 78% used fertilizer and 22% did not. Pesticides were used in about 45% of cases, while 55% of farmers said they did not use them. Irrigation was use dby 15% of farmers. Only 9% of 650 respondents said that they used organic fertilizers and practised organic farming. These results suggest that the agricultural practises within the FLC are depended on the use of chemicals and the amount of nutrients captured by the soil are expected to be high with a high possibility of regular leakages in downward slopes.

Figure 35: Frequency of annual and perennial crops in either single, mixed or other plantings

Values above the bars are percentage for each type of planting for each crop type



Livestock: There were 94 parcels of land used for livestock farming (108 respondents to this question). Based on data from respondents about 65% of livestock was concentrated in the central district whilst 35% was found in the eastern district.

There were 19 types of livestock kept of which 54% were cattle, 26% pigs, 14% horses and 3% sheep or goats.

Waste

The survey found many different types of waste on the beaches around the lagoon (Figure 36). A result of the survey was the cleaning up of some areas and the installation of signs designed to improve waste disposal practices.

Overall about 47 tonnes of waste were collected from 37 truckloads. The majority comprised plastics and cans. In addition, 81 sign posts were installed, with most villages receiving 3 signs, except Vaini with 4 signs installed and Ma'ufanga with 6.

Figure 36: Waste dumped on lagoon edge near a mangrove

Figure 37: No littering signs installed

Reclamations & Developments

Prior to 2009 Ministry of Lands had a plan for land reclamations and allocations along a large part of the Fanga'uta Lagoon shoreline. Implementation of that plan has resulted in severe damage to the coastal ecosystems. Coastal vegetation such as mangroves protects the lagoon from pollution, and the lands from adverse effects of climate change and sea level rise. The large land reclamation plan was later terminated by the Privy Council.

The decision to cancel the allocation and reclamation of lands at the fringes and areas surrounding the lagoon made a large difference to the biodiversity, and specifically mangrove ecosystems. There are, however, still signs of illegal land clearings and reclamations around the Lagoon.

A survey by the Land Commission in 2011 (with mapping done by the Lands Geospatial Information Services Unit of MLNRS) showed that 78 hectares of land

were reclaimed at the Nuku'alofa beach fronts and or at lagoon coastlines around Tongatapu for development and residential purposes. Approximately 35% of these reclaimed lands were found within the areas surrounding Fanga'uta Lagoon (Figure 38).

A total area 27.6 hectares has been cleared from the coastal areas of the lagoon for land developments, specifically for residential, public purposes or Township extension (Table 4).

Table 4: Different Categories of Land Reclamations (GIS, MLSNR 2015)

Categories of Tenure	Number	Area (ha)	%
Registered lands	37	6	21
Leases	17	3	10
Allocated but not yet registered	28	3	10
Public (cemetery, road, jetty, market)	17	5	17
Township Extensions	4	6	22
Others	3	2	6
Unknown	11	4	14
Total	**117**	**28**	**100**

Figure 38: Land Reclamations at Nuku'alofa beachfront and Fangaúta Lagoon

3.4 Conclusions & Recommendations for Coasts

Springs, Wells & Water Pollution

Discharge from springs appeared to be related to how well they were maintained and whether they wre kept clean by the community. They are also seen as a force that helps to flush pollutants out of the lagoon. To improve the springs we recommend that:

- Beautification, reconstruction and cleaning of springs should be carried out by communities
- Only suction pumps should be used for cleaning springs
- Surveys of lagoon water movements and depth (hydrographic surveys) should be carried out to understand the lagoon's natural systems prior to any works. Discourage dredging in lagoon shallow areas
- Strict application of Environment Impact Assessment (EIA)
- For sewage pollution in the short term improve existing systems using sand filtration; For sewage in the longer term investigate a centralised sewage system capable of exporting nutrients away from the lagoon; Use composting toilets in remote areas where centralised service would be impractical (similar to Vava'u)
- High ammonia levels at Anana should be investigated; The high phosphate composition at Lapaha and neighboring areas should be investigated, including doing surveys of landuse practices in the Hahake region so that mitigation measures can be formulated.

Mangroves

The following recommendations are made for mangroves:

- Mangrove monitoring should be carried out permanently
- The water and geologic characteristics of the lagoon should not be changed if it will affect the conditions necessary for healthy mangroves (e.g. not blocking tides)
- Use of mangroves for fuel wood, medicine, fisheries and traditional products should be managed, accommodating traditional uses.
- Mangrove greenbelts should be protected for their community-protection qualities, especially in Popua and Patangata. Protection should focus on weather and livelihoods
- Protect rare mangrove species, especially in Nukuhetulu and Folaha which have old and very diverse mangroves. Nukunukumotu should be protected to prevent further damage
- Create a mangrove nursery

- Replant mangrove propagules and seedlings where mangroves have been lost, but not in non-mangrove areas
- Create a Mangrove Management Plan to management each mangrove area
- Restrict or ban damage to rare mangroves in danger of disappearing from the lagoon: *Bruguiera gymnorhiza, Lumnitzera littorea, Xylocarpus granatum* and *Heritiera littoralis*
- Improve public awareness on the importance and sustainable use of mangroves

Land Cover & Coastal Vegetation

Apart from soil erosion and sea-level rise, the two most significant issues for coastal vegetation in FLC are the dumping of rubbish and the presence of roaming pigs. These two threats to tree species are affecting the ability of the catchment to naturally regenerate itself. The data show that the problems are affecting the density of trees more than diversity. Tree planting is costly, so a combination of planting and natural regeneration is needed. Securing areas to ensure the reforestation is effective is also needed. Residential and agricultural lands can provide safe places for reforestation, enhancing success of the effort. The following recommendations are made:

- Further detailed study and mapping is needed
- Regeneration of coastal vegetation and the success of replanting depend on the security of each site. Legal protection should be considered
- Natural crawling plants and undergrowth should be encouraged along the lagoon coast to stabilise soils, prevent erosion and minimise flow of silt and chemicals into the Lagoon
- Safeguards are needed for birds, mammals and other agents that disperse seeds
- Take steps to stop rubbish dumping and damage from pigs
- Encourages regrowth of coastal plants in town allotments where they will be protected

Soil & Agriculture

During the last 20 years, the intensification of agriculture in Tonga for food production and increasing crop production for local and export markets has led to land degradation and pollution. Catchment land by definition slopes towards the lagoon making groundwater outflows, and contamination by fertilizer and pesticides inevitable. Several studies (*20, 21*) found a wide range of pesticides, including DDT and metabolites, in soils from fields cultivated with squash in Tufumahina, Lafalafa and Vaini. Public awareness and programmes aimed at encouraging organic farming are needed.

Waste

- Further clean up at the coastal areas is needed to clear space for coastal vegetation and mangroves to regrow.
- More awareness program be in place to educate and change people's mind set with regards to treating of waste.

Reclamations & Developments

- A community Land Reclamation Watch should be formed to limit illegal developments along the Lagoon coastal areas
- Policies and laws governing land reclamations should be enforced

Chapter 4: The Human Dimension

4.1 Introduction

Strengthening knowledge and awareness of Fanga'uta Lagoon's ecosystems and associated socio-economic benefits is critical. This needs to occur within national stakeholders and local communities. To do this, we first need to understand human attitudes and behaviour towards the lagoon. It is humans who decide what will be broken and whether, where it is possible, things will be fixed. This socio-economic survey was designed to capture human attitudes that need to be understood before we can develop effective approaches towards the conservation of Fanga'uta lagoon.

4.2 Methods & approach

A total of 933 households were interviewed and analysed for this report. This is about 17% of the total number of households in the 26 communities in the Fanga'uta Lagoon Catchment area. The interviews were conducted in the Tongan Language, by a team of 50 trained enumerators who visited each household. Using a purpose-built form (available from the R2R Project Office), the enumerators interviewed either the head of the household, or in their absence, another adult living in the house. Data were recorded in either Tongan or English and entered into a purpose-built database by 12 data entry staff for storage and later analysis. All data collected were and still are kept in strict privacy and all information presented here is presented without reference to the identity of the person(s) interviewed. The privacy of these data never expires.

Most of the survey questions were in the form of Yes/No, multiple choice or numeric values and were used to generate frequencies of responses or average values plus or minus the standard deviation (+/-SD). A total of 50 of the questions in the survey were in the form of free text used to allow respondents to give us information outside the scope of what we may have anticipated. These text answers were reprocessed using a system of 'spanning' where the answers were presented within the database to data staff who broke the ideas in the answer down into simple concepts, adding as many of these concepts as needed against each text response. The concepts were generalised enough that similar concepts would be scored as the same responses. This resulted in simple frequency information for ideas in the way people responded to questions. At the same time, any text answers that demonstrated a particular, unique or significant point of view were flagged in the database and used as quotations to illustrate points. All currency values are in Tongan Pa'anga (TOP), all distance measures in m or km, and land areas in acres or poles.

4.3 How Fanga'uta Households interact with the Lagoon

General household details

Overall 933 household interviews were conducted reaching a total of 5,875 people, including 2,857 females and 2,814 males. Of the 26 communities surveyed, the greatest numbers of respondents were from Kolofo'ou (12%) followed by Haveluloto (11%). These are two of the largest communities in the lagoon catchment. The respondents from other communities ranged between 1% to 8% of the total. Forty-nine percent of the respondents were female and 48% were male (the gender for 3% was not recorded). The majority of the households was made up of children and grandchildren of the head of households. A very low percentage of the households were nieces and nephews, and parents and parents-in-law. Of all the people identified as members of the households in surveyed areas, 94% indicated that they live on a long-term basis in these households.

A large percentage of household members was under the age of 6, with the next most common age group of people 31-40 years (Figure 39). This information is consistent with the large percentage of household members that were never married (Figure 40).

Figure 39: Total number of males and females in each age group

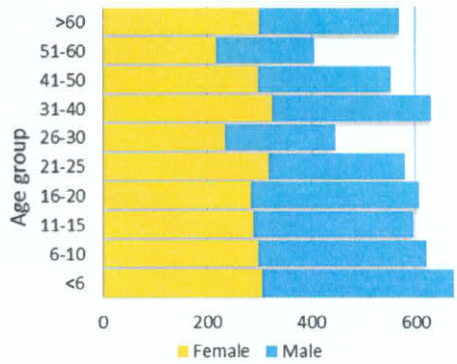
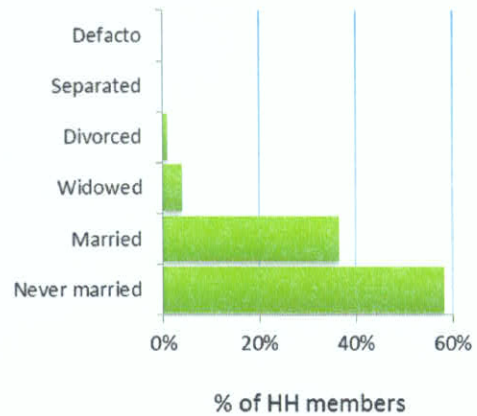


Figure 40: Marital status of household members



Overall 92% of the household members attended school, and it is likely that the other 8% is made up by the 12% of the household members that are under 6 years of age. Of those that attended school, 62% obtained some level of secondary education and 16% indicated that they undertook some level of tertiary education. From the survey, an even proportion of both men and women accessed school. During the time of the survey, only 34% of the total household members indicated that they are currently in school.

In terms of the health conditions of the household members, 61% of the household members indicated that they did not suffer from any chronic illness or disability that has lasted more than 6 months and only 5% indicated that they did suffer from such illness. A large percentage (35%) of the household members did not respondent to this question. A similar reluctance to reply was observed when asked whether they contacted new illnesses or injuries in the past six months. Of the 5% that responded as having suffered from an illness or an injury, even numbers of males and females were observed. However, the average number of days that prevented females from performing normal activities was around 12 days, while only about 7 days were lost to illness by males. On the other hand, the average cost for healthcare for men is much higher, at an average of $54 compared to just $18 for women.

When asked about whether members of the household spent one or more month working for wages in the past year, only 57% responded, while the remaining 43% did not provide an answer either because they did not want to, or because they did not work over the past year. Of the 57% that responded, 40% indicated that they did not work for wages and only 17% indicated that they worked for wages. Of the total household members that worked for wages, 62% were male and only 38% were female.

Most of the household members indicated that they worked in an office (22%), shop (12%) and for the government (10%). A few worked in construction; electricity and computer (8%), taxi (6%), and agriculture and teaching (5%). A low percentage worked in tourism-related activities (3%) such as hotels, restaurants and other forms of tourism. Only 4% worked in community service activities such as church work and village administration. Around 3% indicated that they worked in fisheries. The average income varied greatly by gender, where males earned an average of $2,700/month compared to only $1,600/month for females. Both genders worked an average of 26 hours per week. Of the total households surveyed, 74% indicated that they received money from another person in 2014. About 33% said that they received more than $1,000 in the past year and 15% said they received less than $500.

Land holdings

Most households, 72%, indicated that they did not own or lease land. An average of 16 acres was found to be owned by households that did own land. Households that leased land had an average of 8 acres for which they pay an average of $840/month. Some pay up to $2100/month. Three percent of households indicated that someone pays the head of the household an average of $700/month to use land owned or leased by the household. Only 1% of the total number of households

indicated that someone pays the head of household to live in their dwelling for which they pay an average of $340/month. Approximately 1% of households indicated that they own other property that provides a rental income averaging $280/month.

Households indicated that school fees are the service on which they spend most money. The cost of school fees averaged $500/month, with the next most expensive costs being church and non-government organization (NGO) donations, averaging $400/month. Households spent an average of $390/month on food items such as vegetables, fish and packaged food, and spent $380/month on transportation. Household expenses on utilities such as electricity, water and cooking gas, averaged $180/month. Less than $70/month was spent on restaurant meals, clothes, shoes and other household goods.

The most commonly-owned durable goods was the mobile phone, where each household had an average of 3. units. The majority of households had at a minimum a television, gas or electric stove, refrigerator, washing machine, DVD player and a passenger automobile (Table 5). These are considered essential goods for comfortable living and requiring households to spend significant amounts on energy.

Table 5: Most commonly-owned durable goods

Durable goods	Total No.
Mobile phone	900
Televisions	814
Gas or electric stoves	782
Refrigerators	731
Automatic washing machines	684
DVD players	593
Passenger automobile or van	438
Other kitchen appliances	416
Personal computers / tablets	341
Bicycles	334
Sewing / knitting machines	207
Cameras / video cameras	178
Chainsaws	94
Trucks (e.g. cane trucks)	51
Generators	44
Motorised boats	39
Satellite dishes	30
Air conditioners	23
Non-motorised boats / canoes	21
Ploughs	20
Tractors	18

Monetary Assistance & Benefits

A few people living in the Fanga'uta Catchment area were receiving assistance from the programs available for the community. There were several types of benefits received by the people with 29% of respondents benefitting from the Old Age Pension (over 60 years old) (Table 6). Another 16% and 14%, respectively received benefits from churches and other private support. Government support and private pensions were among the least common programmes reported. Ten percent of households reported receiving a government pension (civil servant, military) averaging an amount of $1,675.82 per month. Just 2% of the households received private pensions which averaged $2,546 per month. Overall 31% of the households received some kind of benefit in 2014.

Table 6: Monetary benefits received by households

Assistance	Responses	% Responses	Avg$
Government pension (Civil servant, military)	29	10	$1,676
Family Assistance Programme	24	8	$425
Disability benefit	19	6	$125
Old age pension (>60 yrs)	88	29	$187
Other government support	16	5	$746
Private pension	14	5	$2,546
Other private support	43	14	$811
School fees and/or school transport	18	6	$863
Church support (cash, gifts, other)	48	16	$716
Others	5	2	$208
	304	100	$830

Agriculture and Livestock

When asked if any member of the household raised crops in the past 12 months, 94% of the total households responded. Overall 40% of the respondents indicated that a member of their household raised crops in the past year. The largest percentages of household that raised crops were in the areas of Lapaha, Tatakamotonga, Vaini, Longoteme, Kolofo'ou and Pea (Table 7). Fewer households raised crops in urban areas such as Kolofo'ou, Haveluloto, Ma'ufanga, Tofoa and Popua. Overall 28% of households owned the land used for growing crops and 19% leased the land they were using. Many (27%) of the respondents indicated that they use 1-3 acres of land and another 27% used 5-8 acres for crops, with 20% owning and using 3-5 acres of land. Of the 19% that responded to leasing land for crowing crops, 17% indicated that they lease around 1-3 acres of land. A significant amount of land was used for growing crops in the Talasiu area where they indicated an average of 1,460 acres was used. Crop growers in Folaha, Vaini, Pea and Nukuleka areas also indicated a significant amount of land was used for their crops.

Table 7: Crops, land area and use of chemicals

Table shows number of households in each village involved in cropping, average number of acres being worked and the number using chemicals

Village	No	Yes	Avg acres	Fertilisers	Pesticides
Lapaha	26	41	23		
Tatakamotonga	31	35	14		
Vaini	34	28	535	6	6
Longoteme	11	24	12	27	19
Kolofo'ou	97	20	256	14	14
Pea	20	20	389	28	33
Hoi	6	18	275	6	6
Veitongo	13	18		9	14
Makaunga	7	17	1	16	16
Talasiu	2	15	1461	16	16
Haveluloto	59	14	7	1	
Tofoa	42	13	7	3	
Malapo	24	12	1		
Navutoka	3	12	2		
Ha'atelho	22	11	6		
Ma'ufanga	55	11	196	3	3
Pelehake-'Alaki	4	8	2	9	9
Talafo'ou	12	8	4	10	1
Nukuleka	7	7	336	6	6
Holonga	12	6	57	5	7
Popua	38	4	127		
Folaha	2	3	844		
Manuka	2	3	2		
Nukuhetulu	1		1		
Total	530	348	198	159	150

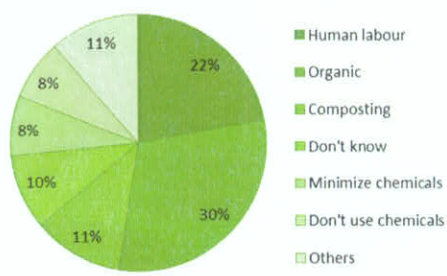
Use of chemicals: Overall 16-17% of the total households responded to questions on use of fertilizers and pesticides for their crops (Table 7). A large percentage of growers in Pea and Longoteme indicated that they used both fertilizers and pesticides. The use of fertilizers and pesticides were largely on three main crops which were

Banana, sweet potato and taro. Pesticides were commonly used on cassava, but not fertilisers. The pesticides in use were mostly herbicides used for weed control.

When growers were asked if they are aware of any impacts on Fanga'uta Lagoon from the use of agricultural chemicals, only 31% of the total households responded. Of these 30% indicated that they were aware of impacts of the use of chemicals, particularly fertilisers and pesticides. Further, 43% of respondents indicated that the use of chemicals affects or kills marine organisms. Around 20% indicated that chemicals do affect Fanga'uta Lagoon, but did not specify how. Some 9% of respondents indicated that if the farm or the crops are grown far away from Fanga'uta Lagoon, then the use of chemicals does not have any impact. A minority (2%) indicated that chemicals are harmless to the lagoon.

When asked what needs to be done about these impacts, 40% indicated that the use of fertilizers and pesticides should be minimized. This result showed that despite being aware of the impact of fertilizers and pesticides on Fanga'uta Lagoon, people consider the chemicals important for agriculture and that they need to be used wisely. A significant number (26%) indicated that the use of chemicals should be stopped, while an 11% suggested that their use be minimised just in areas near Fanga'uta Lagoon. One safety practice which was often suggested was to use human labour for weeding crops rather than weed control substances (22% of people suggesting safety measures). About 30% of respondents suggested the use of organic fertilizers and pesticides and 11% suggested composting (Table 8).

Table 8: Solutions to impacts of agricultural chemicals



Harvesting crops: The data on harvesting of crops were difficult to interpret because households use a wide range of units of measurement (kg, bundles, bags, containers etc.) and often grouped crops according to method of harvest instead of type (species).

About 46% of total households responded to questions on lost crops due to drought, disease, flooding or pests. Of these 31% of respondents indicated that they lost an average of 52% of their total crops, mainly due to drought. The impacts of drought were severe for farmers in Vaini, Veitongo and Pea. Growers affected by disease were mainly from Pea and growers from Kolofo'ou were mostly impacted by boars and pigs.

Crops sold: Growers were grouped into those focusing on vegetables, root crops, fruits, bananas (including plantain) and others. Vegetable growers indicated that on average 90% of their crops such as tomatoes, cucumber, capsicum and cabbage were sold. This generated an average income of $2,500 over the past year. The selling of root crops varied depending on the crop. Taro and sweet potato growers sell 100% of their harvest. Taro earned them an average of $2,300 and sweet potatoes $940 in 2014. The other crops sold were cassava and yam where 48% and 46% of their harvests were sold respectively. Cassava generated an average income of $1,390, while yam generated an average of $1,500 in 2014. The only fruits planted and harvested were pineapple and watermelon, however, only watermelon was sold earning an average of just $175 in 2014. Bananas growers indicated that they sell close to a 100% of what they harvest, earning an average of $1,750 in 2014. Plantain bananas generated an average of $600 in the past year.

Expenditure: Crop growers indicated that their major expenses were for leasing of the land for planting, followed by hiring labour for clearing, planting and harvesting. Agricultural taxes and fees were also significant. Expenses for pesticides and imported seeds or seed stocks were relatively lower.

Problems: The major problem faced by crop growers was the damage to crops caused by pests. This was rated as occurring very often and as being of major importance. Unaffordable fertilizer and lack of capital were considered problems that happened often and of great importance to growers. Some growers identified lack of water for agriculture as a problem, happening sometimes but of great importance. Although drought was identified as the main cause for the loss of crops, most growers do not consider natural disasters as a problem that occurs frequently and rated disasters of low importance overall.

Livestock

Most of the households (89%) responded that a member of their household raised livestock in 2014. Chicken was the most commonly-raised livestock both in 2014 and at the time of the survey (2015) (Table 9). It was also the most consumed livestock where a household raising chicken consumed an average of 10 chickens in 2014. A large average number of horses was said to have been lost to disease, drought or natural disasters. Ducks were the most commonly-sold livestock, however, its low value yielded an average earning of just $60 in 2014. This compares unfavourably to cattle, where an average of 1 cattle sold by households raised an average earning of close to $2,000. Few households raised sheep and none were consumed or sold in the past year.

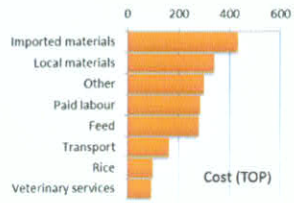
Table 9: Livestock held and uses

Livestock	2014	Lost	Eaten	Sold	Earnings	2015
Chickens	21	2	10	1	$28	10
Ducks	10	1	2	5	$60	9
Pigs	10	1	5	3	$729	8
Goats	17	3	2	1	$650	7
Cattle	5	1	2	1	$1,956	5
Horses	4	17	3	1	$300	4
Sheep	3	0	0	0	$0	3

Households who said that they spent on inputs for their livestock identified imported materials as their main expenditure item. This included vaccinations, saddles and ploughs, costing an average of $430 in 2014. The

survey indicates that household expenses for livestock were more on materials, less on feed and much less on veterinary services (Figure 41).

Figure 41: Expenses used in keeping livestock



Fisheries

Around 12% of the households surveyed indicated that a member of their household had fished in 2014 and of this percentage, just 8% indicated that they fished in Fanga'uta Lagoon. The communities that fished in Fanga'uta Lagoon were mainly from the villages of Hoi (15%), Longoteme (14%), Malapo (10%) and Nukuleka (10%). When asked to identify their fishing ground, 34% identified area J as their fishing ground, followed by area F (12%) and H (12%) (Figure 42).

Figure 42: Main fishing grounds

Households that undertook fishing at Fanga'uta Lagoon spent an average of 7 days per month in which they caught an average of 140 pieces of fish and other marine products, compared to an average of 12 days fished outside of the Lagoon. Reef fishes were identified as the most harvested marine species from both Fanga'uta Lagoon and from elsewhere. Fishermen reported that seaweed and crustaceans (e.g. prawns) were mostly harvested inside Fanga'uta Lagoon and not from fishing grounds outside of the lagoon (Table 10). Overall 39% of the fishermen that responded indicated that gleaning was the main fishing method used (Table 11) particularly for harvesting shellfish (bivalves) and sea cucumbers. Spear (18%) and net fishing (15%) were the most commonly-used fishing methods for harvesting reef fishes and crustaceans. Handline used at night (10%) was predominantly used for harvesting reef fishes.

Table 10: Marine products caught in Fanga'uta Lagoon and elsewhere

Data are average number caught and days spent fishing

Catches	No. FL	Days FL	No. Else	Days Else
Reef fish	1,371	21	49	6
Shellfish (bivalves)	113	12	46	5
Sea cucumbers	86	11	47	4
Seaweed	64	7		
Crustaceans	63	5		
Other invertebrates	24	4	12	1

Table 11: Fishing methods used

Method	Frequency	% Responses
Gleaning	51	39%
Spear DAY	23	18%
Net DAY	19	15%
Handline DAY	13	10%
Net NIGHT	9	7%
Handline NIGHT	5	4%
Spear NIGHT	4	3%
Trolling NIGHT	4	3%
Trolling DAY	2	2%
Total	**130**	**100%**

Fishermen indicated that 57% of their catch was sold or traded in which they identified 50% were sold in the local markets and 21% were sold for export overseas or visitors from overseas. Fishers in 35% of the overall communities surveyed indicated that they sold a portion of their catch, where a large percentage of the fish sellers were from Vaini, Veitongo, Ma'ufanga and Talafo'ou. Fish sellers earn an average of $340/month.

Households were asked about any changes they have observed on the number and sizes of fish on an average fishing trip. Overall 65% of households said that had fished in the past year and answered questions on changes in catches. Of these 49% said that they caught less fish and 39% indicated a decrease in the size of fish caught compared to 5 years ago (Table 12). About a third, 32% indicated that number and 40% that the size had stayed the same since 5 years ago. Legal work and public awareness were the two top responses as management measures to be put in place to improve the sustainability of the resources in the lagoon (Table 13).

Table 12: Comparison of harvests between 5 years ago and now

Change	Change No.	% No.	Change Size	% Size
Much less	5	11	4	9
Less	18	38	14	30
Same	15	32	19	40
More	7	15	7	15
Much more	1	2	2	4
Don't know	1	2	1	2
Total	47	100	47	100

Table 13: Measures needed to address changes in fishing

Responses	% Responses
Legal work	30%
Public awareness	30%
Establish community committee	15%
Close fishing areas	15%
Special Managed Areas	10%
Total	**100%**

Fishing households indicated that their highest fishing expenditures were on hiring labour (average $510 per year) followed by boat maintenance and repair ($200). Expenses for bait and fishing gears were relatively low costing an average of less than $100 in 2014.

Special Management Areas (SMAs): Just 17% of households indicated that they are aware of the Special Management Area Programme. In total 77% said they did not know about the programme and 6% did not respond to this question. When asked about their support for the program, a considerable 64% indicated that they fully support the program, 19% were not sure and 16% do not support it. Kolofo'ou (15%) and Haveluloto (14%) showed great support for the SMA program, 7% of the supporters of the program were from the areas of Tatakamotonga, Lapaha, and Vaini, followed by 6% from Pea and Ma'ufanga. On the other hand, a high percentage of those not supporting the SMA program were from Kolofo'ou, Tatakamotonga and Lapaha. Few supporters were seen in the areas of Nukuhetulu, Folaha, Manuka, Navutoka, Talafo'ou and Pelehake-'Alaki. The main reason behind the support for SMA stems from the need to conserve marine resources (19%), revive the growth of marine organisms in the lagoon (12%), restrict fishing access to the adjacent coastal community people only (11%) and to those who use it as a source of livelihood (11%). Among the 12% of respondents that indicated their lack of support for SMAs, the main explanation given was related to the open access nature of the resource and the program is seen as people acting selfishly.

A large number of households indicated that they were satisfied with the current management systems for the lagoon (Table 14). A surprising 17% of respondents indicated that they did not know about the current management systems in place for Fanga'uta Lagoon, and 17% also indicated their dissatisfaction with the current management system. Despite the 40% of respondents who were satisfied with the current management systems, a large number of people suggested that fisheries laws and regulations need to be enforced as a way to improve things (Table 15). Other means for improvement included supporting the establishment of SMAs and to improving public awareness.

Table 14: Responses to current managements systems for fishing

Result	No.	% Responses
Satisfactory	312	40%
Don't know	136	17%
Dissatisfied/Not good	136	17%
Needs improvement	52	7%
Unsuccessful	36	5%
Works well maybe	27	3%
Some people fish selfishly	19	2%
Laws/regulations not enforced	16	2%
Resource depleted	14	2%
Prohibit destuctive fishing	13	2%
Enforce laws to protect Fanga'uta	12	2%
Fanga'uta needs upgrading/major clean up	6	1%
Harsh regulations/minimize access to source of livelihood	3	0%
Increase SMAs	2	0%
Many people from other communities	2	0%
Supports measures that benefits everyone	1	0%
Not taken seriously	1	0%
Total	788	100%

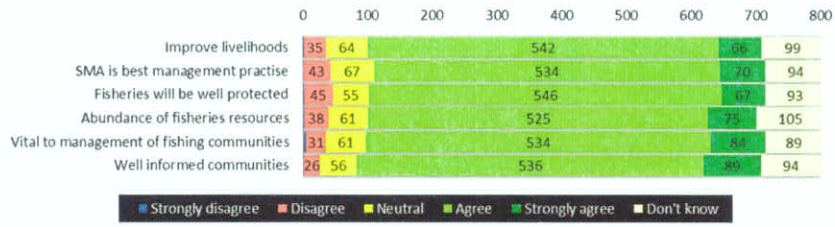
Table 15: Top ten responses on what needs to be done to improve fisheries management in the lagoon

Result	Responses	% Responses
Enforce fisheries laws/regulations	180	26%
Establish program to better manage fishing/SMA program	162	24%
Don't know	61	9%
Raise public awareness/existing management instruments	54	8%
Fish sustainably/wisely	48	7%
No destruction fishing/poisoning/dynamite	46	7%
Current management system is fine	45	7%
No commercial fishing/prohibit foreigners from fishing here	12	2%
Fisheries and community to work together	11	2%
Stop fishing temporarily	10	1%

Households were asked about their perceptions on some statements relating to the establishment of SMAs the majority of households agreed (but not strongly agreed) that SMAs would improve livelihoods. They also agreed that it's the best management practice for fisheries management and will protect and increase fisheries resources

Figure 43). Some households indicated that SMAs would be a good way of informing the community of the importance of better management of the lagoon and its marine resources.

Figure 43: Perceptions about SMAs



When asked if they would comply with any management measures under SMA, 72% of respondents said that they would and 28% of respondents indicated that their main reason for complying was to conserve marine resources, particularly for the future generations. A further 20% indicated their willingness to comply was because it's the law and everyone must obey the law. Another 16% indicated that they would comply for the benefit of the whole community and their development. Households were also asked if they would be willing to participate in enforcing management measures under SMA and 62% of households indicated their willingness. A large number of people disagreed that the establishment of an SMA would cause disagreements among fishermen or cause disagreements between neighbouring communities. Many people thought that SMAs would lessen any disagreements among fishermen. This is a good indication that SMAs are likely to be well accepted by communities.

Mangroves

Four key questions were examined during the mangroves survey. These were: (i) on conservation values of mangroves; (ii) questions on awareness and

capacity development; (iii) information on changes that occurred over the past 10 years; and (iv) questions on legislation and law enforcement.

Overall, just 10% of households said that they used mangroves over the past 10 years (Table 16). The uses of mangroves were found to be different among communities. Attitudes on conservation value, training needs of community leaders, awareness, changes in cover and health and enforcement of legislation also varied strongly among the communities.

With 90% of households answering questions on conservation, only an average of 4% per community believed that mangroves should be conserved. The highest percentage of people agreeing that conservation of mangroves was important was from Kolofo'ou at 13%. The next highest values were from Haveluloto (10%), Ma'ufanga (7%), Tatakamotonga (7%), Lapaha (7%) and Vaini (7%) (Table 16). A few communities expressed the wish to claim mangroves for settlement because they don't have enough land, and have increasing populations and developments, such as at Manuka (0.8%), Nukuhetulu (0.1%) and Folaha (0.6%).

Training needs were identified as a priority at Kolofo'ou and Havelu. The conservation programme was said to have struggled with a lack of enforcement of legislation, with this being reported most at Manuka (0.8%) and Pelehake-Alaki (1.3%). A lack of awareness and training were concerns at Nukuhetulu, which is the largest mangrove area in Tonga and oldest in the Pacific (*16*). Despite being identified as issues, a lack of training, awareness and law enforcement were not considered a priority. These had low importance at Nukuhetulu (0.1%) and Folaha (0.6%). Almost all uses of mangroves were considered to have declined more urban areas compare with rural areas.

The greatest number of households that reported a perceived change over the past 10 years was in Kolofo'ou (15%). Other communities recognising significant change included Lapaha (8%), Ma'ufanga (9%), Tatakamotonga (9%) and Vaini (8%). The most important change in the past 10 years was identified as human pressure on mangroves for tapa making (54% of responses) and subsistence fishing (20%) (Table 17). In general, 6% of the households used mangroves for tapa making in the past 10 years. The greatest use of mangroves for tapa making were Kolofo'ou, Ma'ufanga and Havelu. Other uses of mangroves were for handicrafts (9.8%), medicine (9%), fuels (7%) and Christmas trees (1%) in Folaha and Nukuhetulu.

Table 16: Use, management and change in mangroves

These results were generated from yes or no questions on conservation, training needs, legislation and changes in mangroves over the past 10 years. Colour scale highlights largest values.

Village	Total	% Use	% Conserve	% Training	% Legislation	% Changes
Folaha	5	0.1	0.4	0	0.5	0.3
Ha'ateiho	34	0.2	3.4	0.1	3.7	2.9
Haveluloto	95	1.0	9.1	0.3	10.2	8.3
Hoi	24	0.6	2.6	0.3	2.6	1.9
Holonga	19	0.1	1.9	0	2.0	1.4
Kolofo'ou	121	1.0	11.0	0.6	13.0	10.7
Lapaha	68	1.4	6.3	0.9	7.3	6.1
Longoteme	36	0.4	3.3	0.1	3.9	2.5
Makaunga	24	0.4	2.5	0.2	2.6	0.6
Malapo	36	0.5	3.8	0.1	3.9	1.1
Manuka	7	0.0	0.6	0	0.8	0.5
Ma'ufanga	69	0.0	6.4	0	7.4	5.3
Navutoka	19	0.2	1.4	0.2	2.0	1.0
Nukuhetulu	1	0.0	0.1	0	0.1	0
Nukuleka	15	0.0	1.4	0.2	1.6	1.5
Pea	41	0.1	3.9	0.1	4.4	2.9
Pelehake-'Alaki	12	0.2	1.3	0.1	1.3	1.3
Popua	43	0.0	4.5	0.4	4.6	4.4
Talafo'ou	21	0.1	2.0	0	2.3	1.1
Talasiu	17	0.1	1.8	0.2	1.8	1.6
Tatakamotonga	69	0.5	6.1	0.6	7.4	5.6
Tofoa	57	1.1	5.9	0.1	6.1	4.7
Vaini	66	1.0	6.6	0.1	7.1	4.8
Veitongo	32	0.6	3.1	0	3.4	3.1
Total	931	10	90	5	100	74

Table 17: Uses of mangroves over the past 10 years

Uses	No. Responses	% Responses	% Households
Tapa making	55	54	6
Fishing	20	20	2
Handicrafts	10	10	1
Medicine	9	9	1
Fuel	7	7	1
Christmas trees	1	1	0
Total	**102**	**100**	**11**

The outcome of this study demonstrates that relatively few households overall valued mangroves for community livelihoods and increased protection of the land and marine environments. The results of the survey indicate that mangroves were less impacted 10 years ago than they are now, and that a large proportion of the mangroves in the lagoon are experiencing very low levels of dieback. Further investigation is needed to establish the cause of mangroves dying along the coastline. The greatest use of mangroves was recorded in the urban areas mainly at Kolofo'ou, Havelu and Ma'ufanga. Despite conservation efforts being highest in urban areas, the lack of training, awareness and law enforcement are challenging efforts at management and sustainable use.

Ecotourism

When asked whether there were potential ecotourism activities that could be carried out in their area, 49% of all respondents responded no, while 51% said that their area did have the potential for such activities. The majority of the respondents who said there was no potential were from Ma'ufanga (where 98% of households said no) and Kolofo'ou (90%). Lapaha (84%) and Pea (80%) were two villages with the highest 'yes' responses. The most common ecotourism activities and sites suggested were historical and heritage sites (33%) (Figure 44). This included sites such as Paepae 'o Tele'a / 'Otu Langi (9.7%), Sia heritage site (6.2%), and Hufangalupe (2.4%). This was followed by water springs suggested by 31% of respondents and beaches with

20.4%. More than 70 water springs were identified in the area. A few other respondents suggested a Tonga National Centre, kayaking, golf course and Bird Park as eco-tourism activities in the Fanga'uta Lagoon area.

Figure 44: Potential ecotourism activities suggested by area

Although, 60% of the respondents agreed that the eco-tourism activities would benefit the community and its people, 40% claimed ecotourism would not be beneficial to them or the community. When asked to describe in what way the ecotourism could benefit their families and community, more than half of the respondents identified sources of income from selling handicrafts and food, and demonstrations of cultural dancing. In addition, a few respondents suggested an increase in site recognition (locally and internationally), clean and beautiful villages and opportunities for site improvements and promotion important benefits for the family and community. About 8.4% of respondents said that they did not know of any benefits of ecotourism activity for the community and 16.2% did not know of benefits for themselves or the family.

Given the conditions of the existing sites, 93.9% of the respondents believed that there is work needed to improve them. The top ten activities needed to improve sites for ecotourism (Table 18) included beautification, community work and government support.

Overall, 93.3 % of the respondents and their families had not previously been involved in the ecotourism industry and were unfamiliar with the sector. The small percentage that had worked in ecotourism said that it had helped them to improve their standard of living.

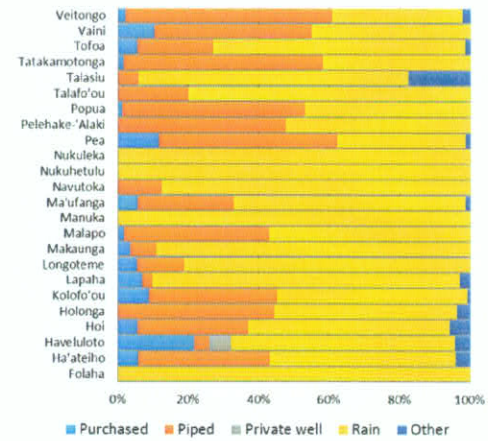
Table 18: Top 10 suggested approaches to enhancing ecotourism potentials

Result	No.	% Responses	% Households
Kept the site and village clean/beautiful/safe	309	47	33
Community team work	66	10	7
Need government financial support	54	8	6
Sites need to be well maintain	34	5	4
Set up other facilities on the site	28	4	3
Put up a sign/information about the site	24	4	3
Protect the water spring by build foreshore around it	21	3	2
Plant more trees	18	3	2
Require road maintenance	16	2	2
Clean villages will attract visitors to the site	15	2	2

Infrastructure

Water supply: A total of 725 of 1248 responses (75% of the total households) gave rainwater as their main source of water (Figure 45). A third of households used piped municipal water, but some areas such as Folaha, Nukuhetulu and Nukuleka had no access to piped water. Just 6 households (0.5%) had a private well, and all of these were in Haveluloto. Two percent of households used other water sources not specified.

Figure 45: Water sources for households



Up to 7% of the households said that they purchased with an average weekly spending of $21.90 (+/- $24.72) for an average volume of 39 litres (+/- 108) and a maximum of up to 1000 litres. When asked to give reasons for purchasing bottled water, 33% of the respondents said they had no water tank. Other reasons given were that the water was used for drinking purposes only (27%) and that bottled water was safer and more reliable to drink (24%), even in households with rainwater tanks. A few households said they bought water because their rainwater tanks were not functional (8%), or because they were buying water to reserve it for drought seasons (7%).

A total of 617 households (of 725 HHs responding about water tanks) (85%) gave more details about their tanks. There was an average of 1 tank per household, with an volume of 5,224 litres (+/-14,316). When asked about the condition of the rainwater system, 91% (559 HHs) said theirs tank was working well. Of those remaining 9% (58 HHs) had non-functioning rainwater tanks. Most of these (61%) said that problems included broken gutters, drains, pipes and pumps (Table 19). Around 24% said that their tank was broken, 4% required replacement of their house roof and 10% required cleaning out of sediments from the tank. The alternative sources of rainwater for households with non-functional collection systems included neighbours (78%), village churches (8%), buying water (8%) and sourcing it from relatives (5%).

Table 19: Problems with rainwater tanks

Problems	No. Resp	% Resp	% HH
Broken gutters, drains , pipes, pumps	30	61	52
Broken tank	12	24	21
Sediments and dirt settles in tank	5	10	9
Roof of house needs replacement	2	4	3
Total	**49**	**100**	**84**

There is access to a reticulated piped water system by about 33% of the respondents and 97% of these pay for the service at an average cost of $32.86 (+/- 30.14) per month. The remaining 3% do not pay because of water committee privileges and/or the water cost is too expensive. Overall, 20% of the people with piped water

supply encountered problems with the supply. The issues named were technical problems (49%), low water pressure at peak hours (27%), and 7% raised problems related to the water committee (Table 20). 13% responded that cost is too high and some brought up water quality issues (2%): that it's not clean and leads to skin rashes. A few households cited problems with water meters and water pumps.

Table 20: Problems with municipal piped water

Problems with piped water	No. Resp	% Resp	% HH
Technical Problems	71	49	7
Low water pressure	39	27	4
Cost is too high	19	13	2
Water Committee issues	10	7	1
Poor quality of water	3	2	0.3
Problem with water pumps	2	1	0.2
Issues with the water meters	1	1	0.1
Total	**145**	**100**	**15**

To improve the piped supply people suggested repairing damage and improving the maintenance of the system (48% of responses) and improve the pumping system (20%). Ten percent suggested that law enforcements should be used to make people pay for their bills (10%). Other actions such as strengthening the water committee (14%), seeking more funding (6%), installing more accurate water meters (2%) and increasing the use of rainwater (1%) were also suggested.

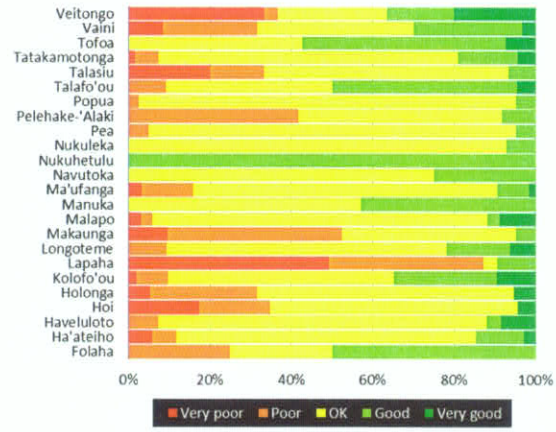
In terms of the quality state and taste of the piped water supply 67% of respondents said that it tastes like rainwater, 28% said it was slightly saline, 4% rated the water quite saline and 1% said it tasted like seawater. Over 50% of the respondents stated that they believed the system was well maintained and that the taste was related to the state of the ground water. The salinity of water was said to be due to drought by 11% of the respondents, while 11% believe it to be due to climate change and proximity to the ocean. About 9% said that the salinity was due to too much pumping, while 3% thought that fertilizers contribute.

Only 2% of the respondents (18 households) had access to a communal rainwater supply in their community in Holonga, Kolofo'ou, Longoteme, Makaunga, Malapo, Nukuleka, Talafo'ou, Tatakamotonga and Veitongo. The average size of the communal storage tanks was 7,000 litres (+/- 3,559) with an average of 2-3 tanks in each community. About 50% said they were able to access the communal supply and that in 2014 they used it 1-6 times. Six households said they had taken 1-10 buckets during 2014 and the remaining 3 households used between 10-50 buckets. The distance of the tanks from their houses was usually between 100-500m, with 1 household saying they had to travel 500-1000m and 3 households saying the communal tank was less than 100 m from their house. Reasons for using the communal rainwater supply included not having a tank, having a non-functional tank, or because their tank was empty, broken or had broken gutters.

Roads, transportation and buildings: The most common means of transportation for households were van (45% of responses), cars (33%) and buses (105 households or 13%). Smaller numbers of households used bicycles (74 households or 9%), trucks (0.4%), motorbikes (0.4%).

Ninety percent of households rated the road network in their area. Perception of the road was satisfactory for 60% of households, 16% said the road condition was good and 5% (42 households) said it was very good. More than 100 households (12%) said the road condition was poor and 64 households (7%) said it was very poor. Road condition was reported the worst at Lapaha and Makaunga (Figure 46).

Figure 46: Road conditions by village



Overall 24% of households were not located on a public road. Of the 7% of households that identified the problems associated with not being on a public road, 44% said that this was a problem when the distance to shops and bus stops was large. A further said it was problematic when it rains and 9% stated that a road could have helped with the issue of water logging at their homes. Some people (1%) said that there were problems with accessing waste collection services. Some households saw their isolation from the road network as a benefit because their children were safer and there was less noise.

Other concerns with roads were raised by 40 households (6 % of respondents). Over 60% of the concerns were with the poor road condition in the area and the need to install drainage on roads. 11% suggested the roads needed widening, 16% suggested the need for more road signs, street lights and sidewalks and 13% were concerned about the need for better maintenance of existing roads, better design for new ones and finding a way to screen waste being taken into the lagoon.

Table 21: Problems associated with not being located on the road network

Problems	No. Resp	% Resp	% HH
Distant from shops, bus stops etc.	31	44	3
Further distance - more expensive and problematic when rains	7	10	1
Water logging and ponding in our home	6	9	1
Access to home is in poor condition and vehicles cant access	3	4	0
Water logging and ponding in our home	6	9	1
No problem and no Noise	6	9	1
Kids are safe from traffic and road accidents	4	6	0
No Problem- its good having our house not on a main road	6	9	1
Not able to get waste collection services	1	1	0
Total	**70**	**100**	**7**

Drainage: Overall 77% of respondents did not have drainage built into their roads. Around 16% said that the drainage system in their area works well with little maintenance required, 6% have drainage that works well but requires regular maintenance and 1% stated that the drainage system on their road does not work at all. The identified benefits of drainage systems included reducing flooding during heavy rain (47% of responses), reduced waterlogging (22%) and diverting water away (20%). Despite the benefits of drainage it was also seen as causing problems as identified by 27% of the households. When blocked, the drains can cause flooding for the area because water cannot flow. It can also be a medium for transferring contaminants and rubbish (17%) and can affect Fanga'uta lagoon (Table 22).

Table 22: How road drainage impacts Fanga'uta Lagoon

How Drainage Impacts Fanga'uta?	Responses	% Responses
Drain contaminants, dirt, chemicals etc. polluting the lagoon	249	55
Affect / Reduce/ Kill fish and other marine species of Fanga'uta	84	19
Drain rubbish and waste into the lagoon	65	14
Affects/Kills mangroves and other plants	20	4
More sediments- reduced clear depths in lagoon	18	4
No Impact / very little impact	13	3
Sea level rise	2	0.4
Less Sea organisms available for consumptions	2	0.4
Coastal and Soil eroded material is washed to the lagoon	1	0.2
Total	**454**	**100**

Buildings & reclamations: Overall, 50% of the households had a wooden house, with 29% having a cement (concrete) house. Twenty percent of households said they had a mix of wood and concrete (Table 23). Only two Tongan fales were reported, located in Haveluloto and Tofoa. One house was made of an empty container and another one made of roofing iron, both of which were located in Vaini.

Table 23: Types of houses

Type of House	Responses	%Responses
Wooden house	436	50
Cement / blocks	255	29
Wood + cement	174	20
Tongan fale	2	0.2
Use empty container	1	0.1
Tin Iron houses	1	0.1
Total	**869**	**100**

Out of 351 HHs, 14% had reclaimed some land from the lagoon and 10 households did this within the past two years. The reason for reclaiming land given by 86% of respondents was that the ground was too low and they reclaimed land to raise the elevation before building (Table 24).

Table 24: Reasons for land reclamation

Reason for reclaiming land	Responses	%Responses
Ground was too low	31	86
Needed more land area for my house	2	6
Erosion of land	2	6
Mitigate water logging and flooding	1	3
Total	**36**	**100**

Waste management

Overall 56% (522 households) use the official waste collection services while 41% (381) said they did not use the service (Figure 47). Of those that use the services, 53% said that they pay for it, and 3% said that they did not pay for the service. A large percentage (44%) did not answer on whether they paid for the services. The villages with the most households using waste collection were Kolofo'ou, Haveluloto and Tofoa (Figure 48). When asked why they pay for the service, over 40% (229 households) wanted a clean environment and a clean home, 27% (128) said it was easier to pay for the service than to do it themselves, 20% (98) said that they must pay because they were using the service, 4% (21) believed that paying would keep the service operating and some (3) were not sure why they were paying.

Figure 47: Use and payment for waste services

Left: Do you use waste collection services? Right: Do you pay for the services? ND=No data

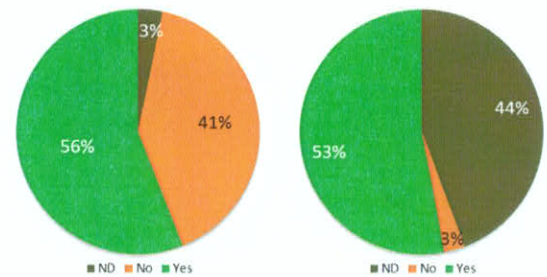
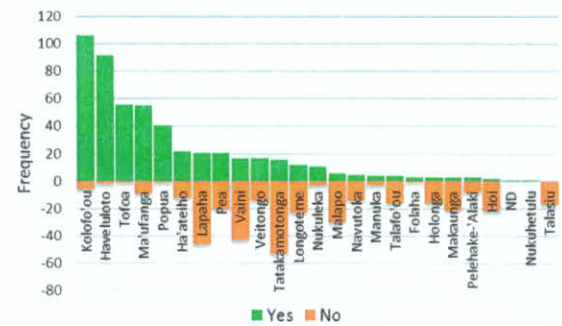


Figure 48: Use of waste collection services by village



Overall most people (93%) were satisfied or very satisfied with the rubbish collection service (Table 25). Low numbers were either neutral, dissatisfied or very dissatisfied (total of 7%) and about 1% were not sure how they felt about the services. When asked who is responsible for put out household waste, over 80% of responders said it was the responsibility of a 'community member'.

Table 25: Satisfaction with rubbish collection services (% of households)

% Satisfaction with service	VD	D	N	S	VS	??	Resp	%HH
Frequency of collection	1	1	3	69	25	0	500	54
Time / day of pickup	1	2	1	70	24	1	501	54
Reliability of collection service	2	2	3	69	24	1	501	54
Cleanliness of road after collec	2	2	3	69	23	1	497	53
Politeness of collection crew	2	2	4	69	22	0	497	53
Cost of the service	1	2	2	71	23	1	492	53
Average	**2**	**2**	**3**	**70**	**23**	**1**	**498**	**53**

People who responded that they did not use the rubbish collection service said that they preferred to burn their

rubbish (30%), or dump at their bush allotment and bury it (19%). A few households said they can't afford to pay the service fee (9%), don't know their collection day (13%) or did not give a reason (14%).

Very few households gave reasons for why they did not pay for waste collection services (18 households) (Table 26). Of those 39% did not believe they should pay, 11% had never received an invoice, another 11% did not know how and who to pay and 11% could not afford to pay a waste fee. Some said they only generated very little rubbish and others said that they were living in a church facility, and it's the church's responsibility to pay for all debt. Among those that do pay for the services, the most common reasons given were that people want a clean home or environment (48%), that it was easier to pay for it than have to do it themselves (27%), or because they felt they should pay if they were benefitting from the service (20%) (Table 27).

Table 26: Reasons people don't pay for waste services

Reasons	Responses	% households
Do not believe I should have to pay	7	39
Don't know	3	16.7
Have never received invoice	2	11.1
Do not know how / who to pay	2	11.1
Cannot afford to pay	2	11.1
Few rubbish	1	5.6
Church facility	1	5.6
Total	**18**	**100**

Table 27: Reasons people pay for rubbish collection services

Reasons	Responses	%HH
Want clean home / environment	229	48
Easier to pay than do it myself	128	27
Feel if use service must pay	98	20
Paying will keep service operating	21	4
Don't know	3	0.6
Total	**479**	**100**

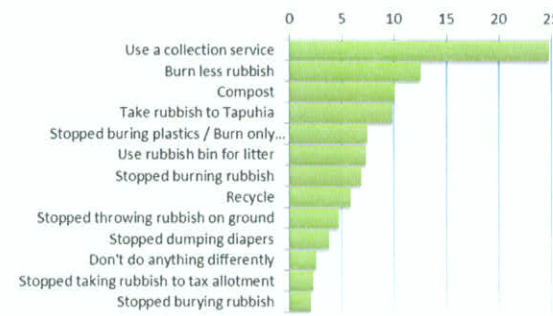
When asked about composting organic waste, 8% of households said they were not familiar with the methods. The most common reasons given for not composting organic waste included 26% (215) households that said they did not have time to make compost, 25% that did not generate enough materials and 17% (136) said they were too lazy. Some people said they had no need of compost (11%) and 5% said that their garden was too small, or that they had no garden (2%). A small percentage said that attracts bugs and rats (2%). Those that do try to compost do so in an 'improper' way (83%) while about 15% used a compost box or device. About 2% of people simply bury organic wastes.

When asking about recycling waste, people were generally not interested with 87% of respondents saying they did not recycle, and just 12% saying that they did. Incentives suggested for recycling included better payment for the materials (34%) and better information (kits) about recycling (24%). Some people needed help with recycling (18%) and 14% requested more convenient recycling cages.

Tapuhia facility: About Tapuhia facility they were asked whether they know that Tapuhia Landfill is the place of proper waste disposal, about 88% of households said yes and 8% said no. When asked whether they are satisfied with Tapuhia services, 67% said they were satisfied and a further 26% that they were very satisfied. Only 4% were either dissatisfied or neutral. Of those people who took their waste to Tapuhia instead of using the rubbish collection service 64% said they had more rubbish than could be accommodated by the normal collection and 10% did not want to wait for their rubbish collection. Over 7% said they took their waste there because it was free to dispose of waste that way.

The biggest change in behaviour around rubbish disposal over the past 3 years was the move to using a rubbish collection service, reported by 51% of all households. Other positive changes included burning less rubbish (26% of households) and composting organic materials (21% of households) (Figure 49). Behavioural changes in rubbish disposal also included less or no burning or burying, using litter bins and no longer throwing rubbish on the ground.

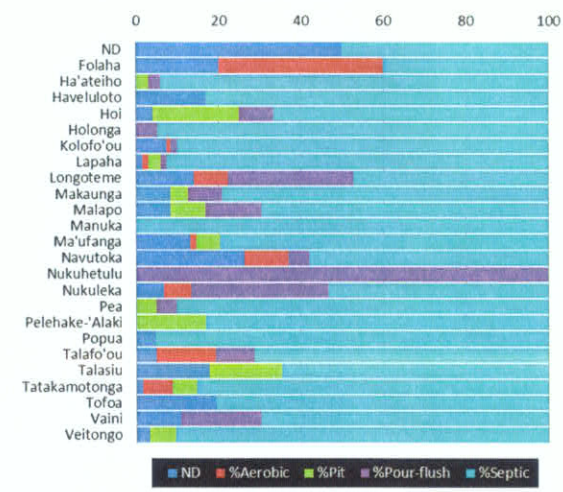
Figure 49: Changes in behaviour for rubbish disposal over the last 3 years



Sanitation

Over 80% of households said they used a flush toilet, with just 6% using a pour-flush toilet and 3% a pit latrine. A small percentage (2%) also reported using an aerobic system, but as these are not well-known in Tonga, further investigation is needed. The type of facility in use in households varied with village with people in Nukuhetulu and Nukuleka heavily reliant on pour-flush toilets and 100% coverage by septic systems in Manuka (Figure 50).

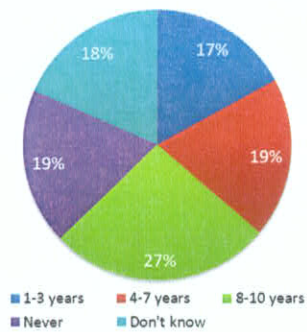
Figure 50: Sanitation facilities in use



Fifty-one percent of respondents said that their sewage system was working well, but 46% said there were problems. The most common problems were overflowing tanks during high tides and heavy rain (21%), poor function leading to frequent pumping (21%) and damage or cracks leading to leakage (32%). Some people (11%) reported problems with unpleasant odours and 5% said there were problems with mosquitoes.

Most, over 60%, of respondents said their sewage waste (sludge) was removed by the septic pumping service. Six percent said the waste is taken to Tapuhia Landfill, but did not specify how that was done. A small percentage said that their septic tank have never been pumped out (1%) and 6% said the waste is safely disposed of buried in the ground. Some people (6%) said that the waste is kept safely inside the tank and 15% said they did not know what happened to it. Among the 774 households with a septic tank, 27% of respondents said they pump the sludge every 8-10 years, 19% every 4-7 years, and 17% every 1-3 years. About 20% never pumped their tank (Figure 51).

Figure 51: Frequency of pumping septic tanks



Overall 67% of respondents said that sewage has an impact on Fanga'uta Lagoon and 33% said there was no impact. The most frequent responses to the kinds of impacts people thought were occurring were negative (29% of households) while only 5% of households said that impacts on the lagoon were positive (Table 28). The most frequent negative impacts were pollution and loss of marine life. On the positive side, people either said that their home was far away and that there were no impacts or their sanitation system was secure. Two households suggested that waste is not toxic.

Table 28: Impacts of sewage on Fanga'uta Lagoon

Red arrows show negative impacts, yellow are neutral and green arrows show positive impacts

YN	Explanation	Responses	%HH
↓	Lagoon water and environment is polluted	85	11
↓	Reduce/Harm/Poison/Kill Marine Organisms	45	6
↓	Rain and High tide wash Wastes & Contaminants to the lagoon	42	5
↓	Unsafe,Collapsed, Leaking sanitation facilities	35	4
↓	Sanitation facility within the shoreline of the lagoon	15	2
↓	Overflow of septic facilities	10	1
↓	Affected marine organisms affect / poison people that consumes them	6	1
↓	Littering -Diapers etc	3	0.3
↓	Impacts on the Groundwater supply	3	0.3
↓	Unpleasant Odours	3	0.3
↓	Contaminants infiltrates underground and to the lagoon	1	0.1
→	Don't know	25	3
↑	Our Home is far from Fanga'uta	20	2
↑	No impact on Fanga'uta	20	2
↑	Our sanitation facility is secured	6	1
↑	Waste is not toxic	2	0.2
	Total	346	37

The most common responses to the impacts of sewage on Fanga'uta Lagoon, where it was believed that there were impacts focused on repairing or replacing facilities (32% of responses), or in maintaining them better (15%). Law enforcement was cited as a solution by 19% of respondents. Other approaches included action by government, better public awareness, more responsibility among householders, improvements in drainage and reducing the cost of septic pumping services.

Environment, Climate and Disasters

When asked to describe and attribute importance to environmental challenges people were facing in their area (village), 45% of households identified drought as a challenge (Table 29). Between 16% and 26% of households also identified heavy rains, coastal erosion, cyclones, declining fish stocks, flooding and accessing drinking water as challenges. Few respondents considered expiring land leases (0.3%), invasive plants (1%) or coral bleaching (3%) significant in their area.

Generally, the importance attributed to each challenge (on a scale of 1-3 from unimportant to very important) tended to increase with the number of households that identified it (Figure 52). The exceptions were declining fish stocks identified in 19% of houses, but attributed the highest average importance of 2.5 and fire, identified in just 6% of HH, but with an average importance of 2.0. Significant challenges, were not automatically the most important and vice versa. The most important challenges included declining fisheries, drought and coastal erosion. The issues considered of lowest importance were expiring land leases, invasive plants and coral bleaching. Nearly all of the challenges were considered to have become worse over the past 10 years. The only exception was that cyclones had stayed about the same, and people were divided about whether heavy rains had stayed the same or become worse (Table 29).

Overall, fewer than 4% of the respondents reported that their household had been affected by disasters in the past 5 years (and 84% saying they were unaffected) (Table 30). The villages with the greatest number of households affected were Haveluloto, Ma'ufanga and Kolofo'ou. Flooding was most commonly reported in Ma'ufaga and Kolofo'ou. Of those households affected, 14% had to evacuate during the disaster; this represents about 1% of all the households surveyed. Where households had to evacuate as a result of a natural disaster, the cost per household was highly variable, averaging $876 (+/- $2,640) and a maximum of up to $10,000. About 2.6% of households said that the structure of their house was affected by the disaster.

Table 29: Environmental challenges faced in the area

Challenges were identified from a list of choices; importance was identified by asking which was the biggest, second biggest and third biggest challenge (scored as 3,2,1 respectively for calculating average so that average importance ranges between 1-3). Each challenge identified was also identified as getting better, staying the same or getting worse.

Challenge	Responses	%Responses	%HH	Avg Importance	Better	Same	Worse
Drought	420	20	45	2.4	77	90	185
Heavy rains	240	12	26	2.0	43	72	84
Coastal erosion	207	10	22	2.2	28	11	121
Cyclones	180	9	19	2.0	43	68	36
Declining fish / seafood stocks	175	8	19	2.5	28	15	96
Flooding	168	8	18	2.1	34	20	76
Lack of drinking water	153	7	16	1.9	28	25	76
Inundation from sea / storm surge	125	6	13	2.0	21	17	57
Increase of in people	119	6	13	1.9	7	8	101
Soil erosion	74	4	8	1.8	7	10	33
Landslips / lanslides	70	3	8	1.6	17	10	29
Increase of in livestock / crops	57	3	6	1.7	10	5	34
Fire	54	3	6	2.0	11	8	24
Coral bleaching	26	1	3	1.6	1	5	14
Invasive trees / plants / vines	10	0	1	1.6	2		6
Expiring land leases	3	0.1	0.3	1.0			1
Total	2081	100	223	1.9	357	364	973

Figure 52: Relationship between % of HH identifying a challenge and the average importance attributed to it

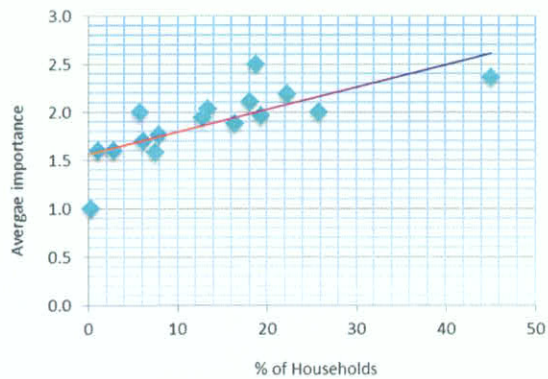


Table 30: Natural disasters that affected the respondent's household in the past 5 years

Disasters	Responses	% Responses	% HH
Flooding from rain	26	41.9	2.8
Drought	11	17.7	1.2
Cyclone (wind)	9	14.5	1.0
Fire	7	11.3	0.8
Tidal surge / flooding	5	8.1	0.5
Earthquake	2	3.2	0.2
Sea-level rise	2	3.2	0.2
Total	**62**	**100**	**6.6**

When asked what future measures should be undertaken to mitigate disasters in their area, few people mentioned specific actions (total of 6% of HH) (Table 31). The measures that were mentioned ranged from more preparedness, to building higher foundations, restoring mangroves and building drainage systems. The low response rate for this question suggests that work could be done in this area to increase public awareness of options for mitigation.

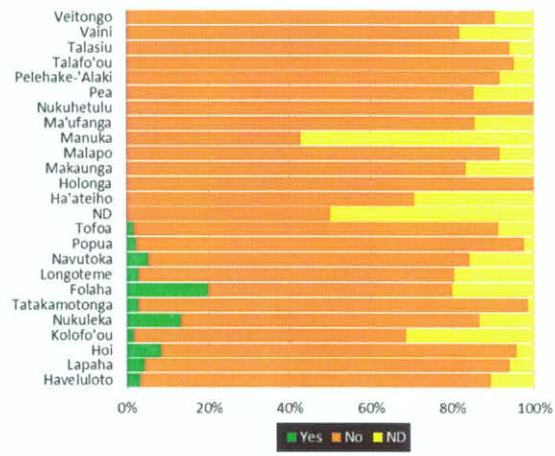
Table 31: What mitigation measures are needed for disasters in your area?

Result	Responses	%Responses	%HH
Be better prepared	11	20	1.2
Build higher foundation	8	15	0.9
Replace damaged mangroves/replant	7	13	0.8
Build drainage	6	11	0.6
Train/advise people/Raise public awareness	4	7	0.4
Grow fruit trees/large trees	4	7	0.4
Don't know	4	7	0.4
Careful about flammable things	3	5	0.3
Prepare water collectors	2	4	0.2
Work closely with Government	1	2	0.1
Should plan how to avoid flooding	1	2	0.1
Pray	1	2	0.1
Money put aside to assist affected people	1	2	0.1
Improve method of construction	1	2	0.1
Emergency drilling exercise	1	2	0.1
Total	55	100	6

Participation in conservation

Just 2% of households said that they had received assistance from or participated in a conservation programme. The majority, 84% said that they had not participated in any government or NGO scheme (the remaining 14% did not answer this question). The villages with the most involvement in conservation programmes were Haveluloto and Lapaha, followed by Hoi, Kolofo'ou, Nukuleka and Tatakamotonga.

Figure 53: Participation in conservation activities in 2014



Membership in organisations was not common, with 13% of households saying that they belonged to some kind of organisation, compared with 71% that did not belong to any organisations. A total of 107 organisations was reported (25% formal and 35% informal and 41% not allocated to either group), with the top 10 accounting for just 5.5% of the responses received. This result suggests that there is an abundance of formal and informal organisations in the area surveyed, with most organisations being relatively small. There was no single large organisation to which large numbers of people belonged. The average number of members per organisation was 21, but this was highly variable (SD=170, calculated over 139 responses).

The majority of people (78%) said that a committee or organisation should be established for environmental concerns in Fanga'uta catchment. The top 3 communities supporting this view were Kolofo'ou (13% of the Yes responders), Haveluloto (12%) and Tatakamotonga

(9%), with least support for the idea from Folaha and Manuka (1% each).

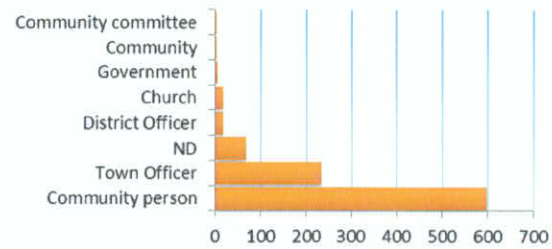
Most respondents (64% of HH) thought that members of the community should be responsible for the conservation of mangroves and the environment in their area (Figure 54). About ¼ of respondents suggested that the Town Officer should be the person responsible. Few people suggested a community committee, the community in general, or government. Some of the responses in their own words were: *"Town Officer will encourage communities to keep the environment clean and help monitor the mangroves of Fanga'uta"* and *"Everyone responsibility to their own place"*.

4.4 Conclusions & Recommendations for the Human Environment

The most important issues and recommendations identified during the socio-economic surveys of the communities surrounding Fanga'uta Lagoon included the following:

12. Raising public awareness on:
    - Sustainable use of mangroves, especially in urban areas
    - Use of agricultural chemicals, noting also farmers close to the lagoon will have higher impacts
    - Special Management Areas (SMAs) for lagoon resources as at present few people know about and support them
    - Current fisheries management measures for Fanga'uta Lagoon
    - Impacts of sewage on the lagoon and options for reducing effects
    - Ecotourism activities suitable for the area.
13. There is a lot of interest among the public (94% of respondents in the survey) in ecotourism activities. Many are interested in improve their existing sites and especially water springs.
14. Half of households surveyed indicated that they use the Waste Authority rubbish collection services, mainly in urban areas. Those not using the service indicated that they burn their own rubbish. There is a need to follow up in communities where only a few use the services to ensure they don't use Fanga'uta Lagoon as a dumping site.
15. Only 2% of household participated in a conservation program in the past year. A large percentage (78%) of households suggested the establishment of a community committee or organization for addressing environment concerns in Fanga'uta catchment area.
16. Drainage was lacking for 77% of respondents, and for many people with drainage there was identified a problem with pollution being transported to the lagoon through the drains (17%) or that drainage affects the lagoon (17%). Drainage systems should be looked at closely.

Figure 54: Who should be the responsible person for the conservation of mangroves and the environment in your community?



Chapter 5: Overall Status of the Lagoon

5.1 Findings on Status of the FLC

This report presents baseline and status information on lagoon habitats, water quality, fish production and human perceptions and attitudes concerning the lagoon in 2015. It is expected that these surveys might be repeated annually to measure progress on interventions designed to address some of the issues identified, with the aim of improving and restoring ecosystem goods and services damaged by past practices. The main issues identified and suggestions for interventions to mitigate them are described in this chapter. As there are two years remaining on the Ridge to Reef Project we expect that at the next status report we might see improvements and identify further problems we could address in a cycle of reactive management and lagoon improvement. The overall issues affecting the entire lagoon and catchment were:

1. The lagoon water quality is deteriorating very quickly. The Pea and Fangakakau Sections have the most water quality concerns, with high faecal coliform counts (indicators of sewage pollution) as well as high Phosphate concentrations (over international standards). In contrast the Mouth and Mu'a Sections are the cleanest parts of the lagoon.
2. Seagrass cover has declined in the lagoon since 1998 and is heavily covered by epiphytes (usually an indicator of nutrient enrichment such as form sewage and agriculture) mostly in the Fangakakau and Mu'a sections.
3. Fisheries resources (finfish) and catches appear lower in the lagoon than at other landings elsewhere in Tonga. During the pilot creel survey a total of 35 species from 23 families was observed and the resources are significant to communities living within the catchment. However, these results are based on insufficient data which should span years.
4. In the coastal environments 73 fresh water springs and bore holes were tested providing baseline information. A range of water quality issues was found that should be addressed as part of lagoon recovery:

- The waters at Nukuleka, Fangakakau (east) and Fanga'uta (west) were unusually alkaline (pH was at 8.0-8.53).
- Ammonia levels were high at Anana (1.2mg/L) and above the safe level for drinking water. The levels were also high at Nukuleka, Lapaha and Hoi (0.46-0.31mg/L).
- Faecal coliform bacteria were high at Vaini, Lavengamlie and Anana (101-300 colonies per 100ml of water) and even higher at 300+ in Popua. These results indicate contamination from human and animal waste in the ground water which is a concern for disease outbreaks.

5. Rates of natural water discharge suggest the Vaini Sector has the highest velocity flow of over 8,000 m^3/hr. This high water flow may be related to beautification work which meant that springs were cleaned at many of the freshwater springs there. Moderate water flows were found in the Mu'a Section, and low flows in the Pea and Nuku'alofa sections of the lagoon (0-600 m^3/hr).
6. Land cover: About 19% of the Fanaga'uta Lagoon Catchment comprises built-up areas, 30% is coconut cropland, 14% is scrubland, 8% of the cover is by mangroves, 7% by grassland and coconut-grassland, 6% by cropland, 4% by woodland, 2% by saline wetland, and 1% each for coconut-scrub, estuarine mudflats, rock and wetland. Less than 1% of the catchment is landfill and sand. Land reclamations were mostly at Nuku'alofa beachfront and Fanga'uta Lagoon section covering about 28ha. These have mostly been used for residential developments, public purposes or Township extensions.
7. The soils within the catchment are mainly of younger volcanic ash soils which are thinner at Lapaha and up to 1 meter thick in the Vaini area. These soils are heavily relied on for subsistence farming, and commercial growing.
8. Coastal vegetation covered about 120ha and was characterised by relatively low diversity, with 129 species of trees found. The area has important economic resources of edible fruit trees (mango, kuava), nuts (ifi, niu), medicines (lala, laufale), pine trees (paini, kauli) and ornamental trees (mangroves, ovava). The vegetation has a low density of adult trees. Two-thirds of the vegetation is dominated by young age-class shade-tolerant canopy trees. Two main issues were identified for any future replanting schemes: the dumping and accumulation of rubbish along the coast and the uncontrolled roaming pigs at villages. Hotspots of damaged coastal vegetation were found at Hoi, Malapo, Alaki, Vaini, Kauvai, Halaleva, Umusi and Popua.
9. Mangroves covered about 419ha, which is 29% of Tongatapu's mangroves. Species richness comprised 6 major species (one unidentified), 5 minor species and 14 mangrove associates. Special attention is needed for Tongota'ane *Bruiquiera gymnorhiza* (white), Hangale *Lumnitzera littorea*, Lekileki *Xylocarpus granatum* and Mamea *Heritiera littoralis* as they are becoming endangered in the lagoon. Seven mangrove hotspots in order of decreasing damage were identified at Talasiu, Vaini/Longoteme, Nukunukumotu, Popua, Nukuhetulu, Patangata and Fanga.
10. The waste collected over two weeks during this survey for characterisation recovered about 46.7 tonnes of waste mainly from coastal areas and residential areas. Most garbage was of plastics and cans of different types. A clean up of the coastal areas has yet to take place in most places around Fanga'uta Lagoon.
11. There were significant issues for which we found poor understanding at a grassroots level during the socio-economic survey. This included topics concerned with the sustainable use of mangroves, impacts of chemical use on farms, the Special Management Area (SMA) program, fisheries management measures for, impacts of sewage on the lagoon and information on opportunities for ecotourism. At least half of the people interviewed were uninformed about the government rubbish collection service and very few households were engaged in conservation programmes. The survey highlighted problems with poor or non-existent drainage systems (usually on roadways) and issues for the transport of garbage.

5.2 Recommendations

A. Poor lagoon water quality, overgrowth of seagrasses by algae (epiphytes) and poor spring and borehole water quality are all, at least in a large part, likely to be related to sewage leaking out of septic tanks and agricultural chemicals that are finding their way to the lagoon. Ongoing monitoring, further investigations and solutions for reducing nutrient enrichment and pollution of the lagoon need to be sought.

B. Ecotourism and the flow of spring waters could be enhanced by beautification projects aimed at cleaning out coastal and spring areas. Other benefits could include increased clean water flows through the lagoon if the nutrient loads from sewage and agriculture are also reduced.

C. Further surveys and monitoring are needed to better understand the lagoon and catchment area, provide data for determining whether interventions are working and identifying new issues as they arise. This could include:

- Hydrographic/benthic survey of the lagoon needed before any dredging or reclamations are done;
- Detailed mapping of mangroves and land cover;
- Monitoring of lagoon fisheries beyond this pilot survey to be carried out for several years;
- Investigations of areas of the lagoon with high pollution loads to identify sources and solutions, focusing on sewage, solid wastes and agricultural chemicals;
- Socio-economic surveys should be repeated periodically to determine if the level of community awareness and patterns of behaviour have changed against this baseline.

D. Legal instruments needed already in place for protecting lagoon and catchment values should be improved and/or enforced. For example, Environmental Impact Assessments (EIA) should accompany any developments and improvements in the lagoon to ensure vulnerable resources and services are protected. Enforcement of policies on reclamations and lagoon developments is also needed.

E. Modifications to lagoon depth and reclamations should be minimised and accompanied by careful investigations and analysis with the aim of promoting the best outcomes for the entire catchment and its people. Dredging machines should be used with caution as they can make significant modifications and should be accompanied by EIAs. Suction pumps should be used in the case of cleaning out springs to minimise damage to surrounding areas. In addition a community group 'Land Reclamation Watch' could be formed to protect against illegal developments. Communities could be encouraged to report unexpected developments.

F. Restoration of habitats and vegetation should be undertaken where necessary to improve the function of the lagoon. This could include:

- Restoration of coastal plants through: planting natural crawling plants along the lagoon coast to trap silts and minimise flow of materials into the lagoon; encouraging replanting of protective undergrowth;
- Minimising clearing of trees which is damaging natural cycles of regeneration;
- Minimising soil erosion;
- Investigating mechanisms for legal protection of areas to be rehabilitated so that regeneration is successful;
- Safeguarding bird, mammals and agents that disburse seedlings;
- Controlling roaming pigs that threaten vegetation;
- Mangrove replating of seedlings and propagules where there has been damage in the past. A nursery should be established for replenishment projects.

G. Pollution in the lagoon is severe and coming from sewage, rubbish disposal, agriculture and chemical use. These find their way into the groundwater, through direct dumping or are washed into the lagoon by surface run-off or through stormwater drains. Low cost technologies for controlling, diverting or minimising these need to be investigated. Regular clean-ups by communities are needed.

H. Sewage pollution is a special case and is probably responsible for most of the nutrient enrichment in the lagoon (even more than agriculture). Current sewage systems if working well digest raw sewage and convert it to a microbiologically safe, but nutrient-rich material more suited to fertilizer. The overflows and sludge even from good septic systems act as lagoon enrichers, leading to damage. A feasibility study is needed to investigate mechanisms of efficiently removing the sewage from within the catchment to allow the lagoon to recover.

I. Drainage systems should be investigated for their contribution to polluting the lagoon and solutions found to prevent further pollution.

J. Public awareness and participation needs to be encouraged to improve attitudes and the ways that people interact with the lagoon. These should focus on waste disposal, littering, agriculture, organic methods, encouraging regrowth of plants in towns and allotments and on the role of mangroves for providing ecosystem good s and services. Pilot activities should be developed to complement the public awareness campaigns.

K. Hydrology and geomorphological features of the lagoon should be changed with extreme caution and thorough environmental assessments. This includes seawalls, dredging and other developments that can alter water movements into and through the lagoon, and change its depth and shape.

L. Mangroves need to be managed and protected. Uses for fuel, wood, medicines, traditional products and seafoods need to be kept to sustainable levels. Mangrove green belts should be maintained for protecting human settlements located behind them, especially in Popua and Patangata. Rare species should be protected, especially in Nukuhetulu and Folaha with the oldest and most diverse mangroves in the region. Further destruction of mangroves at Nukunukumotu should be prevented.

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Acronyms & Terms

Term	Details
BA	Basal area
DBH	Diameter at breast height
EMP	Environmental Management Plan
ESRI	Environmental Systems Research Institute
FCA	Fanga'uta Catchment Area
FLC	Fanga'uta Lagoon Catchment
FLS	Fanga'uta Lagoon System
GEF	Global Environment Facility
GIS	Geospatial Information System
GPS	Global Positioning System
HH	Household
IEMP	Integrated Environmental Management Plan
IEMP-FLC	Integrated Environmental Management Plan of Fanga'uta Lagoon Catchment
IUCN	International Conservation Union
LIDAR	Light Detection and Ranging
M&E	Monitoring and Evaluation
MAFFF	Ministry of Agriculture, Food, Forestry and Fishery
MEIDECC	Ministry of Meteorology, Energy, Information Disaster Management, Environment, Climate Change, and Communication
MEIDECC	Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications
MESCAL	Mangroves EcoSystems for Climate Change Adaptation & Livelihoods
MLSNR	Ministry of Land, Survey and Natural Resources
NRD	Natural Resources Division
R2R	Ridge to Reef
SMA	Special Management Area
SRF	Strategic Result Framework
TCZ	Terrestrial/Coastal Zone
TWG	Technical Working Group
UNDP	United Nations Development Program
LGIS	Lands Geospatial Information Services Unit