Status of Fanga'uta Lagoon 2016

Ridge to Reef Project, Kingdom of Tonga

DEPARTMENT OF ENVIRONMENT

Government of Tonga

STATUS OF FANGA'UTA LAGOON 2016

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This work was carried out in collaboration with and on behalf of the villages of Fanga'uta:

(village names in alphabetical order)

'Alaki
Folaha
Haveluloto
Ha'ateiho
Hoi
Holonga
Kolofo'ou in Tongatapu
Kolonga
Lapaha
Longoteme
Makaunga
Malapo
Manuka
Ma'ufanga
Navutoka
Nukuhetulu
Nukuleka
Nukunukumotu
Pea
Popua
Talafo'ou
Talasiu
Tatakamotonga
Tofoa
Tukutonga
Vaini
Veitongo

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Message from the CEO

This is the 2nd Status Report produced in the management of Fanga'uta Lagoon Catchment area through the efforts of the Technical Working Group for the year 2016. As part of the expected annual report on the status of the catchment area funded by the Global Environment Facility (GEF), this Ridge to Reef (R2R) project is implemented under the Department of Environment under the Ministry of MEIDECC supported by the United Nations Development Programme (UNDP).

The report outline the current realities observed at the catchment area and the noted learning gained from the various implemented activities to improve the ecological services of the lagoon in order to sustain the livelihoods, reduce poverty and improve climate resilience of the surrounding communities of Tongatapu. As such an ongoing monitoring system is implemented for the management of the area to inform of its ecosystem health, results of the interventions with recommended solutions for immediate attention to restore the lagoon.

This ridge to reef approach is inclusive of the nature of Fanga'uta Lagoon of which its success depends largely on the strength of collaboration fostered amongst the multi-stakeholders, experts and institutions responsible for activities on land to sea.

I wish therefore to acknowledge all those who were involved in the preparation of this report. This provides the opportunity to share the learning gained from the management of Fanga'uta Lagoon to assist in the efforts in dealing with the challenges identified. This gratitude is also extended to the Deputy Prime Minister, Minister for MEIDECC and Chair of the National Environment Coordinating Committee (NECC) and its members for their continued support and direction with the implementation of this program.

This gratitude is also extended to the members of the R2R Technical Committee, its Scientific Technical Advisor, the Department of Environment and the Project Management Unit for their valuable assistance and ongoing support in the development of the report.

Thank you,

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

Paula Ma'u

Chief Executive Officer for MEIDECC

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 47,529 persons in 29 villages and 8,279 households. This population of the Fanga'uta catchment accounts for 64% of the population of Tongatapu. 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 the lagoon to a state where it can better sustain and provide the goods and services humans require.

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 on-going survey and yearly reports were designed to inform all stakeholders, including communities, government and users of the catchment area, of the current status of Fanga'uta Lagoon and its surrounds. By providing up-to-date facts on current conditions, 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. These status reports will serve to detect changes over time and provide answers to peoples' concerns on the environment that they are living in, and assist them with information relevant to Fanga'uta's protection and improvement.

This annual update report is divided into three sections covering:

1. Marine environment: Lagoon water quality, and bottom-dwelling organisms such as seagrasses and invertebrates;
2. Coastlines and catchment land: Springs and wells, mangroves, land cover and vegetation, soils, agriculture, waste management, reclamations and developments; and
3. Birds: Focusing on diversity and abundance of birdlife in the Fanga'uta area.

Other surveys on fisheries, mangroves, waste management, developments and socio-economic information, reported in the baseline survey in 2015 were not repeated in 2016. They are scheduled to be updated in future years. Some of these other elements of the Fanga'uta area are expected to take longer to change and do not need yearly surveys. Some of these are expected to be repeated every 2-4 years, the results of which will appear in future Status Reports. Details of the scheduling and types of surveys to be undertaken are provided in The Fanga'uta Lagoon Catchment Monitoring manual 2016 (*1*).

For this update Status Report a series of scientific surveys was undertaken between October and December 2016 using field surveys, laboratory assays and community meetings to characterise the current state of the Fanga'uta Lagoon catchment area. The work was carried out by 40staff from 5X ministries, 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. linkages between environment, GIS 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:

This report builds on the baseline report of 2015 (14) updating the current status of the lagoon and for some measures (such as benthic organisms, water quality and freshwater spring discharge rates) allows us the opportunity to examine changes over time. It is expected that repeated surveys will allow us 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.

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

The main outcomes of this 2016 survey were as follows:

1. The depth of the water in the lagoon is changing. At two sections of the lagoon, Mouth and Mua, depth has increased since 1998, though this could just represent long term fluctuations. At the 4 remaining sections of the lagoon (Fanga Kakau, Fanga'uta, Pea and Vaini) there has been a significant shallowing of the lagoon. At Fanga Kakau there has been an average change of 1.2m, with the current depth at just 0.5m, compared with 1.7m in 1998.
2. Physical aspects of water quality such as salinity, temperature and acidity/alkalinity have fluctuated in the period 1998-2016, without any significant overall trend. That is, these measures have stayed about the same throughout sampling. Dissolved Oxygen (D)) underwent an increase after 1998, but it is likely that the earliest data were in error and can safely be ignored – it was noted at that time that the probe used for the survey was malfunctioning. Overall, it is unlikely that there has been significant change in the dissolved oxygen levels. It is unclear how turbidity levels changed in 2016, but in 2015, slightly clearer water quality was recorded at Mouth and Mua, while all remaining sites remained as they had been since 1998. Turbidty tube measures will be undertaken in 2017 to continue the timeline.
3. Nutrient levels in the lagoon appear to have been dropping and levels of Nitrate, Ammonia and Phosphates appear to be below ANZECC guidelines for recreational water quality. These results have not so far led to improvements in the symptoms of eutrophication. Murky waters and algal growth are still dominant. It will be necessary to keep monitoring as periods of low rain could have reduced transport of nutrients into the lagoon and long term information will be needed to understand trends.
4. Benthic (bottom-dwelling) animals and plants have continued to decline, and very significantly since 2015. Corals are virtually absent from the entire lagoon system, and have remained so since 1998. There was, however, a sharp decrease in the cover by seagrasses and algae in the past year or so. The overall average cover by seagrasses in all sections of the lagoon dropped to 4.5% in 2016, declining from a high of 29% in 1999. The cover by algae in dropped to 13% in 2016 compared with a high of 25.5% in 1999. At the same time, the amount of mud, sand, rubble and rock has increased and now covers 73% of the lagoon floor. That is, the cover of the lagoon floor is now mostly non-living sediments, showing that conditions in the lagoon are overall continuing to deteriorate, despite the apparent decreases in some of the nutrients noted above.
5. For freshwater springs, there was a large increase in the water discharges recorded since last year (2015), with 50-60% more being discharged in Mu'a and Pea Sections, and a 15% at Vaini. On-going sampling is needed to understand the nature of and reasons behind the variations in flows.
6. Road drainage systems were identified as a significant pathway for lagoon pollution. It was recommended that water retention ponds be developed to filter out sediments and prevent them moving towards the lagoon.
7. A Landuse Zoning Plan is proposed to protect the lagoon from agricultural chemicals. The plan proposes the following zones:

- Zone 1: 150m buffer - Crops with a need for or very minimal usage of agricultural chemicals, such as kava, pineapples, hopa, bananas, kape, vanilla, etc to be located at lower end of the catchment, close to the lagoon;
- Zone 2: Lower half of the catchment - Crops with medium usage of pesticides and fertilizers are root crops such as taro, cassava, sweet potatoes, yams, etc. to be located halfway down the catchment; and
- Zone 3: Upper half of the catchment - Crops that are mostly in need of agricultural chemicals such as fertilizers and pesticides - water melons, vegetables, hina, etc to be located higher up the ridge and away from the catchment area.

8. Other suggestions for improving the catchment lands included the following, some building on recommendations made last year:

- Declaring selected sites as Eco-tourism and Historical / Heritage sites;
- Cleaning up all Fresh water springs by communities and seeking financial assistance;
- Systematic hydrographic/bathymetric survey of the lagoon to understand its bottom topography and what/ where to deepen before allowing any execution of suction pumping method;
- Strictly apply Environment Impact Assessment (EIA) requirements;
- Discourage dredging machines for 'cleaning up' shallow areas and restrict use of suction pumps around springs;
- Further, more detailed surveys on illegal land reclamations are needed;
- Form a community 'Land Reclamation Watch' on illegal development along the Lagoon coastal areas and encourage the reporting of suspicious developments;
- Examine enforcement of the relevant laws and policies;

- Further consultations with key personnel from relevant stakeholders and communities to obtain feedback on the Landuse Zoning Plan;
- Encourage planting of natural and protective plants and trees along the Lagoon coastal areas;
- Discourage and/or limit raising pigs in low-lying areas near the lagoon and enforce policies and laws on pigs.

9. In soil samples used to determine the pollution levels of the land and potential sources of pollution for the lagoon high levels of heavy metals were found, but that there are currently no detectable issues with pesticide residues (Organo-chlorides or Organo-phosphates). Extremely high levels of Arsenic, Copper and Chromium were found at the timber treatment site of the Tonga Forest Product at Tokomololo. Issues were also found for Arsenic, Cadmium, Nickel and Chromium at other sites, including some town and farming areas. Many of these find their way into the coastal areas. Work is needed on promoting sustainable land use, organic farming methods and best practices for the use of chemicals containing heavy metals.
10. Coastal and terrestrial vegetation replanting programmes varied in their effectiveness depending on the skills of the community members involved. There were also impacts due to dry periods, damaged caused by pigs and the demand for coconut seedlings for human food. The success of replanting efforts will depend on regular monitoring and training.
11. Mangrove cover has continued to decline due to dredging, clearing and reclamation, land issues and over-use of mangroves. The Stewardship Plan will need to address these issues, including questions raised by the community on the development of a park and golf course within mangrove areas. There is a particular need for the EIA Act 2003 to be enforced. On-going monitoring and restoration projects are still needed. The R2R Project can provide guidance on options for sustaining mangrove ecosystems and the aesthetic values of the area.
12. Waste problems continue increase within the FLC, with the clear need for education and awareness programmes. The amount of recyclable waste being collected suggests that incentives for proper disposal need to be considered. This might include support for local recycling companies and a levy on end of life for goods. Clean-up campaigns should be on-going both as a public awareness and ecological improvement activity.
13. A wide variety of birds use the lagoon as habitat, particularly for feeding at high tide and for roosting. The greatest numbers of birds were observed in the Popua area. A total of 12 species was recorded via vehicle and boat surveys. This includes herons, wading birds, seabirds, rails and gallinules and land birds. Mangroves were identified as important to many species. The main threats to bird habitats were clearance for housing, reclamations, roads, pollution, eutrophication and overfishing. In particular productivity of mudflats is dependent at least in part on water quality, so that pollution and nutrient enrichment are issues. Repeated surveys are recommended.
14. A key site identified as habitat for birdlife included the area of mudflats and sandflats to the east of Popua. The main issues for bird habitats in Popua included rubbish dumping, foraging by pigs and encroachment by housing developments.
15. On-going monitoring of the lagoon in 2017 and beyond will be necessary for identifying the main trends and any improvements brought on by interventions. These will require that the teams follow the strategies established in the Fanga'uta Lagoon Catchment Monitoring Manual 2016.

CONTENTS

Chapter 1: Introduction

1.1 Project Objectives

This UNDP supported Ridge to Reef program is known under the name of Integrated Environmental Management Plan (IEMP) of the Fanga'uta Lagoon Catchment Project (FLC) (or IEMP-FLC). This program was formed as part of the "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) (*2*). 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 (*3*). However, in recent years yields have dropped and some species are no longer sustainably exploited. For example, mangroves have been exploited and areas reclaimed (*4*).

The lagoon also provides services such as habitats to support our fisheries, attenuate our pollution, carbon sequestration, recreational opportunities (*5*) 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.

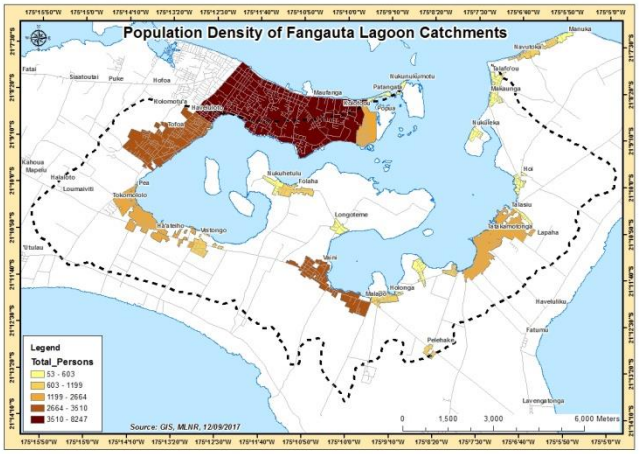
In recent years, considerable community concern has been expressed about possible contamination and loss of productivity of the lagoon due to the effects of urbanisation, changing land use, pollution and overfishing. Therefore, the main objective of the project was to identify the current issues and 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 The Communities of Fanga'uta

A total population of 47,529 persons in 29 villages and 8,279 households are currently living within the Fanga'uta catchment area, accounting for 64% of the population of Tongatapu (Figure 1). The human population is distributed in five districts: Kolofo'ou (38% of the catchment population), Kolomotu'a (15%), Vaini (27%), Tatakamotonga (8%) and Lapaha (12%).

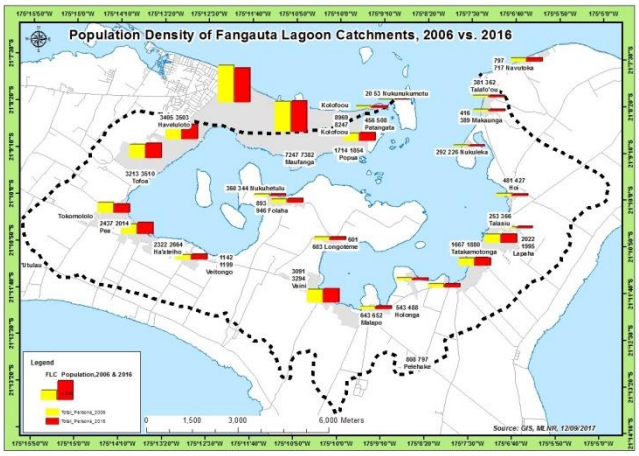
Figure 1: Population distribution within the Fanga'uta catchment area

(Source: GIS Unit – MLSNR 2016)



Over the past 10 years the populations around Fanga'uta have remained fairly steady. Figure 2 shows similar to slightly fluctuating population numbers in the villages around the catchment since 2006, with small increases in some areas, and decreases in others. In terms of planning for improvements in the catchment area this suggests that the villages and their populations there now are likely to persist and will continue to be an important way of contacting and working with the residents of the area.

Figure 2: Trends in population over the past decade



Of the villages within the catchment 27 (93%) are participants in the R2R project, being both contributors and beneficiaries of the project.

1.3 Environmental & Physical Context

Fanga'uta Lagoon is a shallow, almost enclosed embayment, covering an area of 38.1km^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 3). 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 3).

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 (*6*). 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 (*7*) 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 (*7*) 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.

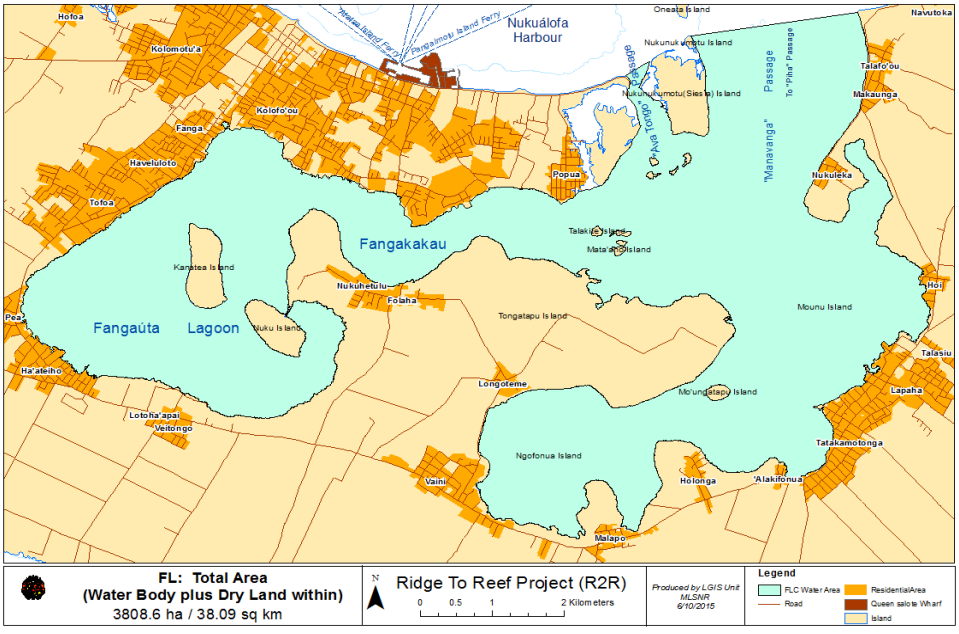
1.4 Purpose of these Surveys & Annual Status Reports

The purpose of this survey and annual status reports was to inform and continually update all stakeholders, including communities, government and users of the catchment area, of the status of the Fanga'uta catchment area and how it is changing over time. By providing up-to-date information on past and current conditions, 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 3: The Fanga'uta Lagoon Catchment Area

(Source: GIS Unit – MLSNR, 2015)



Chapter 2: Fanga'uta 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' (*8*). 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 (*9*). 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 24 October to 2 November 2016 in six sections of Fanga'uta Lagoon. The sites used were the same as those established during the TEMPP Project in 1998-2000 (*10*) to allow for status now and comparisons with data collected up to 18 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 4).

Figure 4: 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 epiphytes[2] 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 (*1, 10*) 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.

The data for the 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

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

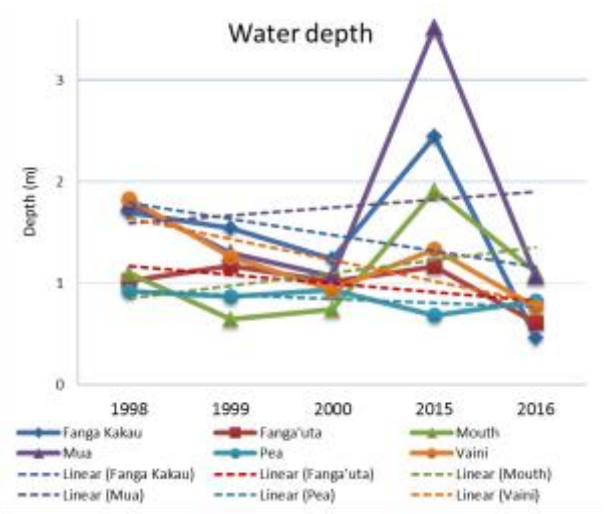
produced by the database and compiled for interpretation. For example, for the benthic survey, this included averages of percent cover by seagrasses and algae per site and for each year of the survey.

2.3 Results: Status of the Marine Environment

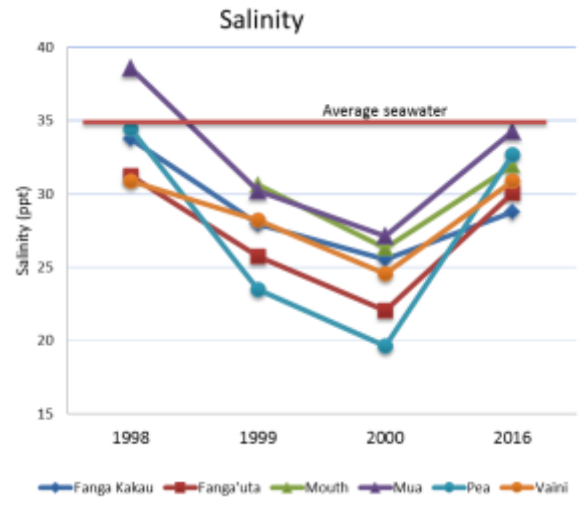
Lagoon Depth & Water Quality

The water depth in the lagoon is slowly changing over time. In two of the 5 sections (Mouth and Mua) water depth has increased since the first survey in 1998 (Figure 5). This pattern is largely driven by elevated depths recorded in these locations during 2015: without those Mua would likely be shallowing. In contrast, the depth at mouth may just be fluctuating. At the remaining locations in the lagoon (Fanga Kakau, Fanga'uta, Pea and Vaini) the overall trend is towards shallowing. The greatest change has occurred at Fanga Kakau where the depth in 1998 was 1.7m reducing to 0.5m by 2016.

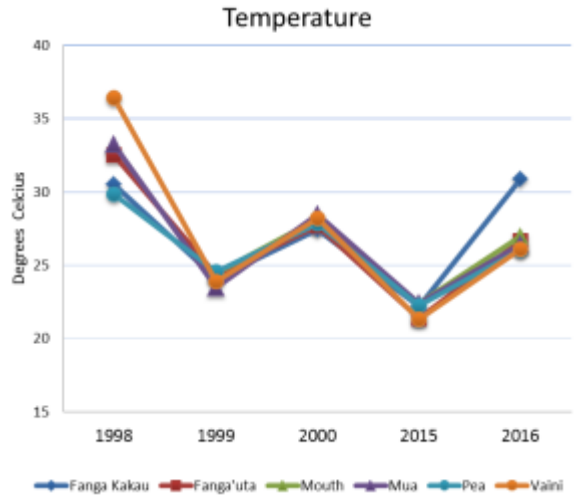
Figure 5: Physical water measures in Fanga'uta Lagoon



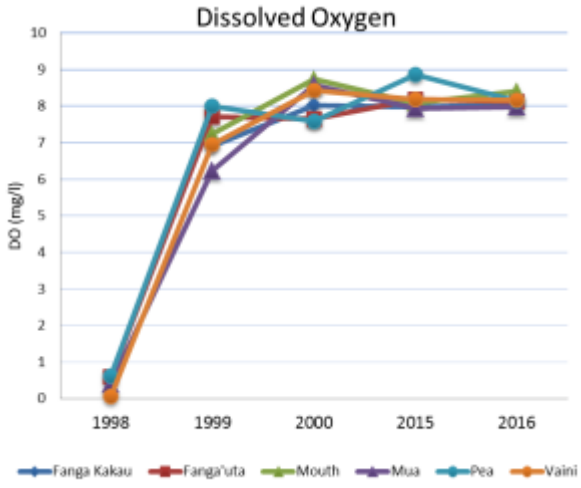
Average salinity has fluctuated over time, probably in response to short term rainfall patterns balanced by tides, with no overall indication of a change. Most of the locations have lower salinity than average oceanic seawater. In 2016 salinity varied between an average of about 28 and 34 ppt in all sections, including surface and bottom waters.



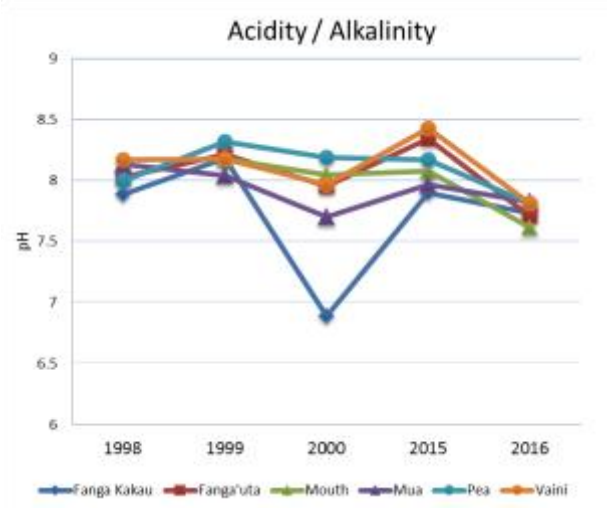
In 2016 the temperature of the lagoon water averaged between 26 and 31 Celcius, with the higest average temperatures recorded at Fanga Kakau. This compares with a range just 21-23.5 degrees in 2015. In general there is no trend towards a change in water temperatures, with values fluctuating over time.



Dissolved oxygen (DO) level was recorded as very low during 1998, increasing from average values below 0.5 mg/l to above 6 mg/l by 1999. This probably represents a problem with equipment in 1998, so the discussion that follows ignores the values for 1998. Since 1999, and especially after 2000 there has been little change in the levels of dissolved oxygen in the lagoon. In 2016 the average DO level was a healthy 8 mg/l.



The pH value, a measure of acidity/alkalinity averaged pH=8 around the lagoon for most of the survey since 1998, but in 2016 appeared to have reduced to a more neutral 7.75. The lowest average pH was found in the Mouth Section of the lagoon at 7.6. By 2016 there were few differences between the different sections of the lagoon (Figure 5).



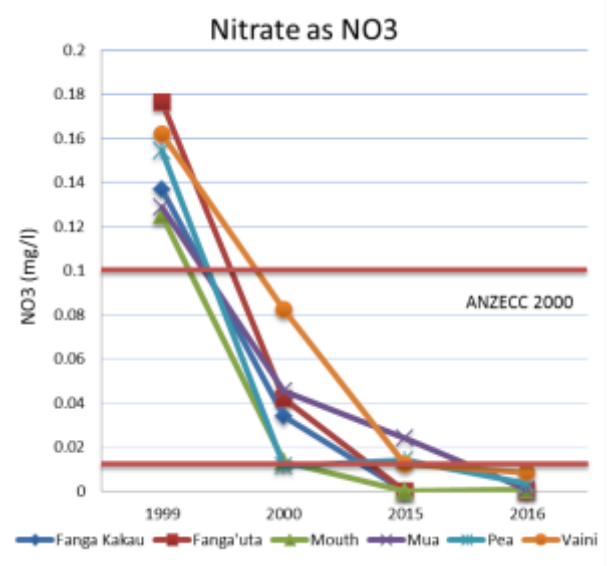
Water clarity and faecal coliform counts were not assessed during the 2016 survey, but both types of data will be included in the 2017 survey.

Nutrients in the Water

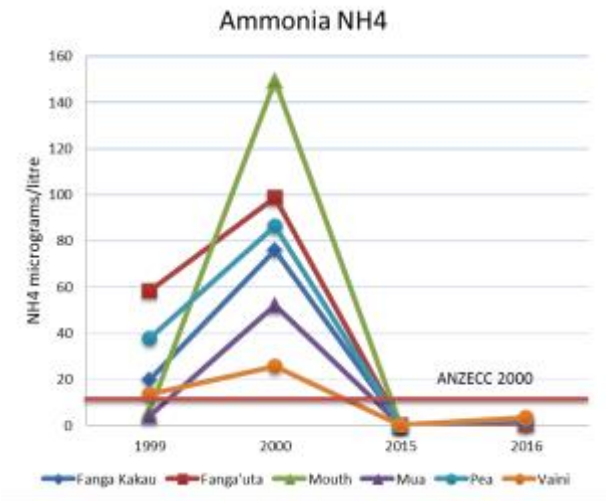
Nitrate and Ammonia levels have been falling in Fanga'uta Lagoon since the initial survey in 1999 (Figure 6).

In 1999 Nitrate levels were high at between 0.12-0.17 mg/l, dropping to about half of that in the year 2000. The sections with the highest values during those years were at Fanga'uta and Vaini. By 2016 Nitrate levels had fallen to less than 0.01 mg/l at all sections of the lagoon. The Australiana and New Zealand ANZECC recreational water guidelines provide a range of between 0.01 and 0.1 mg/l for Nitrate and by 2016 levels were all below the guidelines for primary contact (e.g. swimming) and secondary contact (e.g. boating and fishing) (*11*). These results suggest that there have been improvements in the water quality of the lagoon. However, by way of caution with these results, the reduction of levels has not yet led to reversal of the symptoms of eutrophication, such as murky water and algal overgrowth.

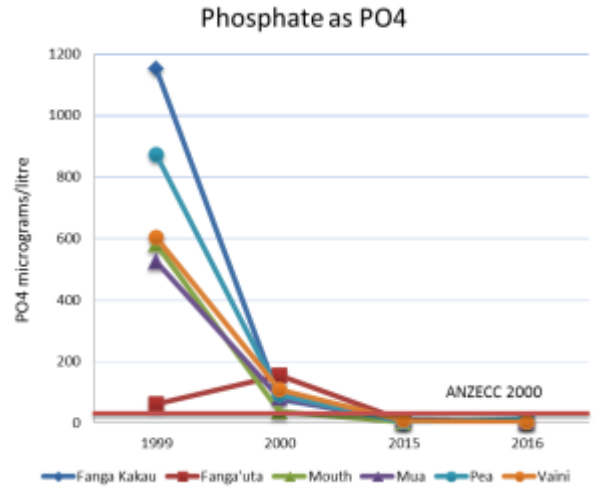
Figure 6: Nutrients in Fanga'uta Lagoon



Ammonia levels were low in all Sections of the lagoon by 2015 and the low levels were maintained in 2016. The current levels of Ammonia are below the ANZECC 2000 guidelines for recreational waters.



Phosphate levels were higher than the Australia / NZ standards (ANZECC 2000) for recreational swimming and boating activities in all sections of the lagoon for most of the surveys undertaken since 1999. Levels were extremely high in 1999 and dropped significantly in 2000. The highest readings were found in Pea, Fanga'uta, and Vaini sections at that time. During the 2015 survey levels had dropped again and by 2016 had fallen to between the 5-15 micrograms per litre range allowed by the recreational water quality standards.

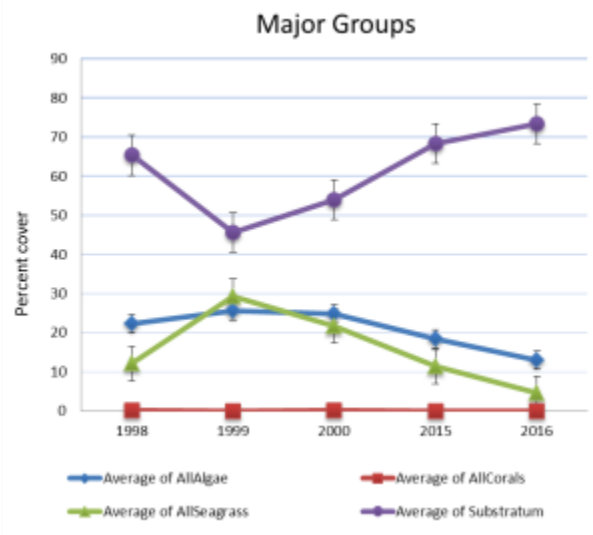


Bottom-dwelling animals and plants

Major changes in the benthic species of the lagoon have been recorded over the survey since 1998 (Figure 7). Corals have been low since 1998 and show no signs of increasing, with average cover only reaching up to 0.1% and in most cases remaining at zero. Throughout most of the survey work, algae and seagrasses have tended to occupy between 10% and 30% of the space, but in the period 2015-2016 both groups underwent a significant decline compared with 1999-2000. The overall average cover by seagrasses in all sections of the lagoon dropped to 4.5% in 2016, declining from a high of 29% in 1999. The cover by algae in dropped to 13% in 2016 compared with a high of 25.5% in 1999. At the same time, the amount of mud, sand, rubble and rock (together termed 'substratum') has increased and now covers 73% of the

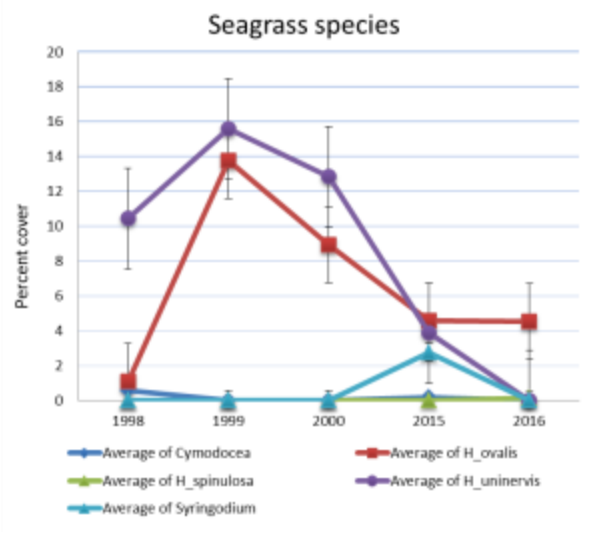
lagoon floor. That is, the cover of the lagoon floor was not replaced by other species, but is now mostly non-living sediments. This result shows that conditions in the lagoon are overall continuing to deteriorate, despite the apparent decreases in some of the nutrients noted above.

Figure 7: Cover by Major Groups of Species



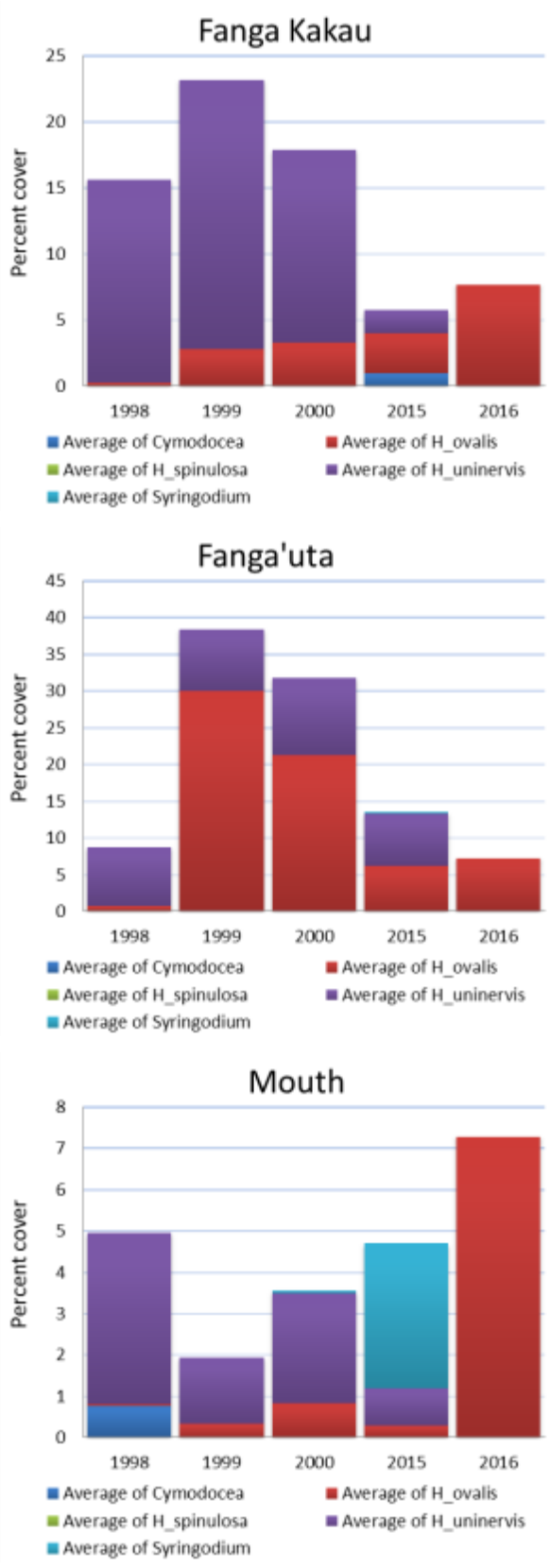
Five species of seagrasses and 13 types of algae were identified during the survey. The most common seagrasses in the lagoon are *Halodule uninervis* and *Halophila ovalis* (Figure 8). These two species are the main ones that varied over time, declining from their highest values recorded in 1999. Alarmingly, the cover by *H. uninervis* dropped to zero in 2016, along with *Syringodium*. H. ovalis dropped to about a 1/3 of its 1999 levels and was recorded at an overall average cover of 4.5% in 2016. There were, however, significant differences in the cover by section and site in the lagoon.

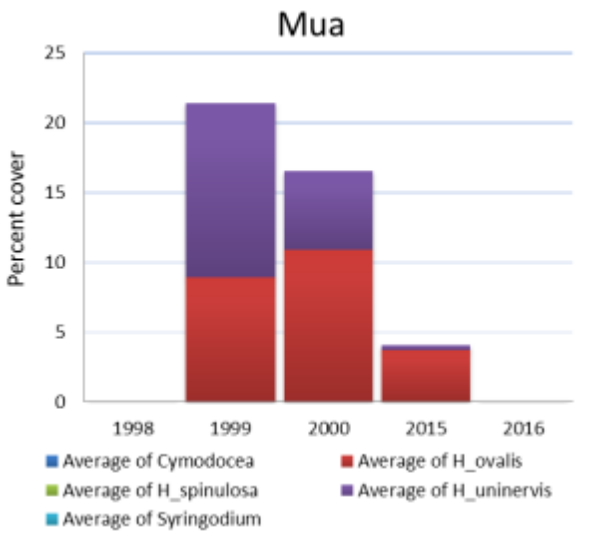
Figure 8: Overall Cover by All Seagrass Species

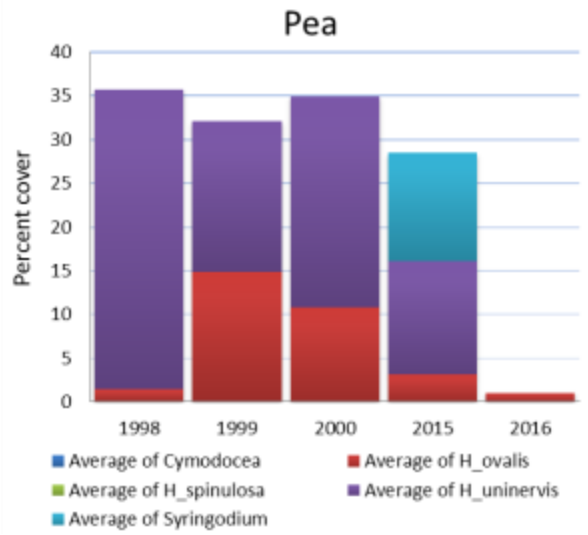


There have been large changes in the species of seagrasses found in each of the lagoon sections since 1998 (Figure 9). Dominance by *Halodule uninervis* fell at all sections since 1999. At some sections (Fanga'uta, Mua and Pea) there was also a drop in *Halophila ovalis* cover over time. Overall, at most of the sections of the lagoon there was a decline in seagrass cover involving both of these species (*Halodule* and *Halophila*) (Figure 10). A different pattern was observed at the Mouth section where there was a greater diversity of seagrass species, and in 2016 an increase and dominance by *Halophila ovalis*.

Figure 9: Distribution and Abundance of Seagrass Species at each Section of the Lagoon over Time







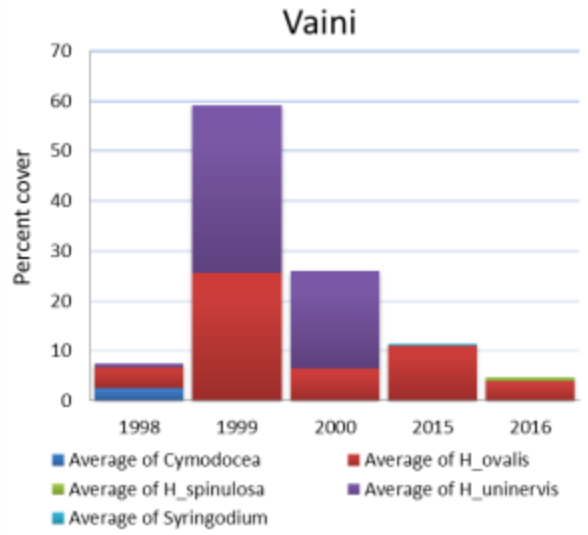


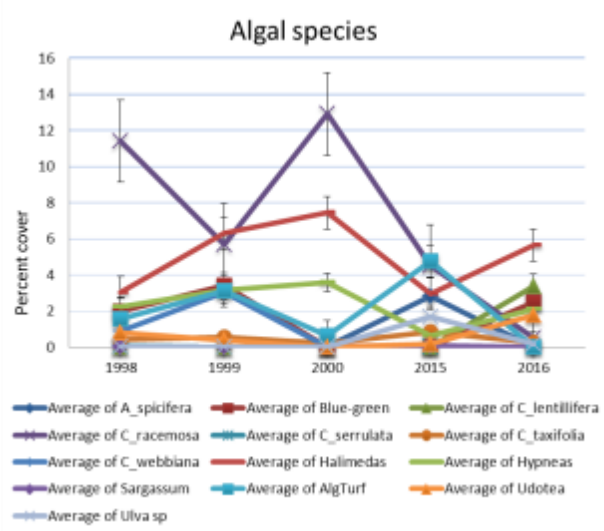
Figure 10: Seagrass species common in the lagoon

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

Epiphytes are an indicator of stress, with seagrasses heavily covered by algae often indicating nutrient enrichment (*12*). During this study, all seagrasses were 100% covered by epiphytes in 2015, but no data on this indicator were collected in 2016. In 2015 the cover by ephiphytes was generally lowest at the mouth of the lagoon and at Mu'a. Monitoring of epiphytes will resume in the 2017 survey.

For algae, cover has fluctuated over the period of the survey since 1998, with an overall decline by 2016. The species that were highest initially and lost cover were *Halimeda spp* and *Caulerpa racemosa* (Figure 11). The remaining species have oscillated between about 0-5% in all sections, with a few, such as *Udotea*, only present in a few transects.

Figure 11: Cover by Algal Species over Time and Averaged over all Sections of the Lagoon



2.4 Conclusions for Marine Areas

The status of the health of the lagoon is still declining since last survey in 2015, and has been in decline since the first survey in 1998.

Interestingly, the levels of some of the nutrients in the lagoon waters has improved, with a reduction in both Nitrates and Phosphates to ANZECC (*11*) guideline levels by the 2016 survey. This was not accompanied by any improvement in benthic organisms which have declined

strongly throughout the survey. Cover of the bottom over much of the lagoon is now about 73% sediments (mud, sand or rubble), 13% algae and just 4% seagrasses, though this varies strongly from Section to Section. In 1998 cover by algae was 22% overall and cover by seagrasses 12%. If this trend continues we have little time left before we could lose living benthic cover.

At next survey in 2017 more information will be collected on turbidity, faecal coliforms, epiphytes and other indicators. By that time steps will need to be taken to prevent further losses.

Chapter 3: Coastlines & Catchment land

3.1 Introduction

The main factors that mostly contributed to the existing critical status of the lagoon, shown in this report, were due primarily to surface runoff from roads and farmland, sedimentation, polluted groundwater inputs, land reclamations, waste dumping, ground disturbance and pollution from roaming pigs, and a general lack of appreciation of ecological benefits of the system.

The objective of this report, then, is to present ways, as contributions for improving the status of the lagoon resulting from monitoring surveys, observations and consultations with key personnel from relevant stakeholders

In 2016, to assist in the recovery of the once-abundant resources of the Lagoon, the GIS Sector of the Terrestrial and Coastal Monitoring activity of the R2R Project conducted a review of the existing governance system of the Fanga'uta Lagoon Catchment involving key personnel from relevant stakeholders by assessing the conditions and status of the following activities:

Fresh Water Springs

The GIS Team initially raised the issues of Fresh Water Springs, therefore, proposed to be included in the Coastal/Terrestrial's GIS activities as it clearly understood the extremely significant values of the springs to the Lagoon, to the catchment area, and the communities within the catchment. GIS Sector understood that the significance of the FWS might contribute greatly to the marine water discharge that improves the whole Lagoon water quality as well as the lives of the mangroves.

This is totally a new activity and was not included in the previous surveys of the Lagoon.

The objectives of this activity as shown in this report, were to (i) survey and map the location of Fresh water springs, (ii) identify their heritage values by consulting with Town Officers (was only included in the 2015 monitoring survey and report), (iii) measure the amount of discharge, and make recommendations for improvements,

Land Use Zoning

This is also a new activity raised by GIS as one of the processes for reducing the flow of pollutants, heavy metals, sediments, pesticides and agricultural chemicals to the lagoon specifically from Urban and Rural areas.

Professional advices and vital recommendations from key stakeholders during consultancy stage of this activity had a great influence on the success of the creation of the Land Use Plan Zoning of the FL Catchment area. This draft Land Use Zoning could simply be one of the measures for improving coastal and resource management of the Lagoon, similarly, as means of reducing the impact of nutrients and pollutants on the Lagoon directly from the Urban and Rural areas..

3.2 Methods & Approach

Freshwater springs: The Lagoon was divided into four main Sectors for the survey of springs (Figure 12), adopting the approach from a previous study (*13*) 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. The Fresh Water Springs were originally identified from previous consultancies, in 2015, with Town Officers, District Officers and some members from each community.

Figure 12: Fresh Water Springs surveyed at 4 Sectors of Fanga'uta Lagoon (Source GIS, MLSNR)

Hydrodynamic Discharge

The main objective of this activity was to survey and map the location of Fresh water springs, identify their Heritage values by consultancy with Town and District Officers, measure the amount of discharge, and make recommendations for improvements of fresh water springs. Every Fresh Water Springs at the Lagoon were identified and mapped, basically 24 of them were thoroughly surveyed to determine the amount of fresh water that had been discharged hourly to the Lagoon, during low tide. The GIS Sector assumed that if improvement is made to these springs, the amount of fresh water that discharged daily into the Lagoon could contribute significantly to the improved water quality of the Lagoon.

A GeoXH GNSS (GPS) set was used for collection of the Lat/Long locations of the Springs, then GNSS data was

downloaded into ArcGIS software for processing and mapping. The discharge at each water spring was calculated by using the formula:

D (Discharge) = V (Velocity) x A (Area)

V (Velocity in m^3) = d (distance/t (time))

A (Area at the entrance) = W (Width) x D (Depth of water)

A plastic measuring tape and stop-watch were also used for measuring the velocity of the water flow (Figure 13). Since the survey must be done during the low tide, a Tide Calendar was also included in equipment required for the survey.

Figure 13: Diagram of how water discharge was measured

Land-use Zoning

The method used for gathering information for Land Use Plan Zoning was a one-on-one consultancy with key personnel from relevant stakeholders. This method was found to be more effective rather than organising a one day workshop with so many participants involved.

The consultancy with the Line Ministries, as well as the Key Stakeholders was a great triumph. Similarly, professional advices from key stakeholders for means of reducing the impact of nutrients and pollutants on the Lagoon had a great influence on the success of creating the Land Use Plan Zoning of the FL Catchment area.

Figure 14: Consultations with key stakeholders

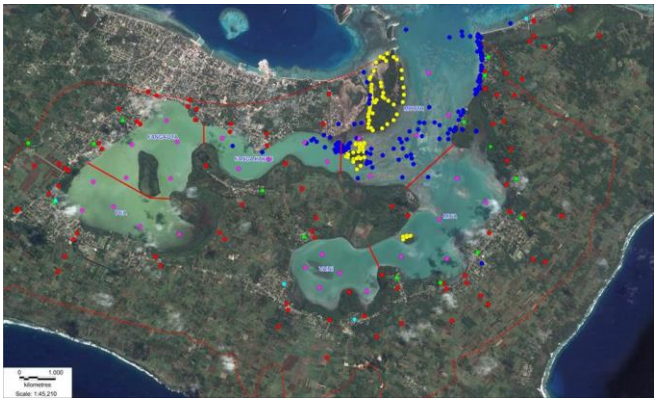
Soils

Soil sampling was done using sampling forms, a Geographical Positioning System apparatus (GPS), tax allotment map, soil-type map, spade, zip-lock plastic bags and permanent marker pen. After the location was determined, the following information was recorded:

- The location and elevation recorded with the GPS and the vegetation, crops, trees and other features recorded. The tax allotment number and the soil type were identified with the respective official maps;
- Soil cores of 15-20 cm deep were dug with the spade and a vertical slice of the soil taken. In a criss-cross pattern about 20 to 30 soils cores were taken at regular intervals over about 2 acres as a representative sample of the area;
- The soil cores were then pooled and mixed thoroughly in a plastic bag and then a sub sampled to extract about 1.5-2 kg of soil into zip-lock plastic bags and labelled using a marker pen; and
- The sample was then transferred to the soil laboratory for further processing.

A total of 99 soil samples were taken as depicted by the red color dots in Figure 15 below.

Figure 15:The location of soil samples in red dots



At the laboratory, the soil samples were placed in aluminium trays. Plant materials, rocks and non-soil particles were removed from the soil sample. The soil samples were then air dried with a fan for about 4 days. The soil was then ground with a mortar and pestle and sieved at 2 mm. This resulted in a sample of about 200 g as the representative for one location.

Due to the budget constraints, only 53 soil samples were selected for chemical analysis. The analyses carried out focused on heavy metals, organo-chlorines and organo-phosphate pesticides. The selection of the 53 samples were distributed as: 18 samples from residential areas (7 urban and 11 rural areas); 4 samples from industrial sites (timber treatment plant, small industries, transformer storage site); 31 samples from agricultural areas (1 primary forest site, 1 secondary forestry sites, 1 shrub vegetation, 4 grass fallow, 14 food crops farms, 1 cattle ranch, 1 vegetable farm and 8 squash farms).

As there were no positive results in the first test for pesticides residues, a second batch of 10 soil samples was sent for re-analysis. The aim was to investigate an alternative process for the quarantine process at the Australian Quarantine Bio-security Pathway treatment for foreign soil samples. The Australian process requires that samples are dry heat treated at 160°C for 2 hours (if the sample does not exceed 500 g in weight); or heat

treated in an autoclave at 121°C and a pressure of 15 psi for 30 minutes; or heat treated in an autoclave at 134°C at 15 psi for 4 minutes; or gamma irradiated at 50 kGray. Therefore, the second soil samples were treated with gamma irradiation in the hope that the Australian treatment would not affect traces of pesticide residue, if any, on the soil samples.

The samples were analysed by Professor Ravi Naidu[3] of the University of Newcastle Australia. The professor and Dr Mohammad Mahmudur Rahman[4] and Dr Yanju Liu[5] guided the preparations of the soil samples, provision of quarantine documents and the chemical analyses of the samples. These chemical analyses were done for 7 heavy metals (As, Cd, Cr, Cu, Ni, Pb, Zn), and for residues of 14 organo-chlorine pesticides and other metabolites and 19 organo-phosphate pesticides.

Mangroves

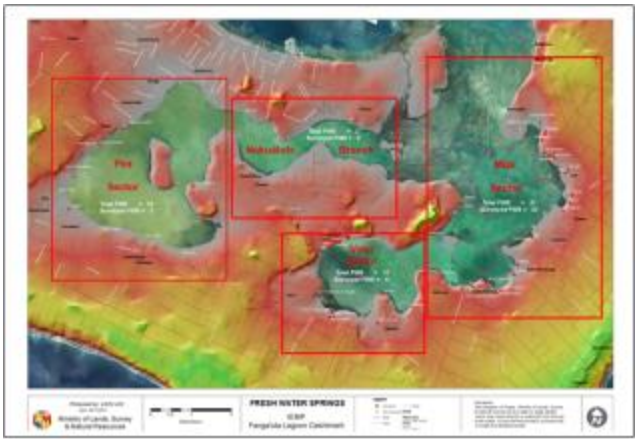
For mangrove surveys the main methods used were centred on community consultation during the implementation stage, satellite imagery and ground toothing of mangroves coverage, and photo taking while field assessment on different hot spots in the lagoon area.

3.3 Results: Status of the Coastal Environment

Freshwater Springs and bores

The GIS Team primarily aimed to survey more than 24 Fresh Water Springs within two weeks (of those identified in 2015, Figure 16) but due to unforeseen issues such as wet weather conditions and variation of tide timetable from that of actual Lagoon tide, simply 22 FWS were managed to be surveyed within a three week timeframe.

Figure 16: Fresh Water Springs identified in 2015
(Source – GIS, MLSNR)



The discharge for most of the springs was greater than from that of the 2015 survey, probably, due to greater amount of underground water storage resulted from heavy rainfalls in the previous weeks.

Some of the freshwater springs (FWS) could not be measured because:

- The FWS was buried under silt
- Rock fall at the opening of the Spring: Photos 2 & 3
- It was fairly high tide at the time of survey

Figure 17: Vai a Fafine – Vai a Tangata at Vaini during 2015 survey

Figure 18: Vai a Fafaine – Vai a Tangata at Vaini during 2016 survey

Soil and landuse Zoning

Urban Areas

From previous studies of the status of the lagoon, it was found that majority of nutrients, heavy metals and sediments flowing into the lagoon from Urban Areas via storm water and road drainage were originally from households and developments around the lagoon as shown in Figure 19 below.

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[5]Research Fellow, Global Centre for Environmental Remediation (GCER), Faculty of Science and Information Technology, University of Newcastle University, University Drive,| Callaghan NSW 2308 | Australia. Tel: 612 4913 8738 Mobile: 614 425 716 579 Email: yanju.liu@newcastle.edu.au and Web: www.newcastle.edu.au

Figure 19: Shows possible Direction of flow of nutrients to the Lagoon from heavily populated Nuku'alofa Urban Areas (source: GIS,MLSNR 2016)

Mechanisms of Pollution Flow to the Lagoon

In regards to professional advices from key stakeholders during consultancy phases of this activity, for means of reducing the impact of nutrients and pollutants on the Lagoon, the team visited crucial sites such as permanent ponds at low-lying areas, unused rock quarries, Drainage Outlets, roaming pigs, etc.

Urban Areas

During field inspection of Urban areas, it was found that means of flow of pollution to the Lagoon were probably from three sources, basically; i. Surface Runoffs, ii. Overflows from permanent polluted Swamps and old Rock Quarries, and iii. from Road Drainage Outlets, as shown in photos below.

All road drainage systems at southern residential areas of Nuku'alofa such as Tofoa, Haveluloto, Fanaga o Pilolevu, Pahu, and Halaleva, are currently drained directly to the Lagoon (Figure 20).

Other possible sources of pollution flow to the lagoon are overflows from permanent polluted stagnant swamps and old rock Quarries as shown below in Figure 21.

Pigs kept at areas around the lagoon are either penned in whilst wastes are drained directly into the lagoon or they are left to roam freely thus damaging the low-lying areas around the lagoon.

Figure 20: Draingage outlets at Fanga o Pilolevu (left) and Pahu (right)

Figure 21: Other sources of pollution flow

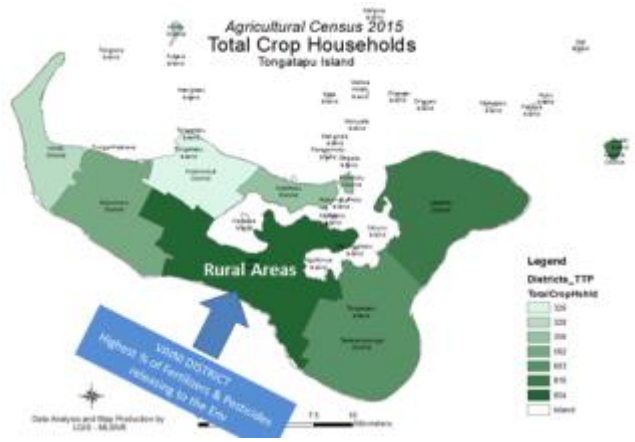
Top left: Swamp at Ngeleia; Top right: 'Ananaa; Bottom left: Low area at Old Pili Quarry; Bottom right: Pig damage

Rural Areas

Data from the 2015 Tonga National Agricultural Census, indicated that highest percentage of total household crops revealed in the survey were found mainly in the Vaini District as shown in Figure 22 below.

Figure 22: Data from Agricultural Census 2015

(Source: GIS, MLSNR 2016)



The map above show that the highest percentage of total household crops from the survey were found in the Vaini District, as a result, the highest percentage of agricultural chemicals such as pesticides and agricultural fertilizers used by commercial farms and released into the Fanga'uta Lagoon via soil erosion and runoffs were from this central District of Tongatapu. It was also found that Village households and village pore holes were riskily located in the immediate vicinity of farmlands.

Soil Survey for Pesticide Residues & Heavy Metal Pollution

During the last 20 years, the intensification of agriculture in Tonga for food production and the increased crop production for local and export markets has led to increased land degradation and environment pollution. Surrounding the lagoon in Tongatapu, the farms and villages are on land that is gently sloping towards the lagoon. The tilting of the highly porous limestone aquifer towards the lagoon, with the natural outflow of groundwater increase the vulnerability of the lagoon to

contamination with farming's fertilizer and pesticides that have leached through the soils of agriculture fields. Only a few studies, have reported of pollution of agricultural soils with the increasing use of fertilizer and pesticides. In 2000, Morrison analyzed 3 soil samples from agriculture fields for *Carbaryl, Chlorfuazuron, Dimethoate* and *Flusilazole* and the analysis found traces of *Carbaryl* residue in one soil of the sample (*14*). In 2006, van der Velde reported traces of a wide range of pesticides such as *DDT* and metabolites, *Myclobutanil, Dichloran, Deltamethrin, Terbufos, Cyfluthrin, Cyanazine, Permethrin, Terbumenton* and *Tetradifon* in soils from fields repeatedly cultivated with squash in Tufumahina, Lafalafa and Vaini (*15*).

The objective of this field survey is to: first, to establish the chemical profiles of agri-chemical pollutants in various land-use in the Ridge to Reef project area ranging from undisturbed forest, secondary forest, cropped land in traditional, semi-intensive to very intensive agriculture lands, industrial areas and rural and urban residential area from the rural areas of Manuka to the urban area of Nuku'alofa and suburbs.

Soil of the Catchment Area

The major soils of Tonga for agriculture are derived from several deposits of volcanic ash from volcanoes in the western side. Two main phases of distinct deposition of soil of a younger volcanic ash of reddish brown (5,000 yrs) on top of an older volcanic ash soil of browner yellowish color (20,000 yrs). The soils are classified according to New Zealand Soil Classification as *Typic Hapludoll/Argiudoll*, very fine *halloysitic, isohyperthermic (16)*. As a result, *Halloysite* is the dominant clay mineral of more than 90%. Subsequently, the younger volcanic ash soils are much more fertile with it's higher amount of nutrient 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 western sides decreasing down to less than 0.5 meter in the eastern side. The iron oxide in the soil aid in aggregation, and also gives the soil it's reddish colour but unfortunately it also chemically bind the phosphate fertilizer applied rendering the applied phosphate minerals unavailable to uptake by plant roots.

The Ridge to Reef project area covers farming area and villages from Manuka in the north eastern side of Tongatapu down to Vaini and to Ha'ateiho in the south and Havelu to the west and to the Nuku'alofa eastern surburb of 'Anana in the north. The project land area has different soil types as depicted in Figure 1 and described in Table 1 below. The soil types ranges 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 correlates very well with the current land-use and existing vegetation with the exception of the urban expansion of the residential zones.

Figure 23: Soil types of land sloping towards the Lagoon

These are 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)

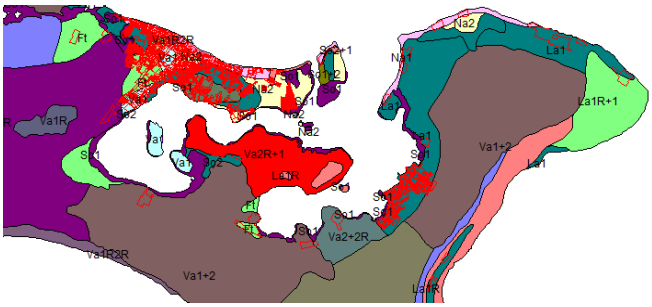


Table 1: The soil type codes used, including descriptions and notes

SoilTypeCode	Description	Notes
Fh	Fahefa Soil	Soils with the younger volcanic ash soils greater than 1 meter thick.
FhR	Fahefa soil, rolling phase	Fahefa soils on 3 to 12 degree slope land
Ft	Fatai soil	Low-lying soils from thick younger over older volcanic ash or re-wash volcanic ash where water level is high during wet season
La1	Lapaha soil	Soils with the younger volcanic ash soils of about 0.3 meter thick
Na1	Nuku'alofa soil	Soils on undulating beach and dune ridges
Na2	Nuku'alofa soil, sandy loam phase	Nuku'alofa soils on older beach ridges
So1	Sopu soil	Low lying soils from coral sand mixed with peat and finer textured materials and periodically flooded by high tides
So2	Sopu soil, peaty sandy loam phase	Sopu soils with poor and imperfect drainage with high saline groundwater but not flooded.
Va1	Vaini soil	Younger volcanic ash soils of 0.6 to 1.0 meter thick
Va1R	Vaini soil, rolling phase	Vaini soils on 3 to 12 degree slope land
Va2	Vaini soil, shallow phase	Vaini soils with 40 to 60 centimeter thick of younger volcanic ash soils
Va2R	Vaini soil, shallow and rolling phase	Vaini soils with 0.4 to 0.6 meter thick of younger volcanic ash soils and on 3 to 12 degree slope land

Sampling of Soil from the Project Area

The sampling strategy are: first, the sampling is representative of all the different land use in the Ridge to Reef project area undisturbed forest, secondary forest, cropped land in traditional, semi-intensive to very intensive agriculture lands, industrial areas and rural and urban residential areas from the village of Manuka to the capital Nuku'alofa. The range chemicals projected to be loaded into the soil of the project area are : first, fertilizer and pesticides (especially herbicides *paraquat* and *glyphosate*, etc. weed control in farming and of offices, airports, infrastructures as well as residential homes); industrial chemicals (Tonga Forest Products Ltd "Tanalith C Oxide" for timber treatments, Tonga Power Ltd "Transformer's POP's residues, etc.,", Mechanical Workshops "Oil and fuel waste products"; Residential areas (general household pesticides including rodenticides, Bleaching and detergent chemicals, paint and other domestic chemicals, etc.).

Arsenic (As)

The concentration of Arsenic in the 63 soil samples ranged from zero to 255 mg Arsenic per kilogram of dry soil. This result is highest in the samples from Tonga Forest Products, indicating that the Copper-Chromium-Arsenic chemicals used for treating timber are polluting the area. The primary forest site had zero Arsenic as the natural state. The next highest group of samples ranged from 5-34 mg Arsenic per kilogram of dry soil sample, with the highest observed value in the town rubbish dump site, the small industry site and the town residential sites with a few farms. However, the majority of the farming sites for squash and food crops were found to have zero detectable Arsenic. The international regulatory limit is 40 mg of Arsenic per kilogram of soil (Table 2). These results indicate a strong likelihood of the main sources coming from wood preservative chemicals, pesticides, veterinary drugs, industrial chemicals, etc. In

2015, Kwon and Lee reported high levels of Arsenic on the coastal sediments from Kolovai (dumpsite nearby) and the main Queen Salote wharf area and lagoon sediments from Hoi and Lapaha of Tongatapu (*17*).

Table 2. The range of heavy metals in the 63 soils samples analyzed, Primary Forest and the international Regulatory Limits

Heavy Metal	63 Soil Samples	Primary Forest	Regulatory Limits[7]
	milligram per kilogram dry soil		
Arsenic (As)	<5 - 255	<5	40
Cadmium (Cd)	<1.0 - 3.0	2	1.00-3.00
Chromium (Cr)	5 - 171	30	150
Copper (Cu)	13 - 492	210	50-100
Nickel (Ni)	<5 - 297	7	1-100
Lead (Pb)	<2 - 29	11	100-400
Zinc (Zn)	21 - 1620	123	20-300

Cadmium (Cd)

The concentration of Cadmium in the 63 soil samples ranged from zero to 3 mg kilogram of dry soil. The highest values were found at the town rubbish dump site, the majority of the squash farm sites, vegetable farms, industrial sites, and town sites. Most of the farms focused on food crops and scrubland vegetation were found to have zero Cadmium. Surprisingly, the primary forest site was at the high range of 2 mg/kg of dry soil. However, the primary forest site is surrounded by squash farms with probable pollution from the drift of dust related to the application of fertilizers. The international regulatory limit is 1-3 mg Cadmium per kilogram. However, this result indicates that Cadmium pollution from man-made sources of phosphate fertilizers, paints, colour pigments, plastic stabilizers, electronics and electro-plates is an issue.

Chromium (Cr)

The concentration of Chromium in the 63 soil samples ranged from 5-171 mg per kg of dry soil. This level was highest for the Tonga Forest Products site, with a reading of 171 mg/kg, suggesting the Copper-Chromium-Arsenic chemical used for treating timber as the source. The primary forest site had 30 mg/kg of Chromium as the 'natural' site. The international regulatory limit is 150 mg Chromium per kg of soil. These results show no pattern and the occurrence of Chromium is similar from industrial sites, town residential areas, farms (food crops, vegetables and squash). In 2015, Kwon and Lee reported high levels of Chromium on the coastal sediment from the main Queen Salote wharf area of Tongatapu (*17*).

Copper (Cu)

The concentration of Copper in the 63 soil samples ranged from 13-492 mg/kg of dry soil. The international regulatory limit is 50-100 mg/kg, indicating high levels. The highest values were found at the town rubbish dump, followed by sites from town, shrub vegetation, the Tonga Forest Products site, vegetable farms, industrial sites. There was no real pattern of concentration of Copper in relation to landuse, and surprisingly, the primary forest site was found to be at the high end of the range at 200 mg/kg. This site is surrounded by squash farms with probable pollution from the drift of spray application of pesticides. However, the result indicates that there is significant Copper pollution from man-made sources, including use of Copper-Chromium-Arsenic chemicals, fungicides, fertilizers, electronics, electric wires, pipes and other sources. In 2015, Kwon and Lee reported high levels of Copper on the coastal sediments from Fatai and the main Queen Salote wharf area and 2 lagoon sediments from Malapo of Tongatapu (*17*).

Nickel (Ni)

The concentration of Nickel in the 63 soil samples ranged from zero to 297 mg/kg of dry soil. The primary forest site had around 7 mg/kg of dry soil. The international regulatory limit is 1-100 mg/kg of Nickel. The highest values were mostly found in town sites and the town rubbish dumps. However, this result indicates that Nickel pollution from man-made sources such as batteries, kitchen appliances, surgical instruments, etc are significant in Fanga'uta. In 2015, Kwon and Lee reported high levels of Nickel in coastal sediments from the main Queen Salote wharf area of Tongatapu (*17*).

Lead (Pb)

The concentration of Lead in the 63 soil samples ranged from zero to 29 mg/kg of dry soil. The primary forest site was had 11 mg/kg of Lead and the international regulatory limit is 100-400 mg/kg, indicating the Lead values are generally not of concern. The highest value recorded at the town rubbish dump site, town, and other town sites were well-below the recognised limits. In 2015, Kwon and Lee reported high levels of Lead on the coastal sediments from the main Queen Salote wharf area and then at the ex-dumpsite of Nuku'alofa close to Patangata and Fatai of Tongatapu.

Zinc (Zn)

The concentration of Zinc in the 63 soil samples ranged from 21-1620 mg/kg of dry soil. The primary forest site had 123 mg/kg dry soil, and the international regulatory limit is 20-300 mg/kg of Zinc, indicating that there is some elevation in levels at some sites. The highest recorded Zinc level was found at the town rubbish dump site, where it was twice the level of the next-closest value. The results indicate that Zinc pollution from man-made sources of metal plating and refineries is significant. In 2015, Kwon and Lee reported high levels of Zinc on the coastal sediments from Kolovai (dumpsite nearby) and the main Queen Salote wharf area of Tongatapu.

Pesticide Residues

The results of analysis of Organo-chlorine and Organo-phosphorus pesticides were all below detection limits and no significant traces of pesticides were found in any of the soil samples. The results of the analysis for pesticide residues in the 63 soil samples is shown in Table 3 and Table 4 below. For the time being there is no concern for the levels of pesticides in soils.

Table 3. The Organo-chlorine Pesticides residues content for 63 soil samples analysed.

Organo-Chlorine Pesticides	Detection Limit (mg/kg)	63 Soil samples (mg/kg)
alpha-BHC	0.05	<0.05
Hexachlorobenzene (HCB)	0.05	<0.05
beta-BHC	0.05	<0.05
gamma-BHC	0.05	<0.05
delta-BHC	0.05	<0.05
Heptachlor	0.05	<0.05
Aldrin	0.05	<0.05
Heptachlor epoxide	0.05	<0.05
total Chlordane (sum)	1.05	<0.06
trans-Chlordane	0.05	<0.05
alpha-Endosulfan	0.05	<0.05
cis-Chlordane	0.05	<0.05
Dieldrin	0.05	<0.05
4.4`-DDE	0.05	<0.05
Endrin	0.05	<0.05
beta-Endosulfan	0.05	<0.05
Endosulfan (sum)	0.05	<0.05
4.4`-DDD	0.05	<0.05
Endrin aldehyde	0.05	<0.05
Endosulfan sulfate	0.05	<0.05
4.4`-DDT	0.2	<0.2
Endrin ketone	0.05	<0.05
Methoxychlor	0.2	<0.2
Sum of Aldrin + Dieldrin	0.05	<0.05
Sum of DDD + DDE	0.05	<0.05

Table 4. The Organo-Pohosphorus Pesticdes residues content of the 63 soil samples analyzed

Organo-Phosphorus Pesticides	Detection Limit (mg/kg)	63 Soil samples (mg/kg)
Dichlorvos	0.05	<0.05
Demeton-S-methyl	0.05	<0.05
Monocrotophos	0.2	<0.2
Dimethoate	0.05	<0.05
Diazinon	0.05	<0.05
Chlorpyrifos-methyl	0.05	<0.05
Parathion-methyl	0.2	<0.2
Malathion	0.05	<0.05
Fenthion	0.05	<0.05
Chlorpyrifos	0.05	<0.05
Parathion	0.2	<0.2
Pirimphos-ethyl	0.05	<0.05
Chlorfenvinphos	0.05	<0.05
Bromophos-ethyl	0.05	<0.05
Fenamiphos	0.05	<0.05
Prothiofos	0.05	<0.05
Ethion	0.05	<0.05
Carbophenothion	0.05	<0.05
Azinphos Methyl	0.05	<0.05

Coastal & Terrestrial Vegetation

The Forestry Department of the Ministry of Agriculture was responsible in leading this activity for the year. It mainly focused on distribution of seedlings to the various communities surrounding the catchment area of Fanga'uta and to education institutions as a follow up on the survey carried out in 2015. There were no new surveying sites but mainly that to areas of which new seedlings were distributed to in order to meet the quota of improving vegetation cover of 50 hectares. Therefore this section is mainly to inform the result of that work.

Although 26 communities were engaged in the tree planting activities from 2015-2016 during tree planting campaign, 7 of those communities were monitored consistently to see progress of the program. They are Makaunga, Longoteme, Folaha, Hoi, Nukuleka, Popua and Navutoka that were progressively followed up in 2016 shown in Figure 22 below. The remaining villages are scheduled to follow after the initial monitoring of the program.

Figure 24: Communities piloted for tree planting activities and monitored

Prior to the distribution of the seedlings there were series of trainings and consultations carried out to inform the communities of best practises to ensure high survival rate of the seedlings distributed.

The variety of seedlings distributed to town allotment was of sandalwood, cultural trees, ornamental, fruit trees and whilst coconut trees were distributed to tax allotments. This mainly address the need of communities for increasing tree crop that preserve cultural tree species, establish food security with sustained livelihoods in places.

There were about 1765 seedlings distributed to town allotments of the 7 communities of which more than 55% of these seedlings survived even during the dry period in 2016. Whilst at the tax allotments there were 1800 coconut seedlings distributed with 1725 seeds planted over a total area of 29 acres.

There are about 26 schools that have received seedlings from the program of which over 3000 seedlings have received this assistance from the program. Due to the regular follow up within the school program to monitor their own mini-projects of tree planting activities the monitoring of these seedlings was not included for the year under the Forestry monitoring activity but it will be followed through in the coming year.

Challenges: Coconut trees has been one of the targeted tree crop for mass replanting in Tonga, mainly there is a huge declining rate of coconuts in Tongatapu due to increased consumption and no replanting. In meeting

both the goal for the project and that of national priority under the Forestry Sector, it is envisioned that the program will assist with the interested communities on this activity.

As a result in monitoring the communities currently engaged from the catchment in the replanting activity, the following trend of issues is identified:

- Areas not fenced are prone to damage from free range pigs still left untended to at some of the villages
- Seedlings distributed are not all planted or if do they are not properly looked after
- The need for consumption of coconuts is greater than that for planting due to low availability of coconuts in the island
- Inconsistency of applying lessons learnt from the training to actual planting – mainly different people attend and different people plant and therefore noted plants are planted together with polythene bags,

It is observed that if communities in Tonga are not actively responsible in replanting coconut trees at their own tax allotment in less than 10 years Tonga will be deprived greatly of abundance of coconut fruit trees, as noted there is increased low supply of available fruits in the island.

Mangroves

Mangroves remained the first line of defence of the coastal areas from the adverse impacts of sea level rise, seasonal storm surge and coastal protection. The healthy states of Fanga'uta Lagoon much depended on the land-based of the 55% of the Tongatapu population. A well-established mangrove along the lagoon margin will mitigate any threats from natural forces and act as a strainer to filter additional nutrients from nearby communities. Mangroves also trapped solid waste from entering the lagoon and floating further to the open sea.

During the reporting period mangrove areas are declining due to natural causes and worsen by latter developments mainly clearing, dredging and reclamation without the proper legal procedures before it is carried out.

Mangrove component of the project effectively completed the building of a nursery at Popua thrived with a capacity of over 6000 pots mainly with Pb12 and Pb10 pot size.

Implementation of restoration works with replanting of nursery seedlings started in selected sites on Longoteme, Holonga, and Talasiu.

The mangrove team with assistance from seven communities (Popua, Longoteme, Nukuhetulu, Holonga, Lapaha, Talasiu, Hoi) successfully constructed a nursery (30m×20m) enriched with species of *Rhizophora samoensis, Rhizophora styloza, Exoecaria agallocha* and *Xylocarpus granatum*. Substrates for seedling pots were collected from proposed replanting sites. Propagules and seedlings were collected from several stations around the lagoon mainly Nukuhetulu.

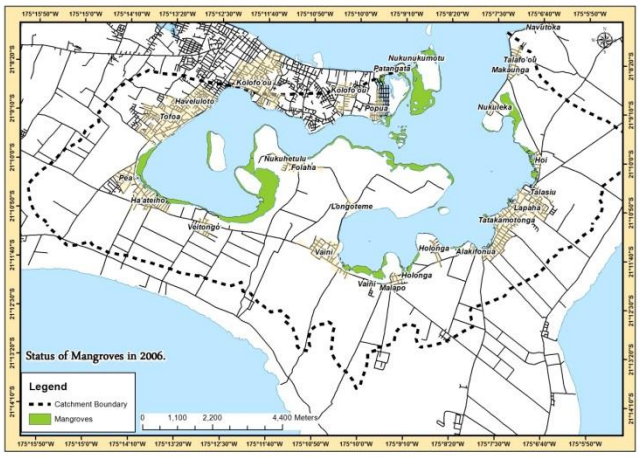
The only exception was the collection of 590 wild seedlings of *Xylocarpus granatum* from different locations of Vava'u mainly Ofu and Olo'ua, Okoa and Makave where bulk of the remaining stock left in Tonga.

In the last quarter the field team started with replanting on three different sites (see map below) proposed by the communities of Longoteme, Holonga, and Talasiu

In 2016 GIS Unit assisted with provision of satellite image to inform the spatial distribution of mangroves in comparison to date at Fanga'uta Lagoon catchment. They were able to provide the satellite imagery comparative to 2006 from 2016 to confirm status of spatial distribution.

Figure 25: Mangrove distribution in Fanga'uta

Data are from 2006 with total extent of 4176883.6 square meters. (GIS Unit, MLNRS)



In the provided map, it advised that Fanga'uta Lagoon has about 417.69 ha of mangroves on sites. Nukuhetulu area is comprised of one of the oldest mangroves in the Pacific comprising of about 330 ha, that is about 79% of mangroves coverage at the lagoon approximately.

Due to the size of this mangroves sites and the numerous issues faced by this area and the limited timeframe the project is to implement, this was not one of the sites for replanting identified due to land issues of which most of the allocated mangroves covers is already assigned lands to be leased. It is estimated that there is about 87.7 ha of mangroves will be affected due to land issues but it is already with a deteriorating mangroves coverage of 14 ha thus far and still increasing at an accelerating level due to multiples issues of interrupted tidal flow with water flushing to the area and high consumption of mangroves by the neighbouring communities.

Figure 26: Distribution of mangroves in 2016

The total extent of in 2016 was 3300265.7 square meters whereas the area assumed to be affected is 876617.9 square meters ((GIS Unit, MLNRS)

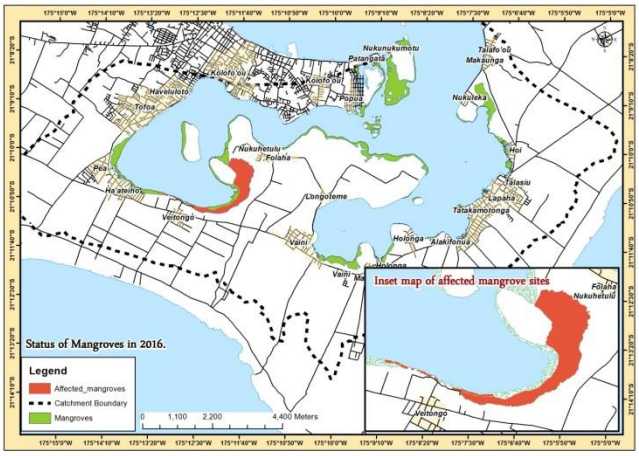
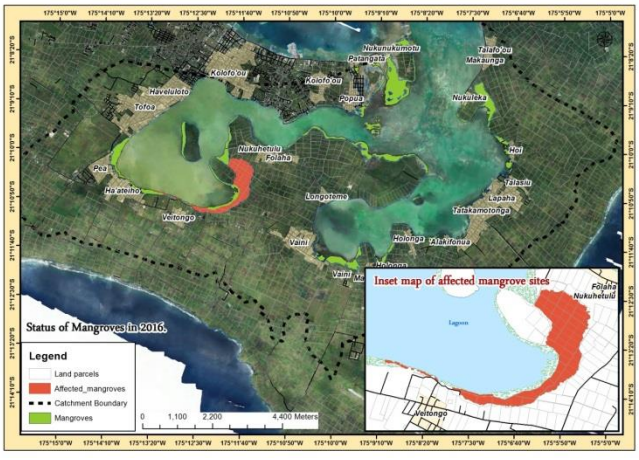


Figure 27: Overlay of subdivisions on mangrove lands

These were undertaken against the mangrove ecosystem around Fangaúta Lagoon Catchment area. GIS Unit, MLNRS)

Figure 28: Satellite imagery as backdrop to ground-truthing

This shows the spatial distribution of mangrove ecosystem over Fangaúta lagoon catchment in 2016. (GIS Unit, MLNRS)



Status at Restoration Sites

During the reporting period several development activities around the mangrove areas of the lagoon have resulted in environmental damage through clearing, dredging and reclamation for different purposes. Any alteration of natural balance either by nature or human will upset the growth and functions of mangrove ecosystems. Within the last 12 months human interventions on lagoon ecosystems.

Figure 29: Development at Popua as Government Park

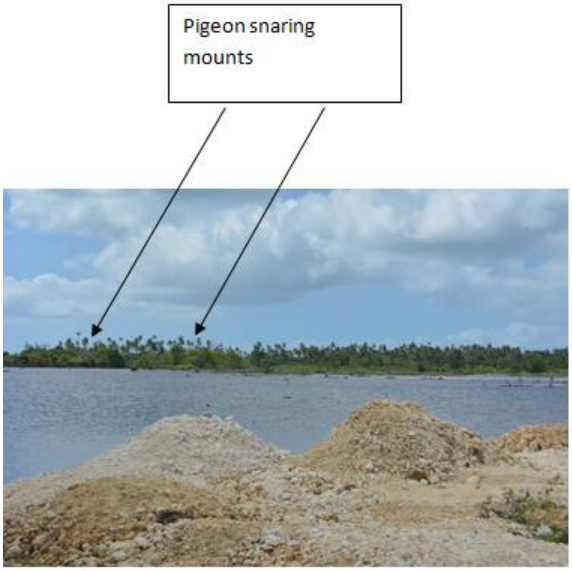
(Photo by Iliesa Tora)

On-going reclaiming of wetlands around the Lagoon margins also poses threats to the immediate mangrove ecosystems, wildlife, and livelihoods of nearby communities.

Part of the dredging area and the proposed Government golf course for the 2019 Pacific Games targeting the area proved to be the main feeding and roosting location for most of bird's species around Fanga'uta Lagoon(see Map below). The historical pigeon snaring mounts in the area (Finepani) are vital homes for these birds. Reclamation and dredging are key threats (Butler: 2016)

Figure 30: A more recent reclaimed area at Popua

This shows the adjacent pigeon snaring mounts, strip of forests (at background) as key roosting and habitats for birds of Fanga'uta. (Photo By Iliesa Tora)



The mudflats and sandflats adjacent to the Popua settlement were identified as a key feeding and roosting site for many of the species. Mangroves, mudflats exposed at low tide and rocky islands were also significant habitats for birds. Direct threats to these areas were identified, the most significant being the ongoing reclamation at Popua for approved housing development.

Figure 31: Reclaimed lands blocked tidal flow

This lead to high mortality of natural regeneration and increase water level in one of the proposed replanting site at Popua. (Photo by Iliesa Tora)

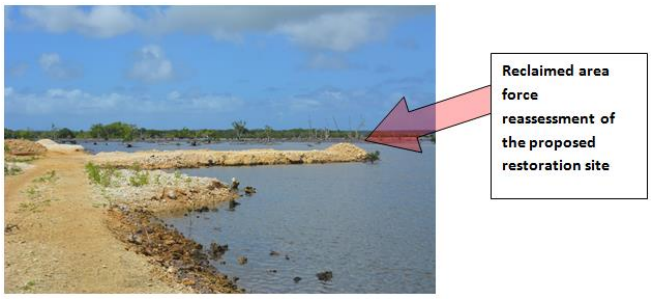


Table 5. Current stock at Popua and Ma'ufanga nurseries

Species	No. of survival	Observations
Rhizophora samoensis (Potted in Pb 12 plastics bags)	890	*R.samoensis* species withstand prolonged dry period and absence of fresh water***.
Rhizophora stylosa (potted in Pb 10 plastics)	689	*R. stylosa* suffered minor shocks due to dry weather and lack of fresh water***.
R. samoensis (direct planting in 3's for later transplanting using metal corer)	3678	Direct planting of propagules adapted seedling well to surrounding substrates and flourish well compared to potted seedlings.
Total	**5257**	
Excoecaria agallocha	646	Easily access to nursery compared to Popua proved to be an advantage for daily tending and watering of these species resulted in high survival rate.
Xylocarpus granatum	136	
Rhizophora samoensis	155	
Total	**937**	

*** Poor quality shade nets to a windy and open area with high insolation caused early breakdown. A good quality net will raise the survival rate for the open Popua Nursery.

Part of the seedlings mainly *E. agallocha* and *X. granatum* are under the custody of the Team Leader due to the prolonged dry summer weather for wary watering and other nursery upkeep(see photo below) with few trial pots of *Lumnitzera littorea* and *Bruguiera gymnorhiza*.

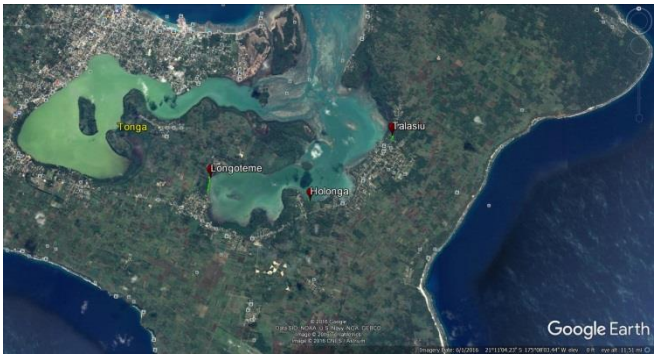
As a precondition for all restoration activities site preparation must include collection of solid, hazardous and bulky wastes from all proposed sites. A special training on waste characterization for some of the replanting areas was conducted at the Tapuhia Landfill. The objectives of the onsite training based on raising the awareness of solid wastes in the environment and to familiarize the opposing impacts of individual wastes to the lagoon ecosystems and human lives.

Fifty five participants consisted of mixed representation mainly by women's' group, youth groups and few male representatives. Bulk of the waste collected was from coastal households in the proximity of replanting sites.

Demand for the conservation of existing genetic stock and recovering of rare mangroves mainly Xylocarpus species led the team travel north to the Vava'u Group where most of the remaining stands distributed to collect seeds to nurse for replanting purpose only. The early stormy season steered the early fall off of seeds incapacitate the collection of seeds instead team collected 590 saplings.

Time for replanting approaching in early summer months of October so sites preparation started with Holonga, Talasiu, and Longoteme villages. Map below indicates the locations of the pioneer villages.

Figure 30: The three pioneer replanting sites of Longoteme, Holonga and Talasiu. Map by Google Earth.



Holonga Restoration Site

The proposed area in Holonga are among the most well protected area, meters away from the settlement area with mixed vegetation of *Exoecaria agallocha*, few *Rhizophora samoensis*, mangrove associates such as *Vitex trifolia, Thepesia populnea, Cebera manghas, Hibiscus tiliaceus, Morinda citrifolia, Inocarpus fagifer* and mixed forest mainly of *Bischofia javanica*, *Rhus taitensis* and *Cocos nucifera*.

Lessons learned from past replanting programs failures reflect that land ownership is always an issue to settle before any ground work start. With help of the Town Officer and the two sole ownerships of tax allotments covered in the replanting supports to continue.

The replanting area extends 186 meters along the northern coast ranging from 10 – 20 meters to the seaward side. With the assistance of field officers, local labourers and community leaders they provide the in-kind contributions like supplying of 230 wooden posts while PMU provide the chain-link galvanized mesh wire for the fence work. A total of 219 mangroves seedlings of Exoecaria agallocha (107), Xylocarpus granatum (97) and Rhizophora samoensis (15) was planted after fencing work to the mangroves sites.

Longoteme Replanting Site

The replanting of the proposed area at Longoteme is an exceptional case study of all the replanting programs due to several factors:

- The roadside area is a government property and public are free to use the beach for picnic fishing and other recreational purposes;
- The field team with assistance of community youths collected 8 full pick – up truckload of solid waste mainly plastics, foam, leather and textiles averaging 25 bags per load (25kg flour bags) from the area of 2000 square meters (200m×10m). Trapped of these huge waste is due mainly to facing the southeast trade wind;
- The team planted 150 seedlings of *Rhizophora samoensis* as the dominant species at the site;
- The southern trade winds have eroded the barren northern part of the proposed area causing strong impact which might affect replanting programs; and
- There was evidence of weedicide application in the area 3 to 5 meters to the roadside.

The field team with the above mentioned reason insisted that replanting on an open public area like Longoteme would not be survived. Managing environmental initiative of this sort will stay as an obstacle in the future.

The 200 metre strip of mangrove along the coast consists mixed coastal vegetation dominantly by *Hibiscus tiliaceus Exoecaria agallocha* and *Rhizophora samoensis*. Few *Baringtonia asiatica* and *Pandanus tectorius are a*lso present at the site at very low numbers.

The team planted 135 seedlings of *R. samoensis* on random open spaces along the beach.

Talasiu Replanting Site

This area has a single owner who supported the replanting effort with assistance from the Town Officer and youth. The community also supplied the wooden posts for the fence work. The area (in light green) extends to 167 meters (from north to south) with 5 to 15 meters from the high water mark.

Vegetation cover is dominated by *Hibiscus tiliaceus, Vitex trifolia, Santalum yasi, Cordia subcordata and Planchonella grayana.* The mangrove species planted included *Xylocarpu granatum, Exoecaria agallocha, and Rhizophora samoensis.* The team planted 216 seedlings of *R. samoensis (53), Exoecaria agallocha (85) and X. granatum (78) along the fenced area.*

Several issues arose at this site:

- In the following weeks after planting of seedlings the problem that emerged from below the mud was the complete cutting of seedlings by the *Cardisoma guanhumi* crabs (tupa). After several replacements of the seedlings (mostly *E. agallocha and X. granatum)* from the crab damage, the team invented an inexpensive 'method of wooden box' to protect the seedlings. This involved the placement of stakes around the young trees to a height of 1.5 feet. The practice was needed for 1-2 weeks before the seedlings adapted in the new territory.
- The summer heat also burned seedlings, requiring numerous replacements. A lack of fresh water supply and low tide level also damage seedlings.

Waste Management Awareness Programmes

To address the issue of waste at the catchment for 2016, two main awareness programs for schools were focused on. In addition, a clean-up campaign was organised for the surrounding communities of Fanga'uta.

The Fanga'uta Catchment Ridge to Reef Project integrated efforts with relevant line Ministries to develop and implement awareness programme to about 25 primary schools around the villages at the lagoon. This programme concentrated on waste as the main issue that caused health problems to people living at villages around the Fanga'uta lagoon. The activities included mainly power-point presentations to the school children and teachers of each school.

Ministry of Tourism's participation encouraged students and teachers to understand the importance of keeping our environment clean for healthy living. It was followed by strongly emphasizing that the cleanliness of schools and communities to promote tourism. Children actively expressed their interests showing that they had acquired new knowledge from the presentations. Questions asked and discussed during the sessions indicated that the program was very supportive by both the children and teachers.

Figure 31: Some of the School Presentations carried out in 2016 (Photo: Iliesa Tora)

The total numbers of students range from 100 to 1000 per school. When the activities implemented in the schools with more than 300 students, they were divided into 2 or 3 groups per session to make it easier to reach out to everyone and to deal with their individual concerns. Topics included in the sessions concentrated on 70% of the topics covered in the syllabus for Class 6 environmental studies.

Clean Up Campaign

Twenty-five villages participated in this campaign, with the exception of Nukunukumotu community. Nukunukumotu is a small island to the east of Patangata, consists of 6 households that each received a rubbish bin for waste collection. A special arrangement was approved for the rubbish collection to be transported to the shore of Patangata for collection by the waste truck.

Waste collection from the 25 villages was transported to two different locations. The recyclable waste including car bodies were taken directly to GIO recycling site at Pili, and the daily household waste delivered to Tapuhia landfill for proper waste disposal. According to the records received from GIO and Tapuhia, there were 83 loads of recyclable waste which was approximately just more than 200 tons, and 72 loads to the landfill equivalent to about 150 tons.

Figure 32: Waste disposal at Tapuhia & Gio-Recycling site at Pili Quary (Photo: Talita Helu)

As shared from Waste Authority the fast pace growth of waste noted in Tonga suggests greater attention for Tonga in importing products who are at their end of life time, making Tonga a rubbish dump for many overseas countries on bulky waste i.e. second hand vehicle, second hand electronics and the increasing growing plastics noted in the categorization of waste in Tonga.

The amount of waste collected in 2015 to 2016 has double in size and volume, and this is mainly because of waste being illegally dump to coastal areas in which the program focused much of the efforts in 2016 to collect these from the suffocating coastal mangroves areas in order to assist with the mangroves rehabilitation program.

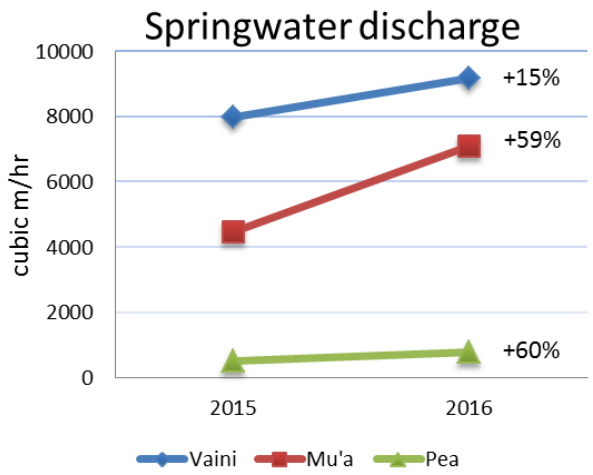
3.4 Conclusions

Freshwater Springs

It has been noted in this report, the excellent use of the extremely effective tool of Geospatial Information Systems (GIS) for identification of status similarly for monitoring of various activities in this project such as Fresh Water Springs and Land Use Plan Zoning. The GIS Sector has identified new range of activities in this Report that was never included in previous studies and reports of the FLC but they could be strongly relevant to the improvement of the Lagoon.

There was a large difference in the water discharges recorded at freshwater springs since last year. The main reason for this major difference was probably due to huge concentration of water underground from heavy rain in previous weeks prior to the survey. Also shown in the graph in Fig 7. above, there is more water discharge from the Vaini Sector than from other Sectors.

Figure 32: Difference in water discharges between 2015 and 2016 surveys



Soil Survey

The survey of potential sources of pollution into the lagoon from agricultural sites, forest, shrub vegetation, industrial and residential sites, a timber treatment site, and town rubbish dump sites showed that there are issues for heavy metals, but not for Organo-chloride or Organo-phosphate pesticide residues. Extremely high levels of Arsenic, Copper and Chromium were found at the timber treatment site of the Tonga Forest Product at Tokomololo. Arsenic was next highest mainly at the town rubbish site and most town sites. Cadmium was highest for the town rubbish site as well as most farming sites for squash and vegetables. Chromium was highest for the timber treatment site and most town sites. Copper was highest for the town rubbish dump as well as timber treatment site and most town sites. Nickel was highest for most town sites as well as the town rubbish dump. Lead was highest for the town rubbish site as well as most town sites. Zinc was highest for the town rubbish site as well as most town sites.

Similarly to Kwon and Lee's conclusion in 2015, that heavy metals pollution of coastal and lagoon sediments from Tongatapu, is that the sources of these metals are from the land. The highest levels of Arsenic, Cadmium, Chromium, Copper, Nickel, Lead and Zinc were found in coastal sediments from the Vuna Wharf port. Sites with high levels were found from the Kolovai coast site with a rubbish dump site nearby, Fatai, ex-rubbish dumpsite at Patangata, Hoi, Lapaha and Malapo. Similarly, in term of the amount of heavy metals on soils of Tonga, the trend is Zinc > Copper > Nickel > Arsenic > Chromium > Lead > Cadmium.

For the pesticide residues, there simply no residue of organo-chorine or organo-phosphorus pesticides were detected on the 63 soil samples analysed.

Coastal & Terrestrial Vegetation

In the current monitoring activities of communities interested to partake of the tree planting activities, it is noted that consistency of skills applied from the on-site trainings on tree planting to that on the field there is increased survival rate of the seedlings distributed. At the same time it is noted that partly much of the

seedlings at communities with known mortality rate it is due to these skills not put into practise with members new to the program. Additional noted issues are the challenge of dry seasons in 2016 that affected less than half of the seedlings distributed, and also from damaged due to free range pigs at unfenced areas as well as demand of consumption of coconut seedlings versus replanting activities.

It is also noted that the two approach of replanting at town allotments and at tax allotments is only successful when coupled with regular monitoring and training provided on the ground.

Mangroves

The status of mangroves continues to degrade compared previous reports. Dredging, clearing for reclamation, land issues and high consumption of mangroves within the periphery of the lagoon is still a continuing problem. It is not a solution that can be solved in the short time frame of the program; however it is hope with the long term implementation of the stewardship plan for Fanga'uta Lagoon that this will be systematic in its approach. It has been noted that series of complaints from the public lodged against these destructive work particularly for established park and recently the golf course at Popua, but no satisfactory response has been provided to the communities.

Replanting on the remaining sites will continue in the near future with application of lesson learned from previous project sites.

Waste

The amount of waste collected thus far by the project has increased 7 fold since its inception, and much of this has been recyclable waste. The need for ongoing awareness for the community is clear. School outreach on waste management is an information sharing that is well received, whilst the need to change the habits of disposing waste an area still in need of further strengthening with the communities at large.

3.5 Challenges & Risk Management

Freshwater Springs

Since the Tide Calendar differs from one Sector to another within the Lagoon and also from that of the main water body out of the lagoon, there is an urgent need for further studies of the tide fluctuations within and out of the lagoon. The survey team could now use the same FWS at each Sector for its annual monitoring.

Landuse Plan Zoning

It is expected that this draft Land Use Plan Zoning would be challenged by many people especially the commercial farmers and should be planned for a soft approach of consultations with various diversity of stakeholders. There is no need for an immediate development of a Policy for this activity until further and greater depths of consultations with the stakeholders are implemented.

Mangroves

The need for close follow up of the monitoring system already in place by the program with increased participation from the communities. The team responsible can systematically assess the mangroves implementation to advise next step forward.

Problems with waste

One of the pressing issues that are leading to the growing waste problem in Tonga is the increasing importation of second hand goods from various countries. This ranges from electronics and vehicles to plastic goods. Most of these second hand goods received are at or close to the end of their lifetime, and because there is no levy established on end of life of these goods in Tonga, managing the disposal of these recyclable wastes and solid wastes proves to be very difficult.

Furthermore, there is limited number of recycling organisations in Tonga, who continue to face the challenge of increase charges for shipping recyclable goods abroad. The R2R program continues to work closely with this limited organisation such as Gio-Recycling and the Waste Authority to find the best means of dealing with the challenging issues of growing wastes in Tonga.

The habits of disposing wastes in Tonga by the community is still an area for further education and ongoing awareness, as observed even after the main two clean-up campaign by the program it is noted that there are still people who continue illegal dumping at sites already cleaned up.

3.6 Best Practices

- Freshwater Springs: On-going monitoring of freshwater springs should be conducted in the same month of each year in order to capture likely similar significant data.
- Urban Areas: As all road drainage systems at Nukuálofa suburbs are either currently drained directly to the Lagoon or to the ocean but they urgently require retention stations to filter and rinse polluted drainage water before releasing to the Lagoon (Figure 33 and Figure 34).
- Rural Areas: Agricultural-chemicals-free Buffer of 150 meter from the Village/Township/wells boundaries - An agricultural-chemicals-free buffer should be created of approximately 150 meters from the Township boundaries, village wells, village water tanks, etc., in order to restrict or minimise usage of dangerous agricultural chemicals in the proximity of the populated areas within the catchment (Figure 35).

Figure 33: Recommended method of absorbing storm water in Water Retention Ponds

These are designed to filter out nutrients and sediments before they reach the lagoon

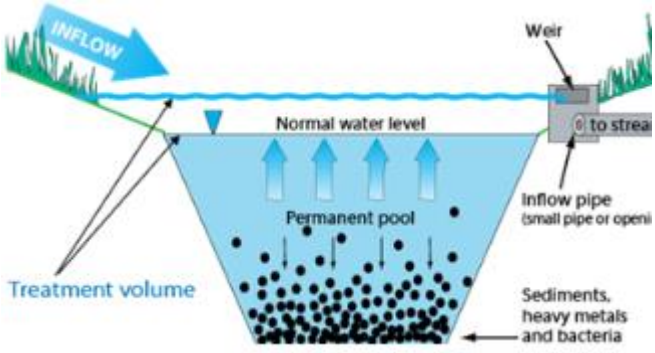


Figure 34: Road drainage network and proposed Water Retention Centers at Lagoon end of each water drainage

Source – GIS of MLSNR, 2016

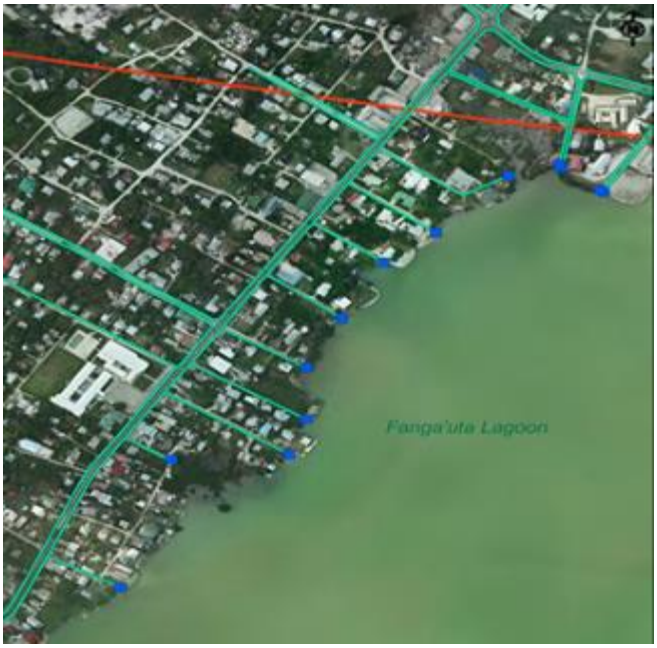


Figure 35: Zone 1 - 150m Buffer – limiting the use of dangerous agricultural chemicals

- It has been recommended by key personnel from relevant stakeholders to categorise crops farming within the catchment into high to low usage of agricultural chemicals then apply them into the Land Use Zoning in the Plan:
- Zone 1: Crops with need for or very minimal usage of agricultural chemicals – Kava, pineapples, hopa, bananas, kape, vanilla, etc – to be located at lower end of the catchment, close to the lagoon.
- Zone 2: Crops with medium usage of pesticides and fertilizers - are root crops such as taro, cassava, sweet potatoes, yams, etc. – to be located halfway down the catchment.
- Zone 3: Crops that are mostly in need of agricultural chemicals such as fertilizers and pesticides - water melons, vegetables, hina, etc – to be located higher up the ridge and away from the catchment area.
- People should be encouraged to plant pineapple, vanilla farms and fruit trees at vulnerable areas that are prone to erosion such as steep areas or close to the lagoon. With the application of suitable crops and vegetation, though these farms would be of great assistance to the improvement of FL water quality but would also resilient to both erosion and wind (Figure 36and Figure 37).
- Roaming Pigs: Inspection of best ways for keeping roaming pigs away from the Lagoon catchment area. It was recommended that all commercial piggeries to be relocated away from the villages to tax allotments, far away from the catchment area. Communities located around the Lagoon need training about special methods of farming of pigs, as shown below, to keep them away from the Lagoon. New breeds should be introduced that are fast to grow, less feed and needs only small space to live in.
- Accessibility of fresh water supply to nursery is vital to future mangrove nursery in low lying areas of Tonga. The method of building home-based nursery is a good technique to adopt in areas with poor supply of water and salinity from underground water lens fit the physiological needs of local species (Figure 29)

Figure 36: Crops suitable for Zone 1

TOP: Left: Pineapple farm at Folaha; Right: Young forest and shrubs at Tufumahina; BOTTOM: Left: Lesi farm at Vaini; Right: Banana plantation at Nualei

Figure 37: GIS map of Zone 1

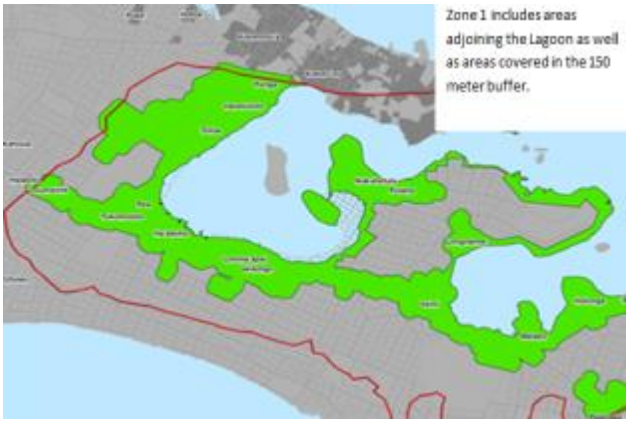


Figure 38: GIS Map layer for Zone 2

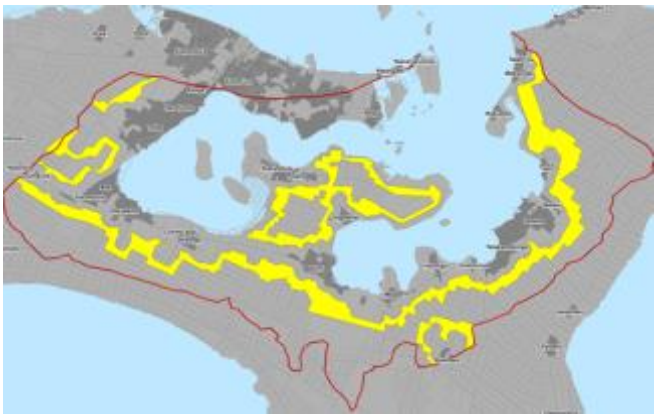


Figure 39: GIS Map layer for Zone 3

Figure 40: Landuse Plan Zoning Map for the FLC

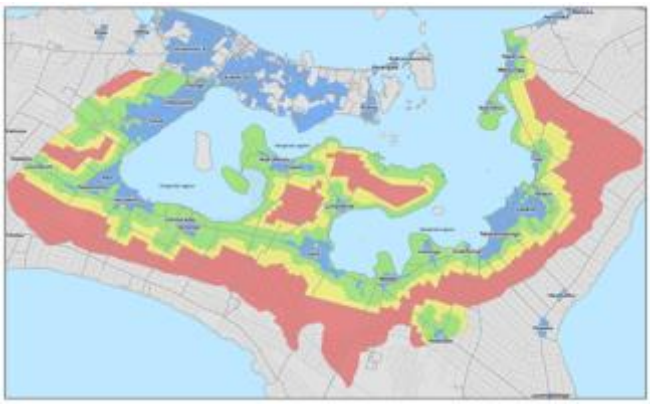


Figure 29: Home-based mangroves nursery to address limited fresh water supply and high salinity

3.7 Recommendations

The GIS Team identified new activities in this Report that there were never included in previous Fanga'uta Reports but they are strongly relevant to the improvement of the Lagoon. It has also discovered in this report the excellent use of the extremely effective tool of Geospatial Information Systems (GIS) for identification of status and for monitoring of various activities in this R2R Project.

The evidence received from the survey of the water discharges from all the three main Sectors above, it was verified that constant developments and clearings of the springs would further increase the fresh water discharges and therefore would contribute much to the improvement of the Lagoon's water quality.

Community and relevant stakeholders should work closely together to find means of stopping illegal land reclamations along the lagoon fringes.

The community should accept the draft proposed land Use Plan Zoning, specifically for agriculture, as other means of reducing the flow of harmful nutrients into the Lagoon. In summary, the recommendations for each aspect of the coastal zone are to:

Freshwater Springs

- Declare proposed sites as Eco-tourism and Historical/Heritage sites/spots;
- Clean up all Fresh water springs by responsible communities and to seek financial assistance for this task;
- Carry out a systematic hydrographic/bathymetric survey of the whole Lagoon to understand its bottom topography and what/ where to deepen before allowing any execution of suction pumping method;
- Strictly apply Environment Impact Assessment (EIA) before making any decision for cleaning up areas around the Lagoon;
- Strictly discourage deployment of dredging machines for cleaning up of the Lagoon shallow areas; and
- Restrict deployment of suction pumps for cleaning areas around water springs.

Land Reclamations

- Carry out further, more detailed surveys and studies of the extent of illegal land reclamations at the FLC;
- Form a community 'Land Reclamation Watch' on illegal development along the Lagoon coastal areas;
- Encourage communities to report on any suspicious illegal developments along the Lagoon Coastal areas; and

- Find a means of enforcing Policies and Acts governing the above.

Land Use Plan Zoning

- Carry out further visits and consultations with key personnel from relevant stakeholders and communities to learn about their feed-back on this draft Land Use Plan Zoning provided in this report;
- Encourage planting of natural crawling plants and fruit trees along the Lagoon coastal areas to minimise flow of silts and agricultural chemicals into the Lagoon;
- Encourage replanting of protective under-growths at Lagoon Coastal areas;
- Enforce the 150 meter no-agricultural-chemicals buffer from residential areas and from village water wells;
- Discourage raising pigs at low-lying areas, adjacent to the lagoon, in order to prevent pollution runoffs to the lagoon;
- Limit raising the number of mature pigs at Zone 1 to merely three and also to introduce new breeds that are fast to grow, less feed and needs only small space to live in;
- Relocate all commercial pig farms to top of the ridge at Zone 3; and
- Enforce policy/Land Act for roaming pigs.

Soil Analysis

- To increase the education of communities and farmers on sustainable land use practises and organic farming;
- To inform timber treat sites and communities at urban area of best practises that reduces the use of dangerous chemicals and heavy metal pollution

Mangroves

- There is a need for Government to enforce all legislation pertaining to the conservation of the remaining swathe of mangroves to provide optimal ecological services to the Fanga'uta communities. Environment Impact Assessment (EIA) Act 2003 and Environmental Management Act is appropriate legal instrument to follow.
- Monitoring should be taken in a fix schedule to realize the current of trend of mortality and survival status of the replanting program.
- Awareness programs must be ongoing covering the recent findings and other environmental sectors impacted as the project progress.
- All proponents should seek advice from the Department of Environment housing the R2R Program or mangrove specialists on other viable options to be used. Such as replanting of mangroves along the banks of dredged waterways and prune young grown mangrove to a certain height to sustain ecological stability and the aesthetic value of each site.

Waste management

- To provide an incentive program or system that enable high participation in proper disposing of waste;
- Clean-up campaign should be a routine activity for all communities with incentives contributed to from line ministries and institutions to encourage greater awareness of importance of waste management;
- Government to provide close support to local recycling companies in Tonga in hiring of recycling machineries to address growing recyclable wastes in Tonga; and
- To establish levy on end of life for all goods so that it can facilitate expense for proper disposal of wastes as well as recycling of waste.

Chapter 4: Birds

4.1 Introduction

A baseline survey of bird species found in the ecosystems of Fanga'uta Lagoon was carried out in later 2016 to describe the species using the area and identify hotspots to be managed.

The lagoon potentially offers habitat to a range of bird species including herons that feed on the shallows on fish, crabs and other invertebrates; migratory wading birds that feed on invertebrates on the surface of or within mud and sand; ducks that feed largely on plant material; and seabirds such as terns which take fish and crustaceans from the water. Their numbers will depend on the availability of feeding, roosting and in some cases breeding habitat; the productivity of the lagoon and its fauna and flora; and threats to survival e.g. from predators and pollutants.

Figure 41: Pea Section showing discoloured water implying possible stressors for bird habitats

4.2 Survey Methods

Survey by vehicle

The road surrounding the lagoon from Nuku'alofa to Makaunga, and within the peninsula from Folaha to Vaini, was driven over two and a half days and all side roads/tracks (viewed on Google Earth) leading to the edge of the lagoon were checked. All obvious routes were checked except for those within Tongatapu township where development extends to the lagoon edge. Many of these roads/tracks ended at the edge of

the coastal vegetation and did not provide opportunities to view wetland bird habitats, but a few led to ponds or mudflats.

The Popua settlement east of Tongatapu borders an extensive area of mudflats and sandflats that are partly covered at high tide and shallow ponds between houses. This area was visited on three days driving to each of the road ends overlooking the lagoon (Figure 42), the third occasion including repeat visits to document bird activity at different stages of the tide.

Figure 42: Popua area on the northern side of the lagoon with roads used in the survey shown in red

Survey by boat

A boat was hired on 8th December to survey the lagoon towards high tide. The survey began off the headland at the entrance to the lagoon north of Makaunga at 11.52am, when high tide at Nuku'alofa was listed at 2.23pm. It followed the coast in a clockwise direction past Mua to Holonga and then crossed to the central peninsula due to the water being too shallow towards Vaini. It followed the peninsula round past Folaha and into the inner arm past Pea, finishing heading out the entrance past Popua at 4.45pm.

4.3 Results

Survey by road

Popua

Table 5 presents the results from Popua which shows that the site is used by a wide variety of lagoon birdlife. The survey on the 9th suggests that it is most significant when the tide is high (Table 3), when it is used for feeding as other areas on the edge of the lagoon are covered by water, and for roosting as it provides open sites above water where the birds can be undisturbed. It acts as a major roost for crested terns, with the 60 counted there probably making up most of the population using the lagoon. Wading birds such as bar-tailed godwits and turnstones also used the area as a high-tide roost.

Other sites

The survey based on the road around the lagoon revealed small numbers of birds at various locations but no areas held as many as Popua. *Figure 43* shows an example of the survey conducted from Ha'ateiho village. Table 2 shows the results of surveying the road ends in *Figure 43*.

Figure 43: Road end locations surveyed from Ha'ateiho village

Survey by boat

Table 7 shows the results of the boat survey during which 95 birds were seen of eight species. The most numerous were black-naped terns (29 individuals), Pacific black duck (20), white-faced heron (13) and golden plover (12).

Table 5: Birds counted at Popua during vehicle surveys from roads and tracks

Survey	Date	Time	Birds seen										
			Reef Heron	White-faced Heron	Pacific Black Duck	Golden Plover	Wandering Tattler	Turnstone	Bar-tailed godwit	Crested Tern	Black-naped Tern	White tern	Banded rail
All tracks[1]	6 Dec	10.30-11.55am	5	1	11	12	1						2
From track ends[2]	8 Dec	9.20-10.00am	4			6				2		1	
From track ends	9 Dec	9.20-9.40am	5	1	3	8	4						
From track ends	9 Dec	11.45-12.10pm	4	3	0	8	3						

Survey	Date	Time	Birds seen										
			Reef Heron	White-faced Heron	Pacific Black Duck	Golden Plover	Wandering Tattler	Turnstone	Bar-tailed godwit	Crested Tern	Black-naped Tern	White tern	Banded rail
From track ends	9 Dec	3.15-3.45pm	7	2	4	14	8	3	6	60	3		

1. Based on driving the tracks shown in red in Figure 42; and

2. Observations made from the ends of the six tracks projecting into the lagoon to the east of the settlement.

Table 6: Road-end observations in Ha'ateiho area at sites shown in Figure 43

Site	Survey result
A	2 purple swamphen, 7 black duck, 1 golden plover, 1 turnstone, 1 reef heron, 1 tattler at edge of mangroves and pond
B	1 white-faced heron, 1 plover
C	No birds or feeding habitat
D	No birds or feeding habitat
E	1 golden plover, 1 tattler on area of mud
F	1 golden plover on small muddy area
G	No birds or feeding habitat
H	Channel cut through mangroves – no birds or feeding habitat
I	No birds or feeding habitat – mangroves cleared for house site
J	No birds or feeding habitat
K	No birds or feeding habitat
L	No birds or feeding habitat
M	No birds or feeding habitat – mangroves removed to shoreline for housing

Table 7: Boat survey results for birds

Boat Survey 8 Dec 2016 11.50am-4.45pm. Weather: Fine & sunny; hot, light wind increasing slightly in afternoon. High Tide: Nuku'alofa 2.32pm

Area surveyed	Golden Plover	Wandering Tattler	Reef Heron	White-faced Heron	Pacific Black Duck	Crested Tern	Black-naped Tern	Frigatebird
Headland to start Makaunga		1						
Makaunga	1	1						
Nukuleka			1					
Mangroves past Nukuleka				2			1	1
Sand bar mid channel	2	1	1				6	
Small rocky islands							19	
Mudflats and coast by Hoi	8			8	4	1	1	
Hoi to Mua			1					
Mua to Cook's Landing								
Landing to Holonga peninsula				1	1			
Then cut across past islands to end of central peninsula								
To between island & coast			3					
Headland before Folaka				1				
Peninsula past Folaka	1				2			
Closest point to island					2			
Cut acoss towards Veitogo			1		1		1	
Start Veitogo to Hauteiko					5			
Hauteiko to turning corner					3			
To next to end of island				1	2			
Power station to Popua			1			1		
To open sea						7	1	
TOTAL	**12**	**3**	**8**	**13**	**20**	**9**	**29**	**1**

4.4 Summary by Species

Herons

Two species of heron are present resident year-round at the lagoon where they space themselves out and may defend feeding areas. (A third species of heron (Mangrove heron *Butroides striatus*) has been recorded twice in Tongatapu but was not seen during the survey (Watling 2006)).

White-faced heron (Ardea novaehollandiae) Motuku

This large heron, with white on its head, feeds in ponds, areas of shallow water and mudflats, and was found in small numbers around all the coast of the lagoon.

Pacific reef heron (Egretta sacra) Motuku

This large heron, which also occupies rocky coastlines as well as areas used by the white-faced heron, was also found right around the edge of the lagoon and more commonly at Popua. It can be found in three colours, either all dark grey (see photo), all white or mottled grey and white. All the birds seen at Fanga'uta were dark grey.

Wading birds

Several birds visit Tonga in summer (September to April) from breeding areas in the northern hemisphere, particularly Siberia and Alaska. Four different species were found during this survey. Two other species have been recorded in Tonga, the threatened bristle-thighed curlew (*Numenius tahitiensis)* Kiu Foa'unga and the sanderling (*Calidris alba*) Kiu, and they are probably occasionally present at Fanga'uta.

Pacific golden plover (Pluvialis fulva) Kiu

This was the most common wading bird found. It feeds both on muddy shores and in open grassy areas like sports grounds and parks, with highest numbers seen at Popua and the mudflats off Hoi village.

Wandering tattler (Heteroscelus incanus) Kiu

This bird also visits Tonga between September and April and was found in small numbers on mudflats or rocky areas on the edge of the lagoon.

Bar-tailed godwit (limosa lapponica) Kiu Foa'unga

This large wading bird which is not common feeds in mud and is often seen in a small flock. Six birds were seen together at Popua.

Ruddy turnstone (Arenaria interpres) Kiu

Three of these small wading birds were seen flying to a high tide roost at Popua.

Seabirds

Two species of tern that feed close to shore were seen using the lagoon: the crested tern (Tala) and black-naped tern (Tala), together with a single white tern (Ekiaki). Frigatebirds (Lofa) were occasionally recorded flying over the lagoon. There are several seabird species that feed largely in the open sea such as frigatebirds, noddies (Ngongo) and boobies (Ngutulei) and there was no evidence that they are using the lagoon. White terns also fall into this category though the occasional individual appears to use the lagoon.

Crested tern (Sterna bergii) Tala

These large terns were mostly seen feeding near the entrance to the lagoon off Popua and a large flock of 60 birds was counted roosting as a group at high tide there. This bird breeds in colonies on the sand and the birds that use Fanga'uta probably nest on Motu Tapu or other islands north-east of Nuku'alofa.

Black-naped tern (Sterna sumatrana) Tala

Small numbers of black-naped terns were seen at Popua and at a few sites in the lagoon, but they were concentrated in the area off Hoi. At least 19 birds were seen on the small, rocky Mounu Island here and they are probably nesting, though the water was too shallow to get the boat close enough to be sure about this. This species has been recorded breeding on Monuafe, Onevai and Tau Islands off Nuku'alofa (Rinke et al. 1992).

White tern (Gygis alba) Ekiaki

Single birds were seen feeding in the lagoon on two occasions, and once in a pond at Popua.

Frigatebird (Fregata sp.) Lofa

Six frigatebirds, not identified to species, were seen flying high over the lagoon on separate occasions, but there was no indication that they were feeding there.

Rails & Gallinules

Two species were recorded feeding in vegetation in damp areas on the edge of the lagoon. Another small rail species, the spotless crake (Porzana tabuensis) moho is likely to be present but it tends to hide in thick vegetation and is very hard to detect.

Banded rail (Gallirallus philippensis) Veka

One rail was seen at the edge of a pond at Popua and two in a wet area opposite the new Popua park area by the main road.

Purple swamphen (Porphyrio porphyrio) Kalae

Two birds were seen feeding in mud at the edge of the lagoon at Ha'ateiho and two at Pea.

Landbirds

Several landbird species use the coastal vegetation alongside the lagoon but the survey was not designed to record them in any detail. None are dependent on habitats such as mangroves that may be influenced significantly by management of the lagoon and its surroundings.

4.5 Conclusions for Birds

Key sites and habitats for birdlife

Popua settlement

The area of mudflats and sandflats to the east of the houses at Popua appears the most significant habitat for wading birds, both as a feeding and roosting site, and

holds a high tide roost for the lagoon's crested terns. There are significant negative impacts on the habitat there that reduce is productivity for birds, particularly the dumping of rubbish (Figure 44) and foraging by pigs (Figure 45) which disturb the structure of the muddy habitats in which the small animals (crabs, worms, etc) live that many birds feed on.

Figure 44: Rubbish at the edge of the lagoon, Popua

Figure 45: Pigs foraging at Popua

However the main threat is the loss of bird habitat due to the settlement itself. Figure 46 shows that a further significant area is due to be occupied by housing including the main areas subject to tidal flow that were used by wading birds during the survey. It is understood that many of the allotments have been leased and registered allocated so that it may be too late to prevent this happening.

Figure 46: Popua settlement showing (in red) all planned sections for development

Source: Ministry of Lands

Mangroves

Mangroves are directly important to many species, particularly herons and rails as feeding and roosting areas, and indirectly by acting as nursery areas for fish. The main threat to mangroves appeared to be clearance for housing, including reclaiming land or creating clear space right to the edge of the lagoon at some locations (Figure 47 and Figure 48), or roading. Those areas of mangroves that remained seemed in generally good condition.

Figure 47: Mangroves cleared for house under construction

Figure 48: Reclamation within mangrove area

Mudflats exposed at low tide

Herons and wading birds feed on mudflats as they are exposed by the tide. It was hard to identify the main feeding areas outside Popua as there were only a few vantage points along the coasts where exposed mudflats were seen, and the boat survey had to be conducted around high tide. Most such areas are in the eastern part of the lagoon from Mata'aho Island round into Vaini. The productivity of the mudflats depends in part on water quality so pollution and eutrophication are key threats. Some areas were lost to roading (photo 7) at several sites in addition to Popua.

Figure 49: Road construction through mudflats

Mounu Island

This small rocky island is a roosting area and probably the only breeding site for black-naped terns in the lagoon, though the state of the tide during the visit to this area made it impossible to determine this.

Factors impacting birdlife

The previous section identified the following factors as having a negative impact on birdlife in different area:

- sub-division development
- rubbish
- wandering pigs
- pollution
- eutrophication.

In addition, over-fishing of the lagoon will have reduced the food for some species and may explain why no seabirds other than coastal terns appeared to fish there. We observed significant fishing effort with many gill nets set within the lagoon (Figure 50). In particular, long sequences of nets were set close to the edge of the mangroves (Figure 51). Apparent overfishing has been documented in the recent R2R survey, with fewer finfish caught than in equivalent surveys elsewhere in Tonga and significant numbers of households reporting declines in catches and fish size compared to 5 years ago (*18*). This has been a continuing trend as household surveys conducted in 2001 revealed that quantity and quality of fish and shellfish catches in the lagoon had declined over the years and were continuing to decline rapidly (*6*).

Figure 50: Hauling in a gill net

Figure 51: Gill net set at edge of mangroves

All these issues have been identified in previous studies and plan developments at Fanga'uta and will be challenging to address, for they depend on changing the attitudes and activities of those communities adjacent to the lagoon as well as improving some infrastructure.

Repeat surveys against baseline

This survey is clearly only a single snapshot so cannot paint a full picture of the use of the lagoon by birds. However it has been conducted during a month in the middle of the period (September to April) when the overseas migrants are present so it should include most species using the site. It did not include the period of the

mullet run in and out of the lagoon (June-September) and it would be valuable to check whether this run is associated with any use of the lagoon by oceanic seabirds following the fish.

A repeat survey should focus on Popua, the few other road ends with bird feeding habitat, and cover the lagoon by boat. The boat survey should begin 1½ hours before the stated high tide at Nuku'alofa to allow its completion and account for the delayed tides within the lagoon.

It must be noted that the lagoon is the year-round habitat for only a few of the species using it: e.g. the herons, ducks and rails. For other species, the number of birds using the lagoon does not only depend on the condition of the lagoon itself, but also conditions in their breeding areas. While some black-naped terns probably nest in the lagoon, other individuals of this species, and all the crested terns, nest on islands outside the lagoon. So their numbers depend on their breeding success on these islands. A programme to eradicate rats from some of these islands has occurred which should increase bird productivity. Similarly, the numbers of the migrating wading birds that use Fanga'uta depends in part on their breeding success in their northern nesting grounds and then on finding suitable feeding areas during their migration.

4.6 Recommendations

1. Encourage appropriate management of the Popua development

- Ideally the size of this development would be reduced from that shown in Figure 3 to retain more significant areas of mudflat and water channels. If all the allotments within the development have already been leased and registered, then measures should be put in place to reduce the impact on birdlife by preventing the dumping of rubbish, and other land-based sources of pollution, ensuring good management of sewage and controlling the wide ranging of pigs.

2. Collect information on birdlife during fieldwork undertaken by the R2R team

- The indications from the survey were that the lagoon was not used by seabirds except coastal terns but there may be times of year when this occurs. Staff should record all instances of flocks of 10+ seabirds feeding in the lagoon. The Popua area is a an easily accessible one for any future staff of the Department with biodiversity conservation responsibilities to observe and learn to identify most of Tonga's wetland birds using Watling (*19*) as a guide.

3. Repeat survey as appropriate

- Repeating the survey after an interval of several years of management activity could contribute to assessing the overall effectiveness of the combined activity. However it would be secondary in value to more specific monitoring such as measuring water quality, fish stocks, seagrass condition, etc.

4. Improve lagoon condition

- This recommendation is largely about implementing the R2R project to ensure that lagoon management is improved and sustained into the future. For birds are affected by most of the negative influences being addressed.

5. Encourage local naming of birds

- Tongan's interest in their birdlife and commitment to conserving it could be increased if every species had a local name. Currently the following examples exist for birds using Fanga'uta lagoon in which a single or two local names cover a range of different species (*19*) with different behaviours, habitat requirements, etc.

Table 8: Local names for birds

Local name	Collective English name	Different species present
Tala or Ekiaki	Tern	Crested tern White tern Black-naped tern Grey-backed tern Bridled tern
Motuku	Heron	Pacific reef heron White-faced heron Mangrove heron
Kiu	Waders	Pacific golden plover Wandering tattler Turnstone Sanderling
Kiu Foa'unga	Waders (larger)	Bar-tailed godwit Bristle-thighed curlew

- The different species could be named individually by making use of their English names, e.g. White tern could be Tala henihina (or Ekiaki henihina). Or alternatively they could be named based on what Tongans think they look like, even with some form of school competition. If it is agreed that this is worth pursuing I suggest the issue is discussed with Dick Watling, Environment Consultants, Fiji who has written several guidebooks on the birds of the region.

4.7 Bird photos

Photos are included here of some of the birds seen during the survey so the reader can be familiar with the different types present.

Herons

White-faced heron

Pacific reef heron (Photographed in Niue)

Wading Birds

Pacific golden plover

Wandering tattler

Other species

Pacific black duck

Crested terns at high tide roost at Popua

Chapter 5: Overall Status of the Lagoon in 2016

This year's survey is the second under the Tonga R2R Project, but for lagoon organisms and water quality it is the 5th survey since 1998, giving us an 18 year timeline on changes in the lagoon. During this survey, data were collected only on lagoon benthic organisms (algae, seagrasses and animals) and water quality, the discharge rates of freshwater springs at the coast, investigations and consultations on landuse within the catchment, information on pollution flows to the lagoon and, for the first time, a study on the bird species found in the lagoon and identification of hotspots to be managed. Some aspects of the survey carried out last year (2015) and which were not included in this year will be continued next year, or in following years according to the schedule shown in the Fanga'uta Lagoon catchment Monitoring manual (*1*).

This report builds on the baseline report of 2015 (*18*) updating the current status of the lagoon and for some measures (such as benthic organisms, water quality and freshwater spring discharge rates) allows us the opportunity to examine changes over time. It is expected that repeated surveys will allow us 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 outcomes of this 2016 survey were as follows:

1. The depth of the water in the lagoon is changing. At 2 sections of the lagoon, Mouth and Mua, depth has increased since 1998, though this could represent long term fluctuations in depth. At the 4 remaining sections of the lagoon (Fanga Kakau, Fanga'uta, Pea and Vaini) there has been a significant shallowing of the lagoon. At Fanga Kakau there has been an average change of 1.2m, with the current depth at just 0.5m, compared with 1.7m in 1998.
2. Physical aspects of water quality such as salinity, temperature and acidity/alkalinity have fluctuated in the period 1998-2016, without any significant overall trend. That is, these measures have stayed about the same throughout sampling. Dissolved Oxygen (D)) underwent an increase after 1998, but it is likely that the earliest data were in error and can safely be ignored – it was noted at that time that the probe used for the survey was malfunctioning. Overall, it is unlikely that there has been significant change in the dissolved oxygen levels. It is unclear how turbidity levels changed in 2016, but in 2015, slightly clearer water quality was recorded at Mouth and Mua, while all remaining sites remained as they had been since 1998. Turbidty tube measures will be undertaken in 2017 to continue the timeline.
3. Nutrient levels in the lagoon appear to have been dropping and levels of Nitrate, Ammonia and Phosphates appear to be below ANZECC guidelines for recreational water quality. These results have not so far led to improvements in the symptoms of eutrophication. Murky waters and algal growth are still dominant. It will be necessary to keep monitoring as periods of low rain could have reduced transport of nutrients into the lagoon and long term information will be needed to understand trends.
4. Benthic (bottom-dwelling) animals and plants have continued to decline, and very significantly since 2015. Corals are virtually absent from the entire lagoon system, and have remained so since 1998. There was, however, a sharp decrease in the cover by seagrasses and algae in the past year or so. The overall average cover by seagrasses in all sections of the lagoon dropped to 4.5% in 2016, declining from a high of 29% in 1999. The cover by algae in dropped to 13% in 2016 compared with a high of 25.5% in 1999. At the same time, the amount of mud, sand, rubble and rock has increased and now covers 73% of the lagoon floor. That is, the cover of the lagoon floor is now mostly non-living sediments, showing that conditions in the lagoon are overall continuing to deteriorate, despite the apparent decreases in some of the nutrients noted above.
5. For freshwater springs, there was a large increase in the water discharges recorded since last year (2015), with 50-60% more being discharged in Mu'a and Pea Sections, and a 15% at Vaini. On-going sampling is needed to understand the nature of and reasons behind the variations in flows.
6. Road drainage systems were identified as a significant pathway for lagoon pollution. It was recommended that water retention ponds be developed to filter out sediments and prevent them moving towards the lagoon.
7. A Landuse Zoning Plan is proposed to protect the lagoon from agricultural chemicals. The plan proposes the following zones:
   - Zone 1: 150m buffer - Crops with a need for or very minimal usage of agricultural chemicals, such as kava, pineapples, hopa, bananas, kape, vanilla, etc to be located at lower end of the catchment, close to the lagoon;
   - Zone 2: Lower half of the catchment - Crops with medium usage of pesticides and fertilizers are root crops such as taro, cassava, sweet potatoes, yams, etc. to be located halfway down the catchment; and
   - Zone 3: Upper half of the catchment - Crops that are mostly in need of agricultural chemicals such as fertilizers and pesticides - water melons, vegetables, hina, etc to be located higher up the ridge and away from the catchment area.
8. Other suggestions for improving the catchment lands included the following, some building on recommendations made last year:
   - Declaring selected sites as Eco-tourism and Historical / Heritage sites;
   - Cleaning up all Fresh water springs by communities and seeking financial assistance;
   - Systematic hydrographic/bathymetric survey of the lagoon to understand its bottom topography and what/ where to deepen before allowing any execution of suction pumping method;

- Strictly apply Environment Impact Assessment (EIA) requirements;
- Discourage dredging machines for 'cleaning up' shallow areas and restrict use of suction pumps around springs;
- Further, more detailed surveys on illegal land reclamations are needed;
- Form a community 'Land Reclamation Watch' on illegal development along the Lagoon coastal areas and encourage the reporting of suspicious developments;
- Examine enforcement of the relevant laws and policies;
- Further consultations with key personnel from relevant stakeholders and communities to obtain feedback on the Landuse Zoning Plan;
- Encourage planting of natural and protective plants and trees along the Lagoon coastal areas;
- Discourage and/or limit raising pigs in low-lying areas near the lagoon and enforce policies and laws on pigs.

9. In soil samples used to determine the pollution levels of the land and potential sources of pollution for the lagoon high levels of heavy metals were found, but that there are currently no detectable issues with pesticide residues (Organo-chlorides or Organo-phosphates). Extremely high levels of Arsenic, Copper and Chromium were found at the timber treatment site of the Tonga Forest Product at Tokomololo. Issues were also found for Arsenic, Cadmium, Nickel and Chromium at other sites, including some town and farming areas. Many of these find their way into the coastal areas. Work is needed on promoting sustainable land use, organic farming methods and best practices for the use of chemicals containing heavy metals.
10. Coastal and terrestrial vegetation replanting programmes varied in their effectiveness depending on the skills of the community members involved. There were also impacts due to dry periods, damaged caused by pigs and the demand for coconut seedlings for human food. The success of replanting efforts will depend on regular monitoring and training.
11. Mangrove cover has continued to decline due to dredging, clearing and reclamation, land issues and over-use of mangroves. The Stewardship Plan will need to address these issues, including questions raised by the community on the development of a park and golf course within mangrove areas. There is a particular need for the EIA Act 2003 to be enforced. On-going monitoring and restoration projects are still needed. The R2R Project can provide guidance on options for sustaining mangrove ecosystems and the aesthetic values of the area.
12. Waste problems continue increase within the FLC, with the clear need for education and awareness programmes. The amount of recyclable waste being collected suggests that incentives for proper disposal need to be considered. This might include support for local recycling companies and a levy on end of life for goods. Clean-up campaigns should be on-going both as a public awareness and ecological improvement activity.
13. A wide variety of birds use the lagoon as habitat, particularly for feeding at high tide and for roosting. The greatest numbers of birds were observed in the Popua area. A total of 12 species was recorded via vehicle and boat surveys. This includes herons, wading birds, seabirds, rails and gallinules and land birds. Mangroves were identified as important to many species. The main threats to bird habitats were clearance for housing, reclamations, roads, pollution, eutrophication and overfishing. In particular productivity of mudflats is dependent at least in part on water quality, so that pollution and nutrient enrichment are issues. Repeated surveys are recommended.
14. A key site identified as habitat for birdlife included the area of mudflats and sandflats to the east of Popua. The main issues for bird habitats in Popua included rubbish dumping, foraging by pigs and encroachment by housing developments.
15. On-going monitoring of the lagoon in 2017 and beyond will be necessary for identifying the main trends and any improvements brought on by interventions. These will require that the teams follow the strategies established in the Fanga'uta Lagoon catchment Monitoring Manual 2016 (*1*).

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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 Communications
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