Community Conservation Resilience Initiative

Global Forest Coalition

SIOSIOMAGA SOCIETY

Report of the

Community Conservation Resilience Initiative

in Samoa

Country report on Samoa
Community Conservation Resilience Initiative (CCRI)
November 2015

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Cover photo: CCRI in Vaiusu community mangrove plantation, Samoa. OLSSI/CIC

The production of this country report has been made possible thanks to the support of the Christensen Fund and the German International Climate Initiative (IKI). The German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) supports this initiative on the basis of a decision adopted by the German Bundestag. The participatory community assessments reflected in this report have been made possible thanks to the support of the community members themselves, Ole Siosiomaga Society Incorporated (OLSSI), The Christensen Fund, Siemenpuu Foundation, the Stockholm Resilience Centre, Natural Justice, Australian Foundation for Asia and Pacific (AFAP) in Sydney Australia and The Government of His Serene Highness Prince Albert II of Monaco.

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COMMUNITY CONSERVATION RESILIENCE INITIATIVE IN SAMOA: FULL REPORT OF THE MAIN FINDINGS

Sapa Saifaleupolu
11/19/2015

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COMMUNITY CONSERVATION RESILIENCE INITIATIVE IN SAMOA: FULL REPORT OF THE MAIN FINDINGS

1. INTRODUCTION

The long-term vision of this project revolves around improving the resilience of village communities – Vaiusu, Saina and Toamua, within the survey area against the impacts of climate change through improving the integrity of their mangrove resources. Each of the village controls part of the Vaiusu Bay mangrove wetlands – once regarded as the longest and largest in Eastern Polynesia. These mangroves have been severely degraded due to natural and anthropogenic forces so their ability to provide the essential ecosystem services for the surveyed communities has declined tremendously. This undertaking although may seem ambitious is not impossible and more importantly, it can result in improving the quality of living and even saving lives.

Realising the vision requires generating an enabling environment for the communities in the survey area to develop a strategic process to rehabilitate and manage their respective mangrove resources which to a large extent are already severely degraded due to both natural and anthropogenic causes. Underpinning this undertaking is an aspiration to improve the resilience of both mangrove ecosystems and the adjacent village communities. Such a process may be achieved through developing a suitable mangrove biodiversity management action plan (MBMAP) that provides a strategic approach to manage mangrove resources in a sustainable manner. Prior to this report, it was difficult to design a MBMAP that is meaningful and practical for these communities simply because some of the necessary information was not available.

The Ole Si'osi'omaga Society Incorporated (OLSSI) in Samoa in partnership with the Global Forest Coalition (GFC) and the communities has already conducted community consultations and mangrove surveys in the villages of Toamua, Saina and Vaiusu as part of its campaign to enhance resilience of both village communities and biodiversity against the impacts of climate change. Samoan villages have sovereign governance directed by cultural protocols with the land and sea controlled by the customary tenure system. This has created problems for mangrove management because the government law states that all land under the high water mark is government land.

Many households in the surveyed communities are still dependent on mangrove ecosystem services to support their livelihoods e.g. fisheries supporting food security and generating incomes. However, the residents claimed that ecosystem services have declined dramatically because a huge part of the mangroves have been destroyed due to overharvesting, urbanisation, industrial activities, population expansion and climate change. Regrettably, legislation and cultural protocols were unable to prevent this disaster. Besides, a large portion of the community population resides on the "mangrove denuded low-lying coastal zone" which is just a few feet above mean sea level. These people as a result are extremely vulnerable to high swells during stormy weather and in the advent of a tsunami.

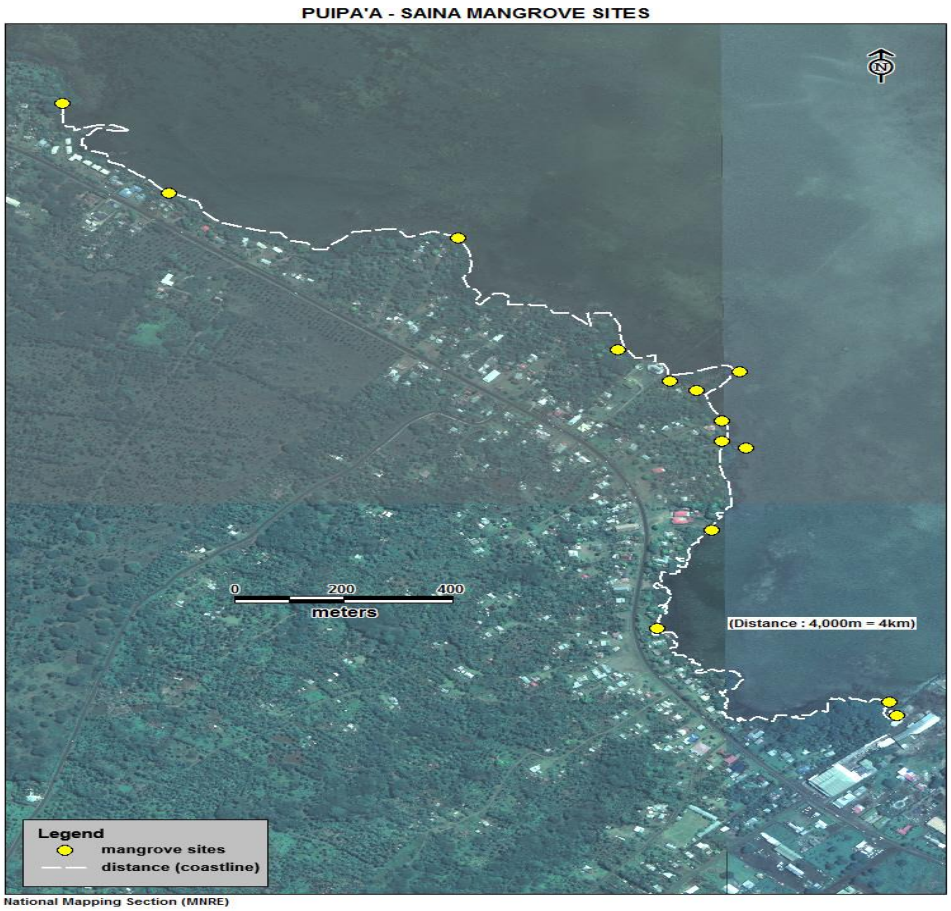
Nonetheless, the government and communities have now joined forces to strengthen mangrove conservation and at the same time enhancing climate change resilience. This is in fact critical to keeping the population from relocating inland. Such a move regardless of its appropriateness can be

culturally devastating because the community will lose touch with its original surrounding that helped mould its cultural identity. Likewise, it will have negative environmental implications since relocation involves land use changes including conversion of pristine habitats into residential areas. Hence the above government-community partnership is as move towards the right direction and should embrace developing proper and relevant biodiversity policies.

2. DATA COLLECTION

Choosing the survey area was based mainly upon the need to initiate mangrove rehabilitation within the Vaiusu Bay mangroves since they play an important role not only to the adjacent villages but also to the biodiversity of the whole region. The most recent estimates of the total mangrove area in Samoa is about 752 ha which is about 0.26% of Samoa's total land area, and is more likely to decrease due to continued unsustainable harvesting, reclamation and the impacts of both population increase and urbanisation. So a timely intervention of properly coordinated rehabilitation and conservation measures to reverse the degradation of these ecologically and economically significant resources becomes a high priority at the community and the national level.

Figure 1. Survey Area - Toamua, Saina & Vaiusu



Procuring data for this project involved a desk review, community consultations and fieldwork surveys. The desk review indicated only a very few studies have been conducted in Samoan

mangroves and only Vaiusu mangroves are included.[1] But even these studies in Vaiusu did not cover the whole mangrove area, nor did they focus on the associated biodiversity.[2] So to acquire an accurate set of data necessary to address the project goals and objectives called for a survey of the whole survey area. This was indeed the best approach in order to capture the most current state and health of these fragmented mangrove scrubs. A hand-held GPS (Magellan Explorist 510) was used to demarcate boundaries and to establish coordinates of points where water and soil samples were collected. This information was digitised using Mapinfo Professional v8.5 Geographic Information System (GIS), and matched up with the Samoa National Inventory 2003-2004 which was then converted to Arview to provide the necessary maps used in this report.

Figure 2. Vaiusu Survey Area

One significant feature that all existing studies agree upon is the fact that the mangroves in the survey area are already severely degraded which is deemed as the major underlying cause of the depleted fisheries and other marine resources inside the mangrove scrubs and in the adjacent lagoons and reefs as well. A major step taken in the past few years inside the survey area with regards to mangrove conservation started in 2006 when the Vaiusu village in close collaboration with the Ministry of Natural Resources and the Environment (MNRE) developed a trial mangrove plantation in the mudflat in the village eastern border. Lessons learnt from this initial trial are also very important to the current study because they provide a useful guidance to the architect of practical rehabilitation strategies.

[1] GoS 2013, Mangrove Ecosystems for Climate Change Adaptation and Livelihood(MESCAL) Samoa Project, MNRE Samoa.

[2] Foliga & Iakopo 2006, Vaiusu Bay Mangrove Area Vegetation Survey; Vaiusu Village 2006, Tusi Ta'iala, Malaki & Sio 2006, Vaiusu Mangroves – First Field Visit Report, and Ellison et al. 2007, Assessment of the Vaiusu Bay Mangrove.

As a result of the lack of accurate and reliable scientific information, it was necessary for the methodology employed to capitalize upon the anecdotal data accumulated through years of experience and retained in the memories of the local communities – the true traditional custodians and rightful owners of the mangroves and all the biodiversity encompassed therein. Consulting the community therefore was a priority and it was initiated by contacting the government representatives in each of the surveyed villages. The approach helped set the platform for more detailed consultations with villages inside their own traditional residences. A formal questionnaire survey was not used because previous experience indicated difficulty in finding willing respondents to cooperate through this data collection method. Local residents are quite sceptical of strangers and are not particularly comfortable with filling up questionnaire forms, hence the need to adapt the methodology to accommodate culturally acceptable measures.

Figure 3. Formal 'ava ceremony in Vaiusu village. Photo by Fiu Mata'ese Elisara-La'ulu.

The following community consultations made possible by the intervention of the government representatives in each respective community began at the highest level of the village hierarchy, that is, at the matai council or the council of chiefs. Figure 3 depicts the beginning of our meeting with the village of Vaiusu which started with a formal 'ava ceremony. The ceremony has a deep cultural significance and also connotes the community's acceptance and is prepared to support the project in principle. This is an integral part of Samoan cultural norms and protocols which is indispensable to the success of any community-based that research.

The ceremony helped set up a pleasant atmosphere for the subsequent exchange which included an interactive discourse with regards to the project's goals and objectives and the fieldwork surveys that need to be undertaken. In all he surveyed communities, the procedure was indeed pivotal because it helped opened up very useful exchange of ideas and sharing of information pertinent to issues influencing the state and health of the mangroves. It was also during these fora that the local traditional experts in mangroves disclosed their knowledge of the biodiversity as perceived from the village socio-economic and cultural context, and how the village community benefitted from the mangrove ecosystem services. In the absence of a scientific baseline database, this pool of local traditional expertise and knowledge becomes valuable. This anecdotal information has been properly incorporated into this report.

Likewise, we reciprocated and capitalised on this window of opportunity to raise more awareness with regards to the underlying principle of the study and how the goals and objectives connect to the revival of the diminishing mangrove ecosystem services through properly organised conservation measures. Community awareness is always important particularly at this stage where enhancing the

basic understanding of the communities about the ecological significance of mangrove wetlands can be very helpful during the rehabilitation phase. The biodiversity audit and its implications to the design of an appropriate MBMAP to promote mangrove conservation and protection were also explicitly explained during these meetings. The interactive discussions that ensued were valuable for they stimulated community elders to recall mangrove usage in past generations and how these have changed with time. The team also benefited greatly via a confidence boost during these formal fora where the community elders and leaders granted its blessings upon the workers and fieldwork to be undertaken.

(a) *(b)*

Figure 4. (a) Toamua elders ready to lead out in the fieldwork survey; (b) Toamua elders joining the field survey. Photos by Sapa Saifaleupolu.

Utilising the Samoan village setting with its traditional and cultural infrastructure worked effectively well and produced amicable working relationship and tremendous community backing which are both essential for information procurement during both the consultations and the fieldwork surveys. Samoan village communities have ancient sacred taboos designed especially for conservation purposes and for good land and marine resource use management. Since the project recognised cultural norms and protocols, the village communities through their respective *matai councils* granted permission and removed taboos to allow safe passage for the proposed surveys of the mangroves.

(a) *(b)*

Figure 5. (a) and (b) Women and men from the surveyed communities taking a leading role during the field survey. Photos by Fiu Mata'ese Elisara-La'ulu.

Further, it was heartening to have representatives from different village groups volunteering to be part of the survey team. This indeed was critical because they were able to provide guidance and at the same time offered specific information about sacred and special sites alluded to during community consultations.

Figures 4 and 5 show leaders in all three communities did participate in the fieldwork. It is also important to point out that throughout the series of consultations and surveys, both men and women were actively involved. The fieldworks also provided a useful opportunity to solicit firsthand information and experience which cannot be acquired in any other way. The experience is useful for the researchers to have a better understanding and be qualified to comment with confidence about the condition of the mangroves and the pressure they are encountering. It also connects the researchers with the associated social-economic impact upon the village communities. An integration of fieldwork outcomes with mechanistic and empirical methodologies is considered a useful pathway to assess the vulnerabilities of mangrove wetlands and the biodiversity they support against the impacts of climate change. Each approach defines a specific aspect of the exposure, sensitivity, and adaptive capacity hence integration will provide a comprehensive and enabling environment to evaluate vulnerability which subsequently allows for fair resource allocation for conservation and adaptation/mitigation.

3. SURVEY RESULTS

3.1. Floral Species

3.1.1. The True Mangroves

The discussion in this section is focused more on the true mangrove species found in the survey area simply because these species will be the main target of the CCRI rehabilitation and conservation activities. The survey area constitutes the western end of the Vaiusu Bay mangrove wetlands and at the end of the survey three true mangrove species were found - the *Rhizophora samoensis*, *Bruguiera gymnorrhiza* and the *Xylocarpus moluccensis*. Prior to their current fragmented and degraded state, Vaiusu Bay was regarded to host the biggest and longest mangrove wetlands in Eastern Polynesia. However, the lack of proper resource management at the community level coupled with ineffective government legislation to protect these useful natural assets in the past have encouraged unsustainable harvesting to dominate resulting in the pathetic condition they are in now. Nevertheless, the ecosystem services and products especially in Toamua and Vaiusu are continuously being harvested by many today – locals and outsiders are fishing and gleaning inside the wetlands on a daily basis.

From the social-cultural perspective, mangroves trees contributed to the manufacture of important handicraft items and herbal medicine. The women in all the surveyed communities used to extract dye from the mangrove park for processing tapa cloth. Balms for treating menopause and mystical illness were also extracted from mangrove leaves and park. With much regret however, these traditional practices are no longer in use today. This project as a result has taken this as part of its focus because traditional knowledge on mangrove use is an important aspect of indigenous identity and must be an integral component of the proposed rehabilitation process. Traditional knowledge in mangrove use is still practised in other parts of the country as well as in other parts for the world. For example in Asia mangrove extracts have been used as a cure for high blood pressure and for treating leprous and epileptic patients for generations.[3] More recent medical research has been

[3] Kathiresan 2000. A review of studies on Pichavaram mangrove.

targeting natural compounds from mangroves to develop a remedy for incurable viral diseases like AIDS.[4]

3.1.1.1. Rhizophora samoensis

Throughout the surveyed communities, *Rhizophora samoensis* or "red mangrove" is the most dominant mangrove species and it occupies about 99% of the total area of true mangroves. In fact the village of Toāmua was originally called "*Togo'ula*" which means "red mangroves" and this may be indicative of complete dominance and abundance of this species in this community. According to the community elders the former village name alludes to the abundance of pristine *Rhizophora* scrubs that formed a contiguous part of the village bio-physical environment. They also claimed the former name signified the immense contribution this mangrove species provided for the local community and the nearby polities.

(a) *(b)*

Figure 6. (a) Rhizophora bearing seeds (propagules), (b) Rhizophora aerial roots – an adaptation necessary for survival in saline conditions. Photos by Sapa Saifaleupolu.

When questioned about the past mangrove composition, the local residents were unsure. Perhaps the fact that the Samoans use the same word (*togo*) for both *Rhizophora* spp. and *Bruguiera* spp. may have something to do with this. The Samoans considered the *Rhizophora* and *Bruguiera* as the female and male members of the same mangrove species. It is therefore impossible to determine why *Rhizophora* is so much dominant based on the anecdotal information.

This feature however persists throughout the Vaiusu Bay mangroves, which according to Suluvale (2001) is closely related to the coastal geomorphology of the Bay that tends to stimulate the growth and natural regeneration of *Rhizophora* spp. more than the other mangrove species.[5] This is useful information to coastal protection design and planning especially with the extreme weather events increasing in both frequency and magnitude and are likely to be exacerbated by sea level rise.

The tsunami of September 29, 2009 that took close to 150 lives in Samoa is a stark reminder of the vulnerability of coastal dwellers to these natural disasters. It is also a wakeup call about the important role coastal ecosystems including the mangrove wetlands provide in terms of protection for human communities, hence the need to be given high priority for protection and rehabilitation to improve resilience and efficiency.

[4] Ibid.
[5] Suluvale 2001, Environmental Change of Selected Mangrove Areas in Samoa.

(a)

(b)

Figure 7. (a) East Vaiusu – unbroken dense impenetrable Rhizophora zone. Photo by Fiu Mata'ese Elisara-La'ulu. (b) Intact Rhizophora scrubs in Toamua. Photo by Sapa Saifaleupolu.

In spite of the severe degradation, there are still areas, especially in Vaiusu and Toamua, of dense impenetrable and healthy *Rhizophora* scrubs which have been providing coastal protection from tidal and wave activities. Besides, there are adequate evidences of *Rhizophora* natural regeneration throughout the survey area. Indeed, this is promising for rehabilitation activities in the surveyed communities. From a biodiversity management perspective, this is an advantage that needs capitalising upon which makes it more necessary to direct adequate effort and attention towards enhancing this natural capacity. Moving towards this direction is highly significant for fragmented sections where other coastal species and alien invasive species have established dominance. An intervention of this sort is very important because once the disturbing force pushes the remnant habitat below the threshold limit, the resilience of the encompassed ecosystems and the associated species will be severely compromised.[6] The concerned communities and partners as a result need to allocate more resources and energy to ensure the above situation is avoided at all cost because it is very difficult for the habitat to recover once it declines below the resilience limit.

3.1.1.2. Bruguiera gymnorrhiza

The second true mangrove species found in the survey area is the *Bruguiera gymnorrhiza*. This is in fact the most common mangrove species in most Samoan mangrove forests[7], however, it constitutes only about 0.8% of the mangrove area and population in the survey area. The scarcity of this species cannot be explained by the geomorphological influence that favours Rhizophora development alluded to above, in the landward location of the mangrove zone. Naturally, the *Bruguiera* trees fare very well in this zone because their pneumatophores (adapted roots) are free from fine sediments and silt thus allowing oxygen to pass through unimpeded.

[6] Walker & Meyer 2004, Thresholds in Ecological & Social-ecological Systems.
[7] Sasaki 1992, Mangrove Vegetation in Western Samoa.

(a)

(b)

Figure 8. (a) One of the very few matured Bruguiera trees in Toamua. Photo by Sapa Saifaleupolu. (b) Young Bruguiera trees in Vaiusu. Photo by Fiu Mata'ese Elisara-La'ulu.

The most plausible underlying cause was provided by the local residents who said that *Bruguiera* trees had been heavily harvested for domestic usage in the past mainly because the village got isolated from traditional community forests. Consequently, the *Bruguiera* trees bore the brunt of wholesale harvesting because they were easily accessed.

Figure 9. Bruguiera adapted root (pneumatophores) also prevents erosion. Photo by Sapa Saifaleupolu.

Fieldwork observations have identified only a very small number of matured *Bruguiera* trees found in the survey area and all are stunted. Saifaleupolu and Elisara 2013 have suggested that this unique feature may be connected to the water deficit.[8] The survey area is located in the northern side of the Island of Upolu which is usually very dry during the dry season from May to September. Figure 8(a) depicts one of these matured stunted trees while 8(b) shows the young trees and seedlings which form the majority of the existing *Bruguiera* population in the survey area.

The *Bruguiera* spp. possesses a very strong interlocking root system that firmly holds the soil together thus preventing the beaches and seafronts from being washed away by the tidal and wave activities (figure 9). This quality is sorely missing in many sections of the survey area and erosion is rife in these areas even in places where the Rhizophora scrubs are abundant and thriving. Restoring the integrity of this quality has now become an integral component of this CCRI because it is quite clear that this important mangrove species is already under threat and is heading towards extinction if it is not properly restored and protected. At the moment the species population

[8] Saifaleupolu & Elisara 2013, Biodiversity Audit for Vaimoso, OLSSI, Apia.

is too small and widely scattered that without prudent community intervention, it is incapable of recovering naturally.

3.1.1.3. Xylocarpus moluccensis (Le'ile'i)

The third and rarest mangrove species found in the survey area is the *Xylocarpus moluccensis* (le'ile'i). This species belongs to the genus of plants in the mahogany family (*Meliaceae*) and indeed the only mangrove genus in the family *Meliaceae*. This family is comprised of three known mangrove species that are native to coastal mangrove forests of the Western and Central Indo-Pacific namely; *X. granatum, X. mekongensis and X. moluccensis*.[9] The only known species of this family found in Samoa is the *X. moluccensis*.[10]

Figure 10. A X. moluccensis tree that had been harvested a few times in the past. Photo by Fiu Mata'ese Elisara-La'ulu.

Prior to the Toamua mangrove wetland survey, the only other location known to host the *X. moluccensis* species is a two acre groove in a small stream bed approximately 2 kilometres east of Si'utu, Sala'ilua in the Island of Savai'i.[11] *X. moluccensis* (figure 10) is very much unknown in Samoa mainly because it is called by the name "le'ile'i" rather than the usual name "togo" so it is not considered by the Samoans as a mangrove species. Besides it is so rare that very few people have seen it, and surprisingly, even the residents in Toamua are not aware of its existence or its ecological and social significance. Now with this survey making this important discovery, it is expected that the profile of the *X. moluccensis* will be raised at the community and national levels because it has significant ecological and medicinal implications.

Literature survey has indicated that *X. moluccensis* has both domestic uses and medicinal properties. For example an extract from the bark has been used in Asia to treat dysentery, while roots are part of a recipe against cholera, and the seeds are used also used to make a concoction for many ailments.[12] Stem and leaf extracts were also screened for antibacterial activity against drug resistant drug resistant Gram positive bacteria viz., *Bacillus cereus*, *Bacillus subtilis*, *Staphylococcus aureus*.[13]

[9] Veni et at, 2014, Antibacterial and Phytochemical Screening of Xylocarpus moluccensis.
[10] Whistler 2002, The Samoan Rainforest: A Guide to the Vegetation of the Samoan Archipelago.
[11] Saifaleupolu & Elisara 2011, Biodiversity Audits & in Whistler 2002. The Samoan Rainforest.
[12] Bandaranayake 1998, "Traditional and Medicinal uses of Mangroves", *Mangroves and Salt Marshes*, 2: 133-148.
[13] Veni et at, 2014.

A key feature of the CCRI approach used during community consultations involves boosting confidence at the community level concerning the imperative necessity of sustaining traditional practices involving components of their biodiversity. Similarly, communities are encouraged to secure these traditional knowledge and wisdom because they are assets of immense importance and value that can make a difference in our society today when they are appropriately used and applied. Despite the lack of community knowledge about the existence and use of *X. moluccensis,* the community has an obligation to prevent further damage to this rare mangrove species. This will require an integrated management of the mangrove resources that promotes a good understanding of the ecological relationship among the ecosystems as well as the biological role that the mangrove scrubs/forests play in the encompassed food web. A better awareness of the role of key species in maintaining the equilibrium of a particular ecosystem is likewise very essential.

3.1.1.4. The Vaiusu Mangrove Planation

Figure 11. Mangrove plantation in East Vaiusu. Photo by Fiu Mata'ese Elisara-La'ulu.

Prior to the community consultations and fieldwork, the mangroves in the survey area appeared neglected. It is easy for outsiders to assume that the communities in the survey area have lost the traditional knowledge of mangrove ecosystems which their ancestors accumulated and utilised through centuries to derive a large part of their livelihood. However, meeting with the village communities in their turf proved that notion very wrong, especially in the Vaiusu camp. In this part of the survey area, the residents are still aware of the ecosystem services and has taken the initiative to start a mangrove plantation.

Before this plantation began, a trial mangrove plantation was launched in 2006 through a partnership between the government of Samoa (MNRE and MAF) and the Vaiusu community.[14] A total of 1500 mangrove seedlings were planted but only 35 survived after the first 9 months. A few possible causes were suggested but the most critical appeared to be the lack of skills and expertise.[15] Nevertheless, the lessons already learnt have contributed significantly with the design of the current project.

The present mangrove plantation covers an area of about 2-3 acres in the mudflat in east Vaiusu, and during inspection in December 16, 2014 mangrove seedlings looked fine as illustrated in figure

[14] Ellison et al. 2007, Assessment of the Vaiusu Bay Mangrove Replanting Trial.
[15] ibid.

11. According to the representatives of the women's committee of Vaiusu village, the most serious challenge comes from the enhanced growth of green fibrous algae (*Cladophora sp*) along the foreshore.

3.1.2. Other Plant Species

3.1.2.1. Other Shrub and Tree Species

Throughout the survey area are many breaks inside the mangrove zone most of which are completely dominated by other coastal species, alien invasive species and food crops. Of the three villages surveyed, Saina is the most affected since more than 80% of its mangrove forests have been destroyed by forces described above. The invasive species *Albizia falcataria and Albizia chinesis* together with thick scrubs of beach hibiscus have now dominated some of these relatively large areas, especially in Saina's coastline as shown in figure 12 below. The expansive canopies of both *Albizia* species extend over the former mangrove zone thus making it impossible for the mangroves to recover naturally, in particular the *R. samoensis* which is shade intolerant.

Figure 12. A huge part of coastline in Saina community is completely dominated by Albizia spp. Photo by Fiu Mata'ese Elisara-La'ulu.

Apparently, mangrove rehabilitation in this village should be regarded as very urgent so a firm decision must be made immediately. With 80% of the mangroves destroyed already coupled with the pressure from population increase and urbanisation, a rehabilitation strategy needs to be designed and implemented soon. The village community and external partners will need to work collaboratively in this initiative since it is vital for the effort to be properly designed, well-coordinated with strong involvement of all. Under these circumstances, all planned activities for mangrove rehabilitation will require prior removal of these resilient and invasive species. So, strong community commitment, support and participation is indeed vital.

Further, it is important for the community to take responsibility and assume ownership of the project. In fact, the CCRI's strategy throughout the survey area is geared towards this direction. Respecting cultural norms and protocols has opened up the gateway for community residents to participate willingly and the CCRI has taken on board and is now an integral component of the strategy. Among the key messages shared during the community consultations was the importance of restoring the integrity of mangrove biodiversity since it is directly linked to improving ecosystem resilience.

(a)

(b)

Figure 13. More breaks in the survey area (a) A mixture of coastal species dominating - pu'a, talie, milo, lala and suni-tai. (b) Beach hibiscus dominance. Photo by Fiu Mata'ese Elisara-La'ulu.

Communities are already aware that when this happens, they will benefit and likewise become more resilient against the impacts of climate change. Figure 13 shows more fragmentations in the survey area where coastal species are in control. For situations of this kind, there are adequate open spaces for rehabilitation because these species are not salinity tolerant so they only dominate the dry edges. A salient feature in both pictures however, is the enhanced coastal erosion, hence the need for urgent mangrove rehabilitation action.

Figure 14. Coastal erosion poses a threat to household food gardens. Photo by Fiu Mata'ese Elisara-La'ulu.

When mangroves are removed, erosion becomes rife in the fragmented space. Figure 14 depicts a common situation in the survey area where the impact of enhanced erosion has destroyed many home fronts simply because households have cleared the mangroves to have easy access into the sea. Although the other coastal shrubs and trees have taken over, they cannot replicate the coastal protection ability that only the mangroves provide against tidal and wave offence. The high water mark is very close to the household food crop garden and coupled with the associated salt water intrusion of the soil, crop productivity has already decline.

(a) *(b)*

Figure 15 (a) Coconut palms in the mangrove zone. (b) Bananas are among the most common food crop grown along the mangrove zone. Photo by Fiu Mata'ese Elisara.

The expansion of community residences towards the mangrove zone also increases the amount of food crops planted there (figure 15 a & b). As land becomes a constraining factor with regards to development, vulnerable areas such as mangrove wetlands become targets for agricultural activities. The survey area is among the communities that have lost huge tracts of agricultural land during the colonial era. As a result, many residents today have to travel great distances inland where lands for agriculture are available only. It is therefore common practice for coastal dwellers to grow staple crops around residential areas.

The increase of population dwelling along the mangrove zone also correlates well with the increase in unsustainable harvesting of mangrove wood for cooking and/or building purposes. The community forests in the bygone years, where traditionally locals used to collect firewood and building materials from are no more. As a result, people living adjacent the mangroves are forced to extract firewood and building material from these ecologically significant resources. Designing and implementing proper MBMAPs now will be a timely and strategic initiative. The households in the survey area will continue to face the challenging issues regarding limited resources for basic needs especially firewood, hence producing an MBMPA now will give the residents more options and opportunities to progress in the right direction. Under current conditions, there are no simple solutions. However, communities need to take control of the situation. In fact, the Vaiusu community has taken initiative in that direction. Through the women committee, Vaiusu has already developed a 2-acre mangrove plantation. The move showcases the fact that practical but affordable options are available to communities but people need to step out of their comforts zones, make sacrifices and be fully committed to be successful.

The rest of the plant species are listed in table 1 and 2 below. The tables are definitely not exhaustible. There are still more species and ecosystems that need to be identified and properly classified in the survey area.

Table 1. Other Tree and Shrub Species

Samoan name	Common name	Scientific name	Place where found	Frequency	Relationship to mangroves
Aloalo tai		*Clerodendum inerme*	Dry edges of the mangroves.	Rare to occasional	Coastal species and found in most mangroves just above water level.
Fa'i	Banana		Close to the inland boundary	occasional	Grown close to the mangroves for household food supply.
Fau	Beach hibiscus	*Hibiscus tiliaceus*	Most on inland boundary.	Common to abundant	A natural species around the mangroves. Hard to re-dominate once it is established.
Fetau	Beach mahogany	*Calophyllum inophyllum*	Inland boundary	Rare	Usual mangrove tree species.
Fisoa		*Colubrina asiatica*	Inland boundary	Common	Natural species of Samoan mangroves.
Futu	Box tree	*Barringtonia asiatica*	inland boundary.	Occasional	A natural coastal species that can be competitive at the inland boundaries.
Gatae		*Erythrina variegata*	Inland boundaries	Occasional	Not a threat. It is a legume thus replenishes soil nitrate.
Ifi	Polynesian chestnut	*Inocarpus fagifer*	Inland boundary of the mangroves	Rare	A coastal species that is sometimes found in the inland edges of some mangrove stands.
Kuava	Guava	*Pueraria Montana var. lobata*	Inland boundary of the mangroves	Occasional	A coastal introduced species. Not very adaptive to saline conditions.
Lala			Inland boundary.	Common to abundant	A coastal shrub species – grows well just above water mark.
Laufala	Pandanus	*Pandanus spurius*	inland boundary.	Rare to occasional	Not athreat.
Laupata			Inland boundary.	Rare to occasional	Not a threat.
Leva			Inland boundary.	Rare to occasional	A coastal species – grow mainly in the dry part of inland boundaries.
Mago	Mango	*Mangifera indica*	Edges of inland boundary.	Occasional	Can be a problem because of its enormous canopy.
Mati	Dyer's fig	*Ficus tinctorial*	On big trees.	Rare	Not a threat.
Milo	Hibiscus	*Thespesia populnea*	Inland boundary.	Rare to occasional	A natural coastal species. Not a threat.
Niu	Coconut	*Cocos nucifera*	Inland boundary.	Rare to occasional	Not a threat.
Nonu	Indian mulberry	*Morinda citrifolia*	Inland boundary.	Rare to occasional	Not a threat.
Pu'a	Chinese lantern	*Hernandia nymphaeifolia*	Inland boundary.	Rare	A coastal tree species that grows well just above the water mark.
Pulu	Bunyan tree	*Ficus spp*	Inland boundary	Rare	A threat due to its huge canopy.
Pulu Intia	Indian rubber tree	*Ficus elastica*	Inland boundary	Rare	A threat due to its huge canopy.
Suni tai			Grows well just above the water line.	Common	A coast species which can easily take over whenever gaps in the mangroves are available.
Talie	Tropical almond	*Terminalia catappa*	On small dry islands within the mangroves.	Occasional.	A natural coastal species. Not a threat.
Tamaligi pa'epa'e	Albizia	*Albizia falcataria*	Inland boundary.	Occasional to common.	A threat due to the huge canopy - an invasive species.
Tamaligi 'ena'ena	Silk tree	*Albizia chinesis*	In the inland boundaries & breaks.	Occasional to common.	A threat due to the huge canopy – an invasive species.
To'ito'i	Half flower	*Scaevola taccada*	On rocky coastline.	Rare	A natural coastal species – not a threat.
'Ulu	Breadfruit tree		Inland location.	Occasional	Domestic food tree. Not a threat.

Table 2. Ferns, vines & grass species

Samoan name	Common name	Scientific name	Where found	Abundance	Relationship with mangroves
Fue moa		*Ipomoea pes-caprae*	On open areas on the inland boundaries.	Occasional to common.	A common coastal vine species. Only found on open space with plenty sunlight.
Fuesaina	Mile-a-minute	*Mikania micrantha*	On open areas in inland boundaries.	Occasional to common.	Not a direct threat to the mangroves because it is salinity intolerant. An invasive species.
Fuefuesina	Beach pea	*Vigna marina*	On open areas in inland edges.	Occasional to common.	A common coastal vine species. Only found in spot with plenty sunlight.
Lau'autā	Wart fern	*Phymatosorus scolopendria*	On big trees.	Common to abundant	A natural species in established mangrove (bruguiera species) communities.
Laugapāpā	Bird's nest fern	*Asplenium nidus*	On the big trees.	Occasional	Provides nesting sanctuary for many birds which share the richness of the mangroves.
Laugasēsē	?	*Davalia spp*.	On big trees.	Very rare	Not a threat to the mangroves.
Lautasi	?	*Pyrrosia lanceolata*	On big trees.	Rare	It grows together with other ferns and orchid species. It is not a threat to the mangroves.
Mutia ole togatogo	Mangrove grass	*Paspalum vaginatum*	On open areas in breaks.	Rare to common	A natural species of mangrove wetlands.
Vaofefe palagi	Sensitive weed	*Mimosa diplotricha syn:invisa*	Opened areas in the breaks.	Rare to occasional	An invasive species. It cannot tolerate saline soil but can be a threat to other coastal species on dry boundaries.
Vaotuaniu	?	*Nephrolepis hirsutula*	Mostly in breaks.	Occasional	Natural fern member of the mangroves.

3.2. Fauna

The following discussion briefly addresses the state of the faunal species that play major roles in the community livelihoods thus providing the reader with relevant background information necessary to capture the flow into the conclusions and recommendation in order to meet the major goals and objectives of the CCRI.

3.2.1. Crustaceans

3.2.1.1. Crabs

Among the most common and abundant animal groups in mangrove wetlands are the crabs.[16] These species play a vital ecological role in these habitats[17] and are also responsible for building burrows that improve the penetration of ground water, water from high tides and freshwater runoff.[18] The burrows help flush out excess salt and reduce soil salinity. They also improve levels of oxygen in the mud by creating air spaces. They also provide safe sanctuary for many organisms, including fish molluscs and worms. Crabs are champions of nutrient recycling, especially nitrogen. Many crabs eat large amounts of fallen mangrove litter while other species eat algae and detritus.[19] The presence of

[16] Smith et al. 1991, Keystone species and mangrove forest dynamics.
[17] Lee 1998, Ecological Role of Graspid Crabs in Mangrove Ecosystems.
[18] ibid
[19] Fell et al 1975, Microbial activities in the mangrove (Rhizophora mangle) leaf detrital system.

crabs in mangrove wetlands is also closely linked to improved mangrove development and growth, as well as increased biomass and diversity of other organisms.[20]

Despite the degradation there were still plenty small crab species like the fiddler crab *(Sesarma erythrodactyla)* and the 'ama'ama (*Grapsus sp.*) observed during the field survey which may be indicative of the potential these habitats still possess to support other components of the biodiversity (figure 16). However, this is not the case with the mangrove crabs (*Scylla erythrodactyla*) – the most important crab species (in the cultural and economic context). Anecdotal comparative analysis claimed that current catches are declining. This is hardly surprising because any massive destruction of the mangrove forests incur a decline in the mangrove crab habitat as well as the crab population.[21] In the absence of a meaningful intervention form the community and external partners, this condition is likely to deteriorate because of human pressures coupled with the impacts of climate-change and sea level rise.

Figure 16. Fiddler crabs are quite common in most parts of the Toāmua mangroves. Photo by Fiu Mata'ese Elisara-La'ulu

The decline in mangrove crabs is a disturbing issue in Toamua because one of its constituents called Puipa'a got its name from this species. Village legends claim the term "Puipa'a" (an abbreviation for "*Puipui e le Pa'a"* which literally means "protected by the crab") was coined in ancient time in honour of the community's god - the "Pa'a". On the other hand, the name may be symptomatic of the significance and abundance of crabs and the importance they played in community livelihood in ancient times. Village elders claimed that the species alluded to in the name "Puipa'a" is the mangrove crab (*Scylla erythrodactyla*). Oral traditions also claim that the mangrove crab was the main god in this part of the Faleata district, and that the community in the ancient times paid homage to it for protection and prosperity.

Today, the whole village community of Toāmua worship the Creator God of the Bible. However, the oral traditions and legends are still very important to indigenous people and local communities because they provide an anchorage to community heritage (land) and all associated natural resources as well as the means by which these natural assets were utilised, managed and controlled.

[20] Lee 1998.
[21] Odum & Heald 1975, The detritus-based food web of an estuarine mangrove community.

Figure 17. O le "Ana o le Pa'a" landmark – the "cave of the crab" – a cultural heritage. Photo by Sapa Saifaleupolu.

Figure 17 shows the "*ana o le pa'a*" landmark (the cave of the crab) where the god-crab lived in ancient times. It is located in the sub-village of Puipa'a. It may be hard to give a meaningful explanation to establish some credibility of these stories but it important to keep in mind that such legends were meant to be narrated with a symbolic connotation. The community is keeping the place neat and clean for to them, the legend and the evidence provide meaning to their existence and value to their own origin and where they are now. It also solicits key directions to maintain community identity as it moves into the future.

3.2.2. Bivalves and Edible Marine Species

All the surveyed communities are among the expert fishing villages in Faleata district and they use a lot of fish and other marine edibles in their diet. Among these are the bivalves especially the venus shell however, like most marine species, they are declining too. Commercial sand mining and associated sedimentation tend to be major culprit. Sedimentation was never a problem before the commercial sand mining and dredging began in Vaitele – Saina's next door neighbour in the east. Both Saina and Toamua communities are blaming the sedimentation for the decline of their fisheries including bivalves and many other edibles which used to thrive in the mangroves and adjacent mudflat. Vaiusu on the other hand is blaming the pollution from the old Vaitoloa rubbish tip as the major driver for the decline in the fisheries as well as many marine and mangrove edible animal species.

Suspended sediments can smother benthic organisms and habitats when it settles, and can cause mechanical and abrasive impairment to the gills of fish and crustaceans.[22] They can also transport contaminants (particulate nutrients, metals and other potential toxicants), promote the growth of pathogens and waterborne diseases, make marine pests difficult to detect and can lead to dissolved oxygen depletion in the water column if it is caused by particulate organic matter.[23] Overall, unnaturally high turbidity levels can lead to a reduction in the production and diversity of species.

[22] Bash et al 2001, Effects of Turbidity and Suspended Solids on Salmonids.
[23] Walter et al 2003, The Biological Effects of Suspended and Bedded Sediment (SABS) in Aquatic Systems.

(a) *(b)*

Figure 18. Oysters (introduced in the early 1980's are thriving in the muddy conditions of foreshore and the lagoon of Saina, and Toāmua. Photo by Sapa Saifaleupolu.

The rock oyster, a newcomer into the scene, on the other hand is flourishing. No study has been done to evaluate the impact of this new bivalve species upon the mangrove ecology but it appears that the Toamua mangroves offer a suitable habitat so it is here to stay. Figures 18 (a) and (b) illustrate the successful oyster quest to dominate the rocks in the mangroves. Even the aerial roots of the *Rhizophora* colonies are populated by oysters. This may pose a problem to the natural regeneration of this mangrove species.

Table 3. Crabs and Bivalves

Samoan name	**Common name**	**Scientific name**	**Where found**	**Abundance**	**Relationship to mangrove**
Pa'alimago	mangrove crab	*Scylla erythrodactyla*	Inside the mangrove scrubs and in the adjacent mudflat.	Occasional to common.	A natural species of the mangrove wetlands. It is part of the Samoan diet and a source of income.
'U'a	red-claw crab	*Sesarma erythrodactyla*	This crab species is found mainly at the inland boundaries of the mangroves.	Common to abundant.	This crab species is naturally small with a big red claw, hence its name. They make good bait for trapping mangrove crabs (*Scylla erythrodactyla*).
'Ama'ama	(?)	*Grapsus sp.*	This species lives in burrows in the floor of the mangrove forest.	Common to abundant.	This is a natural member of this mangrove habitat
Tugane	Venus shell	*Gafrarium spp.*	In the mud-flat.	Common.	An indigenous species of the mangroves.
Tio	Rock oyster	*Saccostrea glomerata*	Rocks and mangrove roots	Abundant	Introduced species and it is possible they may have impacted upon the marine ecosystem. Need further research to evaluate.

The community residents have capitalised on this opportunity; many residents are harvesting rock oysters for sale. This looks like a burgeoning income generating activity because oysters are not common in Samoa. Hence, the community of Toamua has taken advantage of the chance to fill in this niche in the local market. The community were not aware of how the rock oysters came to be a component of the mangrove wetlands. It is possible that this bivalve species was first introduced into the country through the Fisheries Division trials in the 1980's in a few areas in Samoa including the Vaitele lagoons just east of the survey area.

3.2.3. Fish Species

The mangroves, lagoons and reefs of the survey area were once considered the richest in fisheries and other marine edible species. A well-known legend linked this abundance to a special gift from the Tui Manu'a to his beautiful queen Sina daughter of high chief 'Ale from the Toamua village and also an award of bravery to her brother Malalatea. The gift embraced the richest lagoons of the Manu'a Islands known as the *Tai Tafola o le Tui Manu'a*. The community elders are still lamenting the declining state of their once-rich marine resources. They admitted that they themselves are partly blamed because they have allowed their mangroves, lagoons and reefs to be exploited for a cash economy at the expense of losing their cultural inheritance. As a result, their fishermen have to go out further and staying out longer today in order to procure a profitable catch.

The same declining trend is evident in the mangrove fish population now. Whereas many people fished in the mangroves in the past, there is hardly any fishing done close to the village today. During the fieldwork we were only able to sight four fish species. The most common species is the mano'o or mud skipper (*Periophthalmus cantonensis*), depicted in figure 19. Since this species is not part of the local diet, it is always found in abundance in all mangrove wetlands in Samoa.

Figure 19. The mud-skipper – most common fish species in the survey area. Photo by Fiu Mata'ese Elisara-La'ulu.

The other fish species sighted during the fieldwork included the aūa or mullet (*Crenimugil crenilabis*) which were seen moving about in small schools, the īse or sword fish (*Platybeloneargalus platyura*) and the tamala *(Lutjanus fulvus*). The remaining fish species listed below were provided by the local team members based on the current and past catches. These include: anae (*Valamugil seheli*), 'ava'ava (*Terapon jarbua*), filoa-vai (*Lethrinus harak*), malauli apamoana (*Caranx melampycus*), matu (*Gerres macrosoma*), mumu (*Leiognathus equulus*), mutu (*Abudefduf septemfasciatus*), nofu (?), ta'uleia (*Parupeneus indicus*) and vete (*Mulloidichthys flavolineatus*).

All the surveyed communities are complaining about the increased sedimentation from commercial sand mining operating in Vaitele just east of the Saina community. According to these claims, the increasing volume of sediments in the mangroves has caused many fish species to migrate into cleaner environment while the less dynamic species are either endangered or already extinct.

Figure 20. Dead blue star fish washed underneath the Rhizopgora scrub by the waves. Photo by Fiu Mata'ese Elisara-La'ulu.

Figure 20 shows a dead blue star fish underneath a *Rhizophora* colony. Local informants said that previously, there were plenty star fish in the foreshore but today this species has become extemely rare. This dead star fish was likely washed ashore by the waves from either the lagoon or the reef. Besides sedimentation, the wider community especially the women group are putting the blame on climate change. They claimed that the sea is getting warmer and strong winds have become more frequent. Coupled with enhanced turbidity caused by increased sedimentation, the slow moving marine animals are most hard hit thus most are dying while some are already inexistent.

3.2.3. Birds

Bird species is an integral component of the mangrove biodiversity in Samoa. They are essential for pollination and dispersal and simultaneously they feed and roost in the mangroves. Regrettably however, the indigenous bird species have declined dramatically because of the loss of habitat. Besides the impact of the invasive species - myna bird *(Acridotheres tristis & Acridotheres fuscus*) and the red vented bulbul (*Pycnonotus cafer)* has driven the indigenous birds from mangrove forests. Both bird species are increasing rapidly and are already dominating the survey area and the fragmented state of the mangroves does not help.

Figure 21. Tulī (Pluvialis dominica), a migratory bird species, resting in the Toāmua mangroves. Photo by Sapa Saifaleupolu.

Samoan mangrove wetlands offer migratory bird species such as the tulī birds (*Pluvialis dominica*) a sanctuary to roost, feed and rest before resuming their global migration (figure 21). The presence of the tulī in the Toamua mangroves has both local and global significance. This species is already classified as rare and probably threatened, so this sighting is important as it gives an indication of hope in restoration. Ecologically, it is pleasing to have safe havens in Samoa to host

the migratory animal species. Table 4 below lists all the sighted birds during the fieldwork and it also includes birds not seen but known to have and still are resident of survey area.

Table 4. Bird Species

Samoan name	Common name	Scientific name	Where found	Abundance	Relationship to the mangroves
Fuīa	Samoan Starling	*Aplonis atrifusca*	Around the forest.	Very rare	Use mangroves both food and nesting sanctuary.
'Iāo	Wattled Honeyeater	*Foulehaio carunculata*	Sighted around the whole forest.	Occasional	Depend on the mangroves for both food and home.
Matu'u	Heron	*Egretta sacra*	At the edge of the seaward boundary.	Occasional	Mangroves host some of the surface fish which this bird species feeds on. Two birds of this species were sighted during the fieldwork.
Myna	Myna bird	*Acridotheres tristis & Acridotheres fuscus*	Inside the mangrove scrubs	Common	Very aggressive against indigenous birds species and because the scrub is quite open in many places, the myna bird can easily establish dominance. Invasive species.
Miti-tai	Polynesian triller	*Lalage sharpie*	Underneath the canopy.	Occasional	Roosts and feeds on flowers and insects within the mangrove forest.
Manu palagi	red vented bulbul	*Pycnonotus cafer*	Mostly in the open areas of the mangrove scrubs.	Common	Feed and roost in the mangroves. An aggressive invasive species taking over territory from indigenous birds species.
Segasega mau'u	Cardinal honey eater	*Myzomela cardinalis*	Underneath the canopy.	Occasional	Roosts & feeds on the flowers and insects within the mangrove forest.
Se'u	Samoan Fan-tail	*Rhipidura nebulosa*	Underneath the canopy.	Occasional	Roosts & feeds on insects and flowers in the mangrove forest.
Tulī	Lesser golden plover	*Pluvialis dominica*	In the front edge of the mangrove.	Occasional	A natural mangrove migratory bird species. Feeds and rests in mangroves.
Tolai				Extinct	A natural mangrove bird. Habitat loss and impact of invasive species especially the myna and red vent bulbul.
Toloa	Pacific black/grey duck	*Anas superciliosa*	Waterways in isolated areas.	Near extinction	This species is nearly extinct from this specific mangrove wetland – most probably due to the loss of a massive portion of the mangrove wetlands.
Manutagi	Purple-capped fruit dove	*Ptilinopus porphyraceus*	Not sighted, but the locals claimed they still haunt the mangroves.	Rare	Seek food and safety in the mangroves during difficult times e.g. tropical cyclones..

3.3. Mammals and Other Animal Species

The only mammal species frequenting the mangrove scrubs in the survey area besides domesticated pigs is the flying fox. Only a few flying foxes were sighted during the fieldwork survey, but the local team members claimed that these flying mammals do haunt the mangroves at night time. Evidence of partially eaten mangrove fruits (propagules) both on the trees and on the mangrove floor was observed. Some of the local young males are still engaged in hunting flying foxes for food. Like many bird species, flying foxes often sought refuge and looked for food in the mangroves after extreme weather events for example, tropical cyclones. This gives another valid reason for conserving and protecting mangroves because by so doing helps safeguard a safe haven for these vulnerable indigenous winged animals.

During the fieldwork we also came across the following animal species which are resident in the survey area. These included two lizard species - black lizard and a green lizard. The sightings were

not inside the mangroves but on big trees now occupying the breaks in the mangroves. Some spider webs were sighted indicating the presence of this arthropod species in the edges of the mangroves. Flying insects were also sighted and felt especially the mosquitoes and flies. A few honey bees were observed in the top of the mangrove canopy where most flowers were found. These are natural mangrove residents and they play a vital role in pollination. Dragonflies were also sighted as they patrolled for food just above the water level. A few hornets on the other hand were also seen roaming about the mangrove canopy.

Figure 22. The Samoan crow butterfly resting on the suni-tai shrubs. Photo by Sapa Saifaleupolu.

We were also able to observe four butterfly species. These were identified as the Samoan crow (*Euploea algea schmeltzi*) shown in figure 22, Monarch butterflies (*Danaus plexippus*), Common crow (*Hypolimna bolinas pallescens*), and the Eastern Pacific albatross (*Appias athama manaia*). These insects were drawn to host plants, fringing the inland edges of the mangroves. Ants are nearly always found anywhere in Samoa and they were present in numbers with 4 distinctive species present in the Toamua mangroves. Table 4 lists the sighted insect species.

Table 5: Insects Sighted in the Survey Area.

Samoan name	**Common name**	**Scientific name**	**Where found**	**Abundance**	**Relationship to the mangroves**
Pepe uliuli	Common crow	*Hypolimna bolinas pallescens*	Inland edges of the mangroves	Occasional	Usual insect species of the mangroves.
Pepe ‘ena’ena	Monarch	*Danaus plexippus*	Inland edges of the mangroves	Occasional	Usual insect species of the mangroves.
Pepe pa’epa’e	Eastern Pacific albatross	*Appias athama manaia*	Inland edges of the mangroves	Occasional	Usual insect species of the mangroves.
Pepe	Samoan crow	*Euploea algea schmeltzi*	Around the scrubs.	Occasional	Usual insect species of the mangroves.
Lago meli	Honey bee	*Apis melifera*	Most near the canopy	Rare	Usual insect species of the mangroves.
Pi	Hornet	*Vespa simillima*	Around the mangrove	Occasional	Usual insect species of the mangroves.
Se’emū	dragonfly	*Arthropoda anisoptera*	Above water surface	Occasional	Usual insect species of the mangroves.
Loi (4 species)	Ants		On big trees.	Common	Possible invasive species.

4. SAMPLE ANALYSIS

Among the objectives of this CCRI is the procurement of accurate environmental data within the survey area. It is very vital to gather both the biodiversity data, as well as this information, especially in regards to the condition of water, soil and air inside the habitat. All these information is pivotal to developing comprehensive MBMAPs. Ideally, all three components should be measured, evaluate and monitored, but available resources allowed only water samples to be collected and analysed. All these samples were hand-delivered to the Scientific Research Organisation of Samoa (SROS) straight after the fieldwork where the analyses were conducted.

A brief reconnaissance of the survey area gave an impression that it would be suitable to do test for heavy metals especially mercury and lead for Vaiusu mangroves which are very close to the old Vaitoloa rubbish tip. For Saina and Toamua mangroves on the other need to be tested for turbidity, pH and biological oxygen demand (BOD) due to its close proximity to the commercial mining in Vaitele. In regards to the microbial water quality, it was decided that all community mangroves will be tested for the total coliform count and total *E.coli* count. The fact that there is still a large number of mangrove users in the survey area makes this part of the CCRI very critical. Although a comparative analysis will be impossible at this stage, the information procured will still be very useful to promote the health dimension of the MBMAP.

4.1. Water Samples

4.1.1. Trace Element Analysis

Table 6:Mineral Analysis

Test	Unit	Sample Reference		Method
		Vaiusu 1 TS 472/1415	Vaiusu 2 TS 473/1415	
Lead	mg/L	8.02	8.77	APHA Methods 3111B
Mercury	µg/L	2.87	2.43	US EPA Method 245.6 (modified)

The analysis results for the two metals in table 6 will now form the baseline database for Vaiusu mangroves. All samples were taken from the surface so comparison of results for the same metal is possible. The respective results for both lead and mercury at the two sites are very similar and in the absence of previous scientific data, determining any existing trend is not possible. At this stage, comparison with other mangroves already surveyed is not recommended because each habitat is subjected to different levels of pollution, urbanisation and development and besides, management measures vary from one village to another hence any analysis will be inconclusive. So unless all those parameters are properly defined and well understood, comparison between habitats will be useless.

There is however an important aspect arising from the results that needs pointing out. That is, all the results for both lead and mercury warrant further examination because they all exceed the maximum contaminant level (mcl) for drinking water which in most developed countries, are 0.01 ppm for lead and 0.001 ppm for mercury.[24] Although the samples were collected from the sea, it is still critical to continue further research on this issue because many local residents are still fishing and gleaning in the survey area, and many households are consuming edible products derived therein.[25]

Lead, even at very low concentrations can still generate a range of health effects including behavioural problems and learning disabilities especially in young children.[26] Young children aged between birth and 6 years old are most susceptible. Children affected by lead poison are associated with slow physical and mental development hence, have some impairment in attention span and learning abilities. Lead poison in grown-ups causes kidney problems and high blood pressure.

Likewise, mercury contaminated water sources (drinking and recreation water) is an extremely serious health issue. In high concentrations, mercury can cause serious damage to body tissues during contact. When ingested, mercury can cause cardiac collapse, kidney failure, and serious gastrointestinal damage.[27]

Table 7. Water Quality Tests

Test	Sample Reference					Method
	Saina TS493/1314 13.18169S 171.80517W	Toamua 1 TS495/1314 13.81434S 171.80610W	Toamua 2 TS496/1314 13.80796S 171.80768W Safune Cape Tiapepe	Toamua 3 TS494/1314 13.80740S 171.80975W Puipa'a east	Toamua 4 TS497/1314 13.80347S 171.81738W Puipa'a west	
pH	7.52	7.38	7.88	7.42	7.63	HACH HQ40d Meter
Turbidity (NTU)	120	33.3	36.5	25.6	370	HACH Meter
TSS (mg/L)	80	68	72	96	228	SPACNET (2008) Method 306
BOD (mg/L)	3.2	5.3	1.3	1.2	1.9	HACH HQ40d Meter

NTU- nephelometric turbidity units, TSS – total suspended solid, BOD – biological oxygen demand

Controlling mercury pollution in water sources at a safe level is more difficult than other metallic contaminants since inorganic mercury can combine with methyl compound in sediment, in fish and in food chain of fish.[28] The task is further compounded because mangroves have multiple sources and entries of mercury contamination. This is also true for all the other metallic pollutants. It is

[24] Australian Government 2008.
[25] Saifaleupolu & Elisara 2015.
[26] Ibid.
[27] Ibid.
[28] EPA 1986, Quality for Water, EPA 440/5-86-001, Washington DC.

therefore crucial for the next series of investigations to accurately identify the major pollution sources.[29] Contamination by naturally occurring pollutants is less likely than those generated from industrial processes, agricultural development and municipal wastes. This makes the task of identifying possible pollution sources a lot more feasible.[30]

Table 7 presents results of the quantitative analysis of the water samples' physical and chemical properties. Turbidity is a measure of water clarity i.e. how much the suspended material in water decreases the passage of light through the water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances.[31] These materials are typically in the size range of 0.004 mm (clay) to 1.0 mm (sand).

Higher turbidity increases water temperatures because suspended particles absorb more heat. This, in turn, reduces the concentration of dissolved oxygen (DO) because warm water holds less DO than cold. Higher turbidity also reduces the amount of light penetrating the water, which reduces photosynthesis and the production of DO. Suspended materials can clog fish gills, reducing resistance to disease in fish, lowering growth rates, and affecting egg and larval development. As the particles settle, they can blanket the stream bottom, especially in slower waters, and smother fish eggs and benthic macroinvertebrates.[32] This analysis has never been conducted before in Samoan mangroves thus, the results now form the baseline database for future use.

4.1.2. Microbiological Analysis

Table 8. Quantitative Analysis

Test	Sample Reference							Method
	Vaiusu 1 (TS472/1415)	Vaiusu 2 (TS473/1415)	Saina TS493/1314 13.18169S 171.80517W	Toāmua 1 TS495/1314 13.81434S 171.80610W	Toamua 2 TS496/1314 13.80796S 171.80768W Cape Tiapepe	Toamua 3 TS494/1314 13.80740 S 171.80975 W Puipa'a east	Toamua 4 TS497/1314 13.80347S 171.81738W Puipa'a west	
Faecal coliform count (cfu/100ml)	3,700	12,800	140cfu/100ml	340cfu/100ml	20cfu/100ml	30cfu/100ml	30cfu/100ml	APHA (2012).Method 9222D
Total *E.coli* (cfu/100ml)	3,000	5,750	90cfu/100ml	290cfu/100ml	10cfu/100ml	30cfu/100ml	30cfu/100ml	APHA (2012). Method 9222D

**cfu – colony forming unit*

Microbiological pollution, especially *E. coli*, of recreational water including the sea and the mangroves has been associated with enhanced gastrointestinal diseases and respiratory problems. Most strains of *E. coli* however do not cause human illness (that is, they are not human pathogens);

[29] Chorus & Mur 1999, Preventative measures.
[30] ibid.
[31] Bash and Berman, 2001 Effects of Turbidity and Suspended Solids.
[32] APHA 1992. Standard methods for the examination of water and wastewater; also in White 1994. Monitoring a watershed; and also in Minnesota Pollution Control Agency 1997.

rather, they indicate the presence of fecal contamination. The basis for recommending criteria that use bacterial indicators of fecal contamination is that pathogens often co-exist with indicators of fecal contamination. Hence this kind of contamination is regarded mostly as a pathogenic indicator.

Table 8 displays results of microbial analysis of the same water samples used in section 4.1.1. Again, comparative analysis to indicate increase or decrease in this kind of pollution is impossible. The results are nevertheless intriguing because they show a general declining trend of both total coliform and total *e.coli* contamination from east to west. At this stage, the possible pollution sources are not known. Nonetheless, it is useful to point out that Vaiusu (in the eastern end) with the highest pollution results is the closest part of the survey area to the old Vaitoloa rubbish dump and it is also the entry point of the Fulu'asou River into the sea.

Despite the variance in conditions surrounding each surveyed habitat, it is still interesting to note that Vaiusu now records the highest total coliform count and total *e.coli* concentrations. This study is probably the first of several researches that will be undertaken in this part of the Samoan mangroves since it is located adjacent the most industrialised section of the urban area. With many households still deriving part of their livelihoods from these natural resources, proper resource management is critical. This will involve designing proper pollution control measures.

Globally, the pollution issue (water, air and soil pollution) has never been given the attention it deserves even though it has been sounded out as extremely dangerous and fatal.[33] Although it kills slowly and stealthily, its total tally is enormous. It is responsible for more deaths than malaria, tuberculosis and HIV combined.[34] Information from the WHO and the Institute for Health Metrics and Evaluation has shown that total pollution (water, soil and air) accounts for nearly 9 million deaths in 2012.[35] Statistically, this is more than one in seven deaths globally which can translate to exceeding the death toll caused by smoking, war or malnutrition. Subsequently, pollution is currently the leading cause of death globally and is also connected to ruining economies as well as inhibiting growth in countries that really need to develop.[36]

Although this may not be the situation in Samoa, global indications provide useful tips to promote good development policies and practices that are economically, ecologically and culturally friendly. This indeed includes prudent pollution control measures. For mangroves restoration, conservation and protection, pollution control needs to go beyond the physical boundaries. Land-based development – agricultural, industrial and domestic, all generate some form of pollution that will end up in the mangroves hence they need to be factored into the pollution control strategy. Proper mangrove management should also target an integration of ecological, cultural and health impact considerations into social-economic development processes.

[33] Fuller 2015, Pollution – The Greatest Killer.
[34] ibid.
[35] ibid.
[36] Ibid.

5. PROBLEMS

The survey area is very vulnerable to the pressures from urbanisation, industrial development and population increase because it is located in the peri-urban area. Mangrove biodiversity in particular has suffered already mainly due to unsustainable harvesting, conversion, and rubbish dumping so the contribution from these external drivers will intensify the pressure. The surveyed communities will continue to suffer because many residents are still deriving their livelihoods from the mangrove ecosystem services. The increased severity of the impacts of climate change coupled with more frequent extreme weather events will only to deteriorate the situation for communities.

This CCRI seeks to improve mangrove resilience in order to reinforce the capacity of mangrove biodiversity not only to provide for community livelihoods but to save community lives. In their pristine state, mangrove biodiversity can provide community needs and security. The following have been identified as the more pressing issues in the survey area and efforts need to be made to reverse the declining trend. The village communities with assistance from the government and other external partners must genuinely address and resolve the problems identified below. Addressing the core causes, both internal and external, is crucial to the remedial process. A comprehensive and integrated approach must be employed to heighten interest and willingness to participate and to contribute throughout the rehabilitation process. This will indeed boost confidence and generate community enthusiasm to make sacrifices via time, monies and skills; all of which are important asset for project success.

5.2. Sand Mining

Commercial sand mining operation in Vaitele (very close to Saina and Toamua) is the biggest of its kind in Samoa, is still in full operation (figure 23a). The operation has contributed significantly to the development of the construction industry in Samoa. Yet it has been identified as the major source of sedimentation in the survey area especially the bordering villages in the west - Saina and Toamua. Enhanced sedimentation contributes to the decline of mangrove and nearshore fisheries and is very unfavourable to the development and growth of mangroves (figure 23b). Sand mining requires a permit from the MNRE; the same government agency with the mandate to protect and conserve the biodiversity including those in the mangroves and the lagoons.

Resolving this challenging issue will require a balanced approach from the government (MNRE) where on the one hand the sand mining operation needs to continue because it provides an essential service for communities and on the other, strict control measures should be put in place to ensure ecologically sustainable and safe limits are adhered to. This is a critical step because most of the coastal development activities in urban areas, involve dredging and sand mining which invariably enhances sedimentation that affects the visibility of the water column. Such condition results in the reduction of the ability of light to reach the ecosystems in the bottom of the water column and this can be detrimental and even fatal. These conditions have been associated with the destruction of mangroves and other ecosystems such corals reefs.[37]

[37] Hughes et al, 2003, Climate Change, Human Impacts, and the Resilience of Coral Reefs.

(a)

(b)

Figure 23. (a) Commercial sand mining in less than a kilometre from Saina and Toamua mangroves. (b) Mud is grey rather the normal dark black due to enhanced sedimentation from commercial sand mining in (a), and is destroying ecosystems in Saina and Toamua mangroves.Photo by Fiu Mata'ese Elisara-La'ulu.

So, neglecting this necessary step allows the commercial sand mining to exploit the resources and making enormous profits at the expense of both the biodiversity and the adjacent communities which are already suffering due to the degradation of fisheries that traditionally provided for their livelihoods and income generation. The balanced approach is crucial and once it is developed and applied, the responsible company will be held accountable for any damage inflicted upon the communities either via the loss of food supply, or health related incidents. For example, when a resident contract some form of allergy caused by turbid seawater or simply the enhanced content of sand dust in the sea, the mining company must be accountable.

5.2. Mangrove Trashing

(a)

(b)

Figure 24. (a) & (b) Solid wastes in the old Vaitoloa rubbish tip 1km east of Vaiusu mangroves.Photos by Fiu Mata'ese Elisara-La'ulu.

Recent mangrove trashing, based on survey observations, was relatively minor. However, solid wastes dumped in the mangrove forests and foreshore in the survey area several decades ago are still visible and are likely to be around for a very long time as illustrated in figures 24 a & b. The communities on their own do not have the resources or the skills to remove, reuse or recycle these wastes. But they are a pollution source and are making these mangroves unusable because they pose a threat to personal safety, hence must be removed and disposed in a proper rubbish dump or

recycled. Wastes not only make mangroves unattractive, but they do contaminate the habitat. The same is true for solid wastes such as used tyres and metallic cylinders thoughtlessly dumped in the mangrove as depicted in figures 25 (a) and (b).

(a)

(b)

Figure 25. (a) Saina – used tyres dumped in the mangroves. (b) Although rare, solid wastes like this metallic cylinder litter the Toamua mangroves. Photo by Sapa Saifaleupolu.

More than ever before, small economies like Samoa are increasingly inhibited by the amount and type of wastes generated, hence it is critical to have this under control and properly managed. Indeed this must become an integral part of Samoa's strategy for sustainable development. Good and effective waste management has the ability to minimise Samoa's global footprint. Ignoring the challenges associated with wastes can be disastrous and may lead to significant health, ecological and socio-economic consequences.[38] The surveyed communities during CCRI consultations are committing themselves to prevent mangrove trashing by reinforcing local taboos that ban dumping rubbish in the mangroves.

5.3. Unsustainable Harvesting

Cutting down mangroves to meet domestic demands at the community level has always been a problem in most mangrove wetlands in Samoa. The problem is more accentuated in urban communities including the survey area due to the limited access to community forests where such resources were traditionally collected. Communities have always been highly dependent on mangrove ecosystem services and products and therefore suffer when mangroves become overharvested. Although very little mangrove cutting is still done in the survey area, the communities are still burdening the consequences of poor use practices of the past.

Unsustainable mangrove harvesting in other countries is also identified with the severe decline of mangroves' dual capacity as an atmospheric CO_2 sink and an essential source of oceanic carbon.[39] Besides, the ability of the mangrove ecosystems to provide the crucial services for terrestrial and marine food webs has already being compromised, and this has caused negative impacts on fisheries.[40] The mangrove loss also poses a potential threat to many mangrove-dependent fauna

[38] Cicin-Sain et al, 2002, Oceans, Coasts and Islands at the World Summit on Sustainable Development and Beyond.
[39] Kavanagh 2007, A World Without Mangroves.
[40] Barbier 2007, Econ. Policy 22, 177.

with their complex habitat linkages, as well as physical benefits like the buffering of seagrass beds and coral reefs against the impacts of river-borne siltation, or protection of coastal communities from sea-level rise, storm surges, and tsunamis.[41] Like the communities in the survey area, human communities living in or near mangroves have already lost access to sources of essential food, fibres, timber, chemicals, and medicines.[42]

(a)

(b)

Figure 26 a & b Beach erosion is a serious problem in the survey area - erosion has encroached more than 25m inland in both pictures because mangroves have been destroyed through overharvesting. Photos by Fiu Mata'ese Elisara-La'ulu.

Resolving this problem is never easy. The community elders have been talking about placing a total ban on mangrove cutting. In reality however, many households are isolated from alternative sources of firewood and building material. So when households are pushed against the wall, even the community ban cannot stop them from using mangrove wood for firewood as this may be a matter of survival. Again, communities need to plan wisely and must look for options that are both ecologically friendly and at the same time able to meet their most basic needs.

Figure 27. Family homes built on former mangrove zone. Photo by Fiu Mata'ese Elisara-La'ulu.

A major consequence of permanent removal of mangroves in the survey area is enhanced beach erosion. Most forests or scrubs display natural zonation where species are distributed according to the resilience to factors such as salinity and inundation. Such a zonation is no longer apparent in the survey area because the mangroves have been exposed to abuse for a long time. As such, the *Bruguiera* zone has disappeared and is now replaced by household dwellings and other coastal species and/or invasive species. In most cases, these spots do not even host the *Rhizophora spp*., as a result, the foreshore

[41] McLeod & Salm, Managing Mangroves for Resilience to Climate Change (IUCN, 2006).
[42] Ewel et al. 1998, Variation in environment characteristics and vegetation in high rainfall mangrove forests.

becomes more vulnerable to erosion because naturally both mangrove species work together in dissipating the wave energy which minimises beach erosion.

Even in areas dominated by other coastal and invasive plant species; the destructive power of the waves is evidently pushing the erosion problem further inland (figure 26 a & b) making households and private properties more vulnerable to inundation during high tides. This is a critical problem for the survey area because the residential area bordering the mangrove zones is very low-lying and can be easily inundated during heavy swell, storm surges and tsunamis. Figure 27 illustrates this situation where the waves and tidal activities have pushed the boundary through erosion into this house's foundation. This household will always live under the threat from the sea during weather extreme events.

5.4. Land Reclamation

The mangrove zone in the western end of the survey area (Toamua west) has been severely modified by land reclamation for business operations and household residences. There are no recent reclamation activities in the surveyed communities however, past practices of this kind have fragmented huge areas of pristine mangrove forests causing irreversible damage because these are now used for business and residential purposes (figure 28 a & b).

(a) *(b)*

Figure 28. (a) Mangrove forests converted into a tourist resort in Safune (Toamua central). (b) Mangrove zone filled for residence expansion (Toamua west). Photo by Fiu Mata'ese Elisara-La'ulu.

In Vaiusu, the only evidence of reclamation is the failed access road project built in the mid 1900's, shown in figure 29 below. The project was never completed but the evidence is a constant reminder that poorly planned development always puts undue stress on the very resources that communities depend on for survival. In the absence of proper scientific data the magnitude of the stress remains unknown but the reclaimed area affects the natural flow of the currents. This in turn impacts upon the various components of the biodiversity that depend on the current for supply.

Figure 29. Remnants of a failed village access road project some decades ago. Photo by Fiu Mata'ese Elisara.

Undisturbed mangrove ecosystems enhance the aesthetic quality and the natural beauty of the coastal scenery which this unfinished road has destroyed. To move forward, the community cannot dwell on the negative; rather the lessons learnt provides and enabling environment to plan with prudence and wisdom. Developments of this kind demands that ecological and cultural values should be integral components of all economic and social policies and development plans at the local community level.

5.5. Invasive Species

A growing problem in most fragmented mangroves today is the dominance of invasive species. Of special significance are the two *Albizia* species – *A. falcataria* and *A. chinesis* which have inhibited the development of mangroves in large areas of all the surveyed communities. Figure 30 depicts this effect on part of the Vaiusu mangrove zone. The two mangrove species found in the part of the survey area (*Bruguiera and Rhizophora*) which are slow-growing and shade intolerant just cannot compete with these fast-growing species.

Figure 30. Vaiusu (middle) – Invasive Albizia falcataria dominates the middle section of Vaiusu coastline. Photo by Fiu Mata'ese Elisara-La'ulu.

In the background of the picture in figure 30 is a domineering grove of *Albizia,* which at the moment is total full control in this part of the Vaiusu coastline. In a situation like this, the village community will need to intervene in order for mangrove rehabilitation to progress. Ideally, these tree species should be controlled when they are young. They can be harvested for firewood before they get really big. In that way, they do not produce too much shade which inhibits mangrove growth and development.

It is also wise to advise the communities at this stage to be more cautious in planting introduced trees species close to the mangrove zone. Some of the introduced tree species are fast growing and can reach enormous height with wide canopies which also constrain mangrove development.

5.6. Algal Bloom

The most challenging threat to the CCRI mangrove planation in Vaiusu community comes from the enormous amount of the long fibrous algae (*Cladophora sp*). The women committee in Vaiusu, who is in charge of the CCRI project, has been removing huge volumes of algae from the plantation on a daily basis. The algae need removing because they can easily smother the young trees and the seedlings.

Figure 31. Dead algae (Cladophora sp) washed ashore by waves. Photo by Fiu Mata'ese Elisara-La'ulu.

This species grows naturally in conditions where there is a balanced mixture of sea and fresh water, but it proliferates very quickly when the proportion of fresh water increases coupled with an enhanced level of nutrients from stormwater and agricultural runoff - especially nitrogen and phosphorus. At this stage, the species poses a potential threat to other marine ecosystems including a young mangrove trees.

Some of the dead algae end up on beach as shown in figure 31. Nonetheless, either dead or alive, they still pose a threat to the young plantation. Literally taking this massive mas of algae from the plantation area and have them dumped in suitable areas inland is not an easy task. But challenges of this nature require total commitment and a lot of sacrifice which the women are very capable of.

5.7. Land-Based Pollution Sources

Even at the lack of reliable data, section 5.6 above provides some form of indicator to gauge both the existence and the magnitude of this problem in the survey area. In order to procure accurate scientific data, further research is necessary. The key task at this stage should focus on identifying the problem. Understanding the problem is critical to designing relevant measures to avert and rebuild declining ecosystem resilience. The same awareness helps community to make appropriate lifestyle and attitude changes that are beneficial to both the mangrove biodiversity and the human community in general.

Chapter 4 deals with the sample analysis which indicates a relatively higher mineral and microbial pollution levels in the survey area compared to safe contamination levels in developed nations. This is not conclusive, however, remedial measures need to be flagged out and comprehensively discussed at both the community and the national levels. In fact this is a crucial step because Samoa is not immuned to the pollution problem. With regards to global water/sea pollution, more than 77% is caused by pollutants that were generated on land, with about 44% of these derived from improperly treated wastes and run-off.[43]

At the global level, sea pollution has recently increased dramatically as more and more nutrient-rich runoffs enter – a direct result of the increase in unsustainable applications of fertilizers and other agricultural chemicals, coupled by increase leachates in sewage and aquaculture wastes. As alluded to in section 5.6, excess level of nutrients in particular nitrogen and phosphorus promote algal bloom in lagoons and on reefs and this depletes oxygen in the water which imperils the existence of other marine and aquatic life forms.[44] Samoa is notorious for poorly planned land-based development mainly in agriculture, forestry and earth moving construction works that almost always exclude strategic measures to minimise the ecological and cultural damages on land and sea.

6. DISCUSSION

Several decades of intensive researches have helped increased the knowledge about mangroves and unveiled a better understanding of the associated ecosystems with the rich and unique biodiversity they support. Healthy mangroves are extremely diverse with complex ecosystems with unique structural and functional adaptations necessary to deal with saline, oxygen deprived soils and regular tidal inundation.[45] Besides being an excellent bio-shield, they are among the most productive and bio-diverse wetlands on earth.[46] Notwithstanding their usefulness and value, mangroves are still the most undervalued and the most threatened species in the world.[47] They are being destroyed at rates 3-5 times greater than the average loss rates of other forest types. Likewise, most mangroves in Samoa including those in the survey area have been severely destroyed due to drivers discussed in section 5.

In light of this enormous rate of destruction coupled with the fact that 16% of the mangrove species are at an elevated threat of global extinction,[48] it is extremely important to acquire a better and accurate understanding of the implications of further loss to biodiversity, and at the same time design an appropriate long-term strategic pathway to ensure these valuable natural assets will not become extinct in the near future.[49] This CCRI project has taken up some of these salient factors in pursuit of securing an accurate baseline database to be sued for the survey area and for Samoa as well.

[43] Cicin-Sain et al. 2002, Oceans, Coasts and Islands at the World Summit on Sustainable Development.
[44] Hughes et al. 2003, Climate Change, Human Impacts, and the Resilience of Coral Reefs.
[45] Russi et al. 2013, The Economics of Ecosystems and Biodiversity for Water and Wetlands.
[46] Parvathy 2012, A brief Review of Merits and Demerits of Coastal Bio-shielding.
[47] Primavera 2014, Magnificent Forests on the Edge.
[48] van Oudenhoven et al. 2012, "Framework for Systematic Indicator Selection.
[49] Saifaleupolu & Elisara 2014, Toamua BDA.

Like other Samoan villages, many households in the surveyed communities still derive their livelihoods from the mangrove ecosystems.[50] This project focuses on providing building blocks (ecological and environmental data) for a robust and meaningful MBMAP since this is a practical and relevant pathway for mangroves to be managed in order for the biodiversity decline to be reversed which should improve ecosystem resilience. Besides the scientific information, the study provided a useful opportunity to raise awareness about mangroves' role in boosting coastal protection, as well as better understanding about their mitigation-adaption suitability as CO_2 sink – all are vital for the MBMAP design and implementation.

The above action is becoming more urgent as the mangroves continue to decline because a large number of mangrove-dependent households are already feeling the pressure due to threatened food security and loss of income. At the global level, this is becoming a legacy of communities in many poor developing countries which are very much dependent on ecosystem services. The decline makes them more vulnerable when natural ecosystems become increasingly degraded hence less productive.[51] The basic elements derived from the ecosystems such as security (food security, personal safety and coastal protection), material (firewood and building), health (access to medicine, clean air and water) and social aesthetic conditions are among the key targets that need to be reinstated through this initiative.[52]

An ongoing problem associated with most of the above services derives from a general perception by the communities that these are public goods hence they are available to all. According to Bolt et al. 2005, the problem with public goods is twofold:[53]

i. Everybody can use them without depleting their availability for others, and
ii. It is very difficult, technically, to prevent people from using them. In other words, public goods are "non-excludable".

As a result in many cases, there is little incentive for communities to either provide or protect these goods. Hence communities tend to ignore the need for proper management; instead they are more inclined to use them in an exploitative manner which consequently inflicts serious damage on the resources thus triggering decreasing productivity and supply shortage.[54] This statement portrays part of the underlying causes of the demise of the mangrove biodiversity within the survey area. For example, Saina has lost 80% of its mangroves while Vaiusu and Toamua have each lost about 60% of their respective mangrove forests. The consequence is painful because the three communities are still carrying the burden. The other important driving forces are of external origin. These include sedimentation, pollution and climate change.

Minimising the internal causes is the less difficult part of the MBMAP because Samoan communities are used to resolving internal matters themselves using cultural norms and traditional precedence which can be strengthened by some assistance from the government and/or other external partners. Ecologically unsustainable practices such as overharvesting and overfishing, local sand mining, rubbish disposal and poor sewage wastewater facilities can be locally addressed. Dealing with

[50] Saifaleupolu & Elisara 2011 & 2013.
[51] WRI 2005, World Resources: The Wealth of the Poor.
[52] MEA 2005, Ecosystems and human well-being.
[53] Bolt et al 2005, Estimating the cost of environmental degradation.
[54] Ibid.

external causative effects at the community level however is extremely difficult because they originate outside the geographical boundaries of the survey area so they cannot be dealt directly by the disadvantaged communities as they are beyond normal cultural jurisdiction.

For example, the impact of commercial sand mining just east of Saina and Toamua has destroyed the fisheries and the marine biodiversity in these two communities. This is injustice! While the sand mining company is making profits, the affected communities are struggling to make ends meet. According to Brown et al. 2008, the poor have had minimal impacts overall the decline in ecosystem services and have also received a disproportionately small share of the benefits of ecosystem services in coastal and marine systems.[55]

However, this does not condone the unsustainable use of these services by the poor, even in situations where other options are restricted, which has been responsible for the destruction of many ecosystems.[56] The first impetus triggering the demise of the mangroves in the whole survey area falls into this category where the actions of the local residents underpin most of the mangrove degradation. The situation surrounding this challenging issue is very fragile and the affected communities and their partners need to plan with caution and wisdom in an attempt to provide remedial alternatives. It is all too easy for outsiders to condemn these communities for destroying the mangroves which have sustained them for many generations. These communities were forced into this situation ever since they lost most of their customary lands during the colonial era which means they lost traditional firewood and building material supplies.

In response under these trying times, the Vaiusu community has already taken the lead in launching the mangrove replanting project - a demonstration of community commitment and solidarity for the common good. The initiative has been applauded and is hoped to generate interest in the other two communities of the survey area as well as others whose mangrove resources are experiencing degradation. The initiative also illustrates an increased ecological awareness at the community level and a simultaneous growing appreciation of the ecosystems and the invaluable services they provide.

Scientific information gathered from many mangrove studies around the world has provided an enabling environment to acquire a better understanding of mangrove ecosystems and the biodiversity they support. This however does not depreciate the value of local research because each habitat has its own unique and intricate characteristics which are absent in others. Besides, local research must be undertaken due to the urgent need to procure accurate scientific information essential for establishing a reliable baseline database. This is a key consideration in this CCRI project but further research is highly recommended to procure more information not only to strengthen the baseline, but to investigate those that have never been examined.

Besides, Samoa like other countries has for some times experienced a high population growth rate which when coupled with a parallel increase in per capita consumption have contributed to a huge increase of the national and world's ecological footprint.[57] For the Samoan mangroves, it is imperative to evaluate the full range of ecosystem services that benefit the communities and have

[55] Brown et al. 2005, Ecosystem services for Poverty Alleviation.
[56] MEA 2005.
[57] Myers 2015, "Clear and Present Danger", in Our Planet, UNEP.

them integrated into the decision making for coastal development at all levels. This cannot be done without a properly coordinated collaborative effort where all the stakeholders are required to contribute, to share and to learn through the experience.

Moreover, Samoa and all the small island countries of the Pacific account for less than 0.01% of the total global CO_2 emissions but will continue to be on the forefront of the destructive impacts of the global climate change. [58] Regrettably this condition continues to intensify as enormous amount of greenhouse gas gets emitted daily thus committing Samoa and all small Pacific countries to more severe climate change for decades or centuries to come, regardless of mitigation efforts.[59] This change is occurring a lot quicker than previously predicted and is causing major problems in most ecosystems as they encounter these unprecedented conditions. This anthropogenic induced climate change has already altered species and ecosystems across the globe.

The above also needs to be strengthened and integrated into the above dialogue at the regional, national and the community levels. Samoa and the rest of the Pacific must explore means to secure accurate data to especially those concerning the ecosystems' and species' perseverance against the opposing forces of climate change. For Samoa, we are obligated to provide answers to questions such as "how resilient are our mangrove ecosystems when bombarded by climate change related events such as super storms or an abrupt temperature increase?" Answering these questions requires global and regional co-operation and Samoa needs to be an active participant. This is critical because recent estimate of global species extinctions is still on the rise with at least 38% of all known species being pushed towards extinction.[60]

A key component of this CCRI involves developing strategies that enable proper evaluations of climate change impacts on specific mangrove ecosystems and species. It is also vital to have accurate information on mangroves' ability as a carbon sink – relationship between mangrove carbon stocks and greenhouse gas emissions. Research has already begun on this topic but is yet to be done in Samoa. Procuring this information and integrating it with other plausible causes of extinction with identified threats, will expedite the process of designing relevant adaptation-mitigation measures that can be implemented at the national and community levels. More assessments and evaluations to determine how carbon, biodiversity and ecosystem services are connected need to be properly planned and carried out in the near future. Understanding this relationship will be an immense help in identifying the most valuable hotspots of mangrove habitat which will be essential in refining remedial strategies in MBMAP.[61]

Further research is also necessary to establish a better understanding of the pollution problem. This will include an analysis of possible drivers. Preliminary results secured in this study have indicated that pollution is a serious challenge that needs urgent rectification. The more toxic metals – mercury and lead have both recorded values that are much higher than safe limits for drinking water in developed nations. It is important to have these monitored in a more frequent and regular basis. While regular monitoring for a large number of chemical contaminants may not be justified, there may be instances where local knowledge or accidental spills justify increased surveillance.

[58] Boden et al. 2008, Global, Regional, and National Fossil-Fuel CO2 Emissions.
[59] Myers 2015.
[60] Vie et al. 2009, Wildlife in a Changing World.
[61] UNEP 2015.

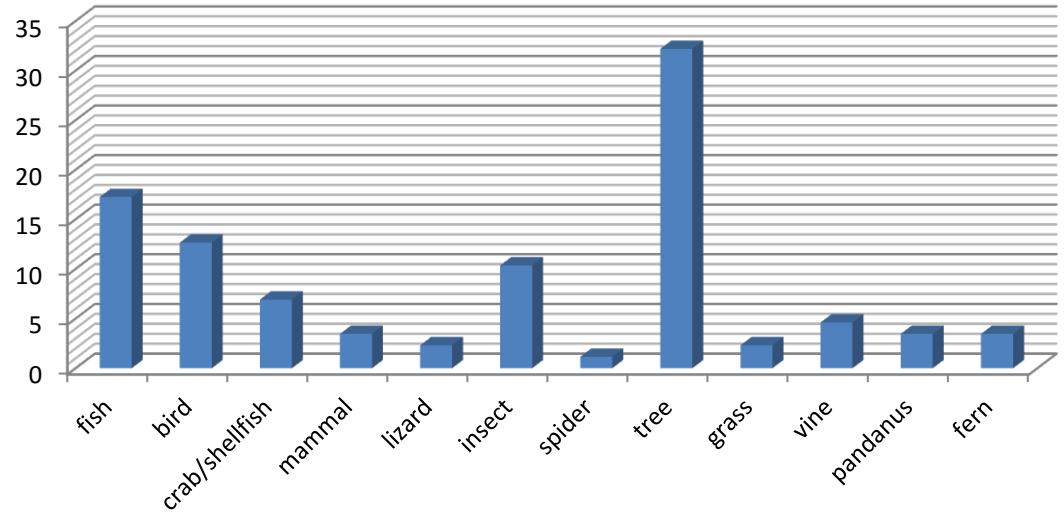
Agriculture-based water/sea pollution also requires proper monitoring and to establish proper control that regulates the use of chemicals to ensure that management practices address all potential chemical contaminants in recreational water. This exercise must stress the fact that sediments usually concentrate chemical contaminants and these eventually get washed into the sea hence they should be included in the monitoring process because their impact can be severe especially in shallow mangrove and lagoon waters.

A similar trend appears in the microbial analysis where all test results exceeded the safe limits prescribed by environmental agencies in the first world countries. Although more testing is necessary, the outcome should not be taken lightly because contamination of recreational water with fresh faecal matter from either humans or animals can lead to health problems because of the presence of disease-causing microorganisms (pathogens). So categorising recreational water by its microbial quality via the combination of sanitary inspection and microbial water-quality assessment is useful. The approach provides information on possible sources of pollution and numerical data on the likely level of faecal pollution. The survey results however should not create panic because further research and analyses are still required to establish the level of confidence and validation. The results now obtained will help form the baseline database which will be used in the design of the proposed MBMAP for each community in the survey area.

Table 9. **Biodiversity Audit.**

Species	Number	Percentage
Fish	15	17.24
Bird	11	12.64
Crabs/shell fish	6	6.90
Mammal	3	3.45
Lizard	2	2.30
Insect	9	10.34
Spider	1	1.15
Tree/shrub	28	32.18
Grass	2	2.30
Vine	4	4.60
Pandanus	3	3.45
Fern	3	3.45
Total	87	100

Figure 29: Plant and animal species in Vaiusu, Vaigaga & Vaitele Mangrove Wetland (%)



A major objective of this CCRI study involves conducting a mangrove biodiversity audit (BDA) in the survey area which is displayed in Table 9. A cautionary note – this survey did not record the less visible species like algae and the multitude of microorganisms that dwell in the mangrove wetlands. It is also important to note that the totals in table 9 were derived by adding the actual sightings during the field surveys and the species claimed by the local communities to be still visiting the mangrove forests although we were not able to see them. All of the absentee species are faunal - especially fish, birds, crabs. It is also important to point out that since this is the first BDA conducted for the surveyed communities, any meaningful comparative analysis is not possible however the BDA plus the sample analysis outcomes will now form the baseline database for the respective communities. This provides an enabling environment for communities in the survey area to design a relevant MBMAP essential for initiating mangrove rehabilitation and conservation.

7. CONCLUSIONS

The mangroves in the survey area are under tremendous pressure from overharvesting, urbanisation, industrial development, population increase and mangrove trashing. As a result huge areas of mangroves have been destroyed and ecosystems are deteriorating. This has generated a significant loss of biodiversity thus inhibiting the potential to regenerate naturally and at the same time disrupting the vital ecosystem services for humans and geographically removed ecosystems. Traditionally, communities in the survey were very much dependent upon these ecosystem services for livelihood support and protection. The decline however has forced many community residents to endure difficult times as they struggle to make ends meet.

Among the major drivers of mangrove destruction is the absence of good governance at the community and national levels. Despite the existing government legislations they have been ineffective to stop the destruction of the mangroves in the survey area. Similarly, traditional laws were unable to prevent the onslaught of the mangroves. The decline as a result will continue to

increase, if properly designed remedial measures are not applied. Hence, both the ecosystems and human communities that are dependent upon them will continue to suffer the consequences and the quality of life declines as a result. For the most disadvantaged within the community, the ordeal has led to income and food loss which can result in poverty and starvation if conditions do not improve. For some, this has become too stressful so they have decided to relocate. Preventing these ramifications requires immediate action – communities with some assistance from external partners must apply proper mangrove management strategies that focus on long-term biodiversity conservation, hence the need for an MBMAP.

The tragedy of the commons as exemplified in the treatment of public goods has severe impacts on the surveyed mangroves. Community residents are more inclined to help themselves without really giving conscious thoughts about the dire consequences to the well-fare of both the resources and the rest of the community. The whole community is now burdening the consequences of such attitude in the past. Even the best designed policy or legislation regardless of their necessity, cannot change this condition. The community need an attitude change. Raising awareness at all sectors of the economy and at all levels needs to be an ongoing process. Community members from all walks of life can only work together if they have a good common understanding of the dire consequences of their actions upon the mangrove biodiversity as well as those depending on the associated ecosystem services. Moreover, the attitude change must be anchored onto a comprehensive and transparent approach that clearly links the economic, social, ecological and cultural aspects (benefits and costs) of mangrove rehabilitation and conservation. If this is ignored, the resilience of the mangrove biodiversity will continue to decline. Hence, the ecosystem services will to deteriorate and the communities will continue to suffer.

External forces destroying the mangrove biodiversity are more difficult to resolve. The ongoing industrial-related destruction of mangrove and marine biodiversity in Saina and Toamua is tremendous and if it is not addressed properly and promptly, the damage may soon become irreparable. The community needs to stand up for their right to access and to use untarnished ecosystem services and products from its cultural heritage – mangrove wetlands. A harmonious solution is required where the government has to intervene. Also the communities do not have the resources or the capability to the address other external forces for some of the solutions will involve scientific research. Assistance from the government and external partners in procuring the scientific information is therefore essential. Mangrove management practices become more useful when they are backed with accurate scientific data.

The whole survey area is fairly low-lying hence the coastal dwellers are always vulnerable to the extreme weather events and tsunamis. The destruction of the mangrove forests has increased the vulnerability and as a result, some have relocated to higher grounds as a safety precaution and more will follow if degradation is not reversed immediately. In some cases, the government and external partners will need to intervene by building seawalls to protect the communities, public infrastructure as well as the biodiversity.

The Toamua mangrove wetland holds special ecological significance because it hosts the most rare mangrove species *X. moluccensis*. While this is a key finding, more information is still needed to ensure the species' protection. The village community is excited concerning the discovery but their strong support is even more important because it holds the key to securing proper protection and

development of this mangrove species. This is imperative because there are only a few *X. moluccensis* trees left in this habitat and since they are not existing as a colony makes them very susceptible to the domineering aggression from other tree species. This also applies to the *Bruguiera* species which is estimated to make up only 0.8% of the total mangroves. Without community support this mangrove species will become extinct in the near future from this wetland.

Strong natural regeneration is occurring in many sections of the survey area and members of the community are taking advantage of this feature e.g. the Vaiusu mangrove plantation. Mangrove species are very resilient and This is evidence of the resilience of mangrove ecosystems which the Vaiusu women's committee has taken advantage of. So despite the deteriorating condition, there is still potential for mangrove restoration and rehabilitation. The outcomes of this study will also increase the ability of communities to develop their own respective MBMAP.

8. RECOMMENDATIONS

In an effort to reverse the deteriorating condition of the mangroves in the survey area and simultaneously improve mangrove ecosystem resilience, it is recommended that an integration of rehabilitation-conservation and mitigation-adaptation strategies be employed. The fight against the decline of mangrove biodiversity cannot be remedied through a conservation focus alone because the issue is intricately connected to climate change. This approach integrates a diverse series of tools, for instance, building a seawall with parallel mangrove planting in the seaward location complemented by simultaneous land-based development programs that encourage the inclusion of soil erosion safeguards and also incorporates pollution prevention measures.

Reversing biodiversity decline and climate change adaptation-mitigation measures demand making difficult but wise choices among sea- and land-use practices - especially in vulnerable but ecologically significant ecosystems like the mangrove wetlands where the competition among the various users is fierce. Since community members are uniquely different, the preferred options are diverse so choices will involve trade-offs and the need to reconcile opportunities for mangrove rehabilitation, developing secure infrastructure, expansion of industry and business or conversion into residential and worshipping areas. The recommended preferences support mangrove rehabilitation and conservation so the mitigation-adaptation measures should emphasise the total benefits associated with reversing the current decline. In so doing, the surveyed communities will become more accountable for the strategic approach to becoming climate change resilient.

The proactive initiative undertaken by the Vaiusu women's committee is applauded for it provides the necessary impetus to expand to all fragmented sections of the survey area. It is strongly recommended that the other communities – Saina and Toamua, need to proceed with similar projects. This is critical, especially in the face of inevitable rising sea level that will continue for many generations. Rehabilitating and protecting these long-term reservoirs of carbon and preventing their emissions back into the atmosphere is a sensible and cost-effective measure to help mitigate climate change and simultaneously maintain other ecosystem services that are vital to the food security and livelihoods of many people. Mangrove rehabilitation and conservation therefore need to be part of mitigation-adaptation measures and a component of community MBMAP.

Mangrove rehabilitation needs nurturing of all mangrove species - *Rhizophora*, *Bruguiera* and *Xylocarpus* since they are ecologically designed to integrate as a harmonious community that provides ecosystem services necessary for other components of the habitat including humans. Together, they form the best bio-shield for human communities. The *Bruguiera spp*. is nearly extinct in the survey area hence arrangement with villages with mangrove forests needs to be made for *Bruguiera* seedling procurement. Mangroves have enormous capacity to absorb CO_2 from the atmosphere thus making them ideal carbon sinks. Comparatively, they are capable of sequestering more carbon than any other forest type, and storing this carbon for an extremely long time. Promoting mangrove rehabilitation and conservation therefore is strongly recommended as part of the community and national effort to be climate change resilient.

Detailed vulnerability and risk assessments for long term human impacts including trends in mangrove loss and degradation and forecasts for future changes should be an integral part of the MBMAP. These assessments need to consider both coastal and inland impacts. Mangrove vulnerability assessments can identify aspects of mangrove areas that are already under stress and allows identification of specific factors of vulnerability in each different mangrove area. This will assist in the process of prioritisation of mitigation-adaptation actions to reduce vulnerability and to assist communities in making informed decisions with respect to climate change which makes the allocation of limited resources more effective.

Further studies on the mangroves' relationships with adjacent ecosystems as well as the food web dynamics and species' roles in regulating and supporting the functioning of the mangrove system is very important. Understanding these improves management practices to maintain healthy mangroves, and thereby improves the quality vital ecosystem services.

Proper mangrove management will require full support and participation of local communities, thus the need to use an integrated approach that is both all-inclusive and participatory. Such a step will enhance the capacity of the communities to respond wisely and more effectively to the multi-dimensional challenges of conservation management, particularly its human, technological and institutional aspects. The outcomes of the recommended research will help facilitate a comparative analysis that enables communities to make well-informed decisions with regards to good practices and innovative methods that are more relevant to species-specific conservation.

As a result of relatively high pollution indicated by sample analysis, it is also recommended that further research with a wider scope and focusing more on pollution be done soon. The mangroves' close proximity to the heavily industrialised area in Vaitele in the west and to the old Vaitoloa rubbish dump to the east demands the establishment of regular pollution monitoring system especially for heavy metal, toxic chemicals and microbial pollution. Such exercise requires outside actors especially the government, donor agencies and NGOs to be actively engaged because this will definitely enhance climate change resilience of both the surveyed communities and the mangrove ecosystems. Village communities neither have the capacity nor the resources to resolve some of the above threats; hence, external assistance is pertinent and is most effective via the following:

- Providing funds and technical assistance to improve mangrove rehabilitation and management and to decontaminate the old Vaitoloa rubbish dump.

- Improve wastewater treatment and disposal – this includes the construction of durable infrastructure as well as designing policies that are relevant and meaningful to communities.
- Improve sewage facilities to minimise leachates – build robust infrastructure and at the same time develop practical legislation that are relevant and meaningful to communities.
- Reduce/control mangrove conversion – modify the existing legislation appropriately so it is more feasible to apply - supported by relevant community and national policies.
- Encourage use of cultural protocols to complement legal law in mangrove rehabilitation and conservation.
- Make sand mining more biodiversity friendly – modify and apply legislation to control sand mining so that sedimentation and turbidity of mangrove and lagoon waters are minimised.
- Assist in replicating the experience in Vaiusu - promote women participation in decision making and project implementation.
- Strengthen monitoring and evaluation of CCRI in the survey area and continue to promote awareness of improving climate change resilience with long-term focus at all

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