NORTH BRAZIL SHELF MANGROVE PROJECT

STATE OF MANGROVES IN GUYANA:

© Conservation International Photo by John Greene
DISCLAIMER

The content of this report does not reflect the official opinion of the project sponsors or their partner organization. Responsibility for the information and views expressed therein lies entirely with the author(s).

SUGGESTED CITATION

TABLE OF CONTENTS

1 EXECUTIVE SUMMARY .................................................................................................................. 3

2 INTRODUCTION .............................................................................................................................. 4

   2.1 PROJECT BACKGROUND ............................................................................................................. 4

   2.2 MANGROVE RESEARCH CONTEXT ........................................................................................... 4

   2.3 REPORT OBJECTIVES ................................................................................................................. 6

   2.4 METHODOLOGY .......................................................................................................................... 6

3 STATE OF KNOWLEDGE OF MANGROVES IN GUYANA ............................................................. 7

   3.1 BRIEF HISTORY, CLASSIFICATION, TAXONOMY, AND DISTRIBUTION OF MANGROVES IN GUYANA .......... 7

   3.2 LEGAL FRAMEWORK FOR MANGROVES IN GUYANA .............................................................. 11

   3.3 FLORA AND FAUNA OF MANGROVE FORESTS IN GUYANA ..................................................... 15

   3.4 MANGROVES AND CLIMATE CHANGE ....................................................................................... 18

   3.5 FACTORS AFFECTING MANGROVES AND THEIR RESPONSE TO NATURAL STRESSES .................... 21

   3.6 PRODUCTIVITY OF MANGROVE ECOSYSTEMS ........................................................................... 27

   3.7 COMMUNITY PARTICIPATION AND EFFORTS IN CONSERVATION ........................................... 29

   3.8 THE REHABILITATION AND RESTORATION OF MANGROVES IN GUYANA ............................. 31

   3.9 2.9 ECONOMIC VALUATION OF MANGROVE FORESTS .............................................................. 34

4 ONGOING, PLANNED AND INACCESSIBLE STUDIES FOR MANGROVE RESEARCH IN GUYANA ............ 36

5 RECOMMENDATIONS .................................................................................................................... 39

6 REFERENCES ..................................................................................................................................... 40
FIGURES

FIGURE 1: WATERCOLOUR PAINTING DONE BY SIR ROBERT HERMANN SCHOMBURGK (1790 – 1814) DEPICTING
          GUYANESE FLORA (RHIZOPHORA SP. IN FOREFRONT OF PAINTING)................................................................. 8

FIGURE 2 TREE AND ROOT SYSTEM OF THE RHIZOPHORA MANGLE (IMAGE RETRIEVED FROM
          HTTP://WWW.EPAUGYANA.ORG/EPA/DOWNLOADS/ENVIRONMENTAL-EDUCATION-
          PUBLICATIONS/ARTICLES/CATEGORY/11-ARTICLES) ......................................................................................... 9

FIGURE 3 THE DISTRIBUTION PATTERN FOR MANGROVES IN GUYANA (EXTRACTED FROM NMMAP 2010-2012) ............ 9

ACRONYMS / ABBREVIATIONS

CH&PA       Central Housing and Planning Authority
CLME        Caribbean Large Marine Ecosystem
EPA         Environmental Protection Agency
EU          European Union
GGBMR       Golden-Grove Belfield Mangrove Reserve
GMRP        Guyana Mangrove Restoration Project
GFC         Guyana Forestry Commission
IDB         Inter-American Development Bank
ICZM        Integrated Coastal Zone Management
NMMAP       National Mangrove Management Action Plan
MNRE        Ministry of Natural Resources and the Environment
UNFCC       United Nations Framework on Climate Change
WPMR        Wellington Park Mangrove Reserve
1 Executive Summary

The study of mangroves has become increasingly popular in Guyana. There are notable studies that have been done on mangrove species and on the mangrove ecosystems as a whole. However, due to the dynamics and vastness of these ecosystems, mangrove research is much more than meets the eye. This report examined the state of mangroves in Guyana including completed, ongoing, and planned research projects. Though there have been fragmented reports of mangroves existing in Guyana as early as the 1800s, there is a serious lack of anecdotal and empirical evidence to support this and the situations that existed then. From the synthesis study, it was also noted that there were satisfactory attempts to examine the avifauna of mangrove forests, along with fish assemblages. Additionally, there were valiant attempts to assess the relationship between mangroves and climate change, and factors affecting mangrove forests, particularly sedimentation. The economic valuation of mangrove forests is almost non-existent locally, so this is a priority and crucial point for research. The scope for advanced research in all the areas discussed in this report is wide and once research gaps are disseminated, there is a large possibility of filling these gaps over a period of time.
2 Introduction

2.1 Project Background

The project entitled “Setting the foundations for zero net loss of the mangroves that underpin human wellbeing in the North Brazil Shelf LME (NBS-LME)” (from here on the “NBS Mangrove Project”), is a one-year primer project to help establish a shared and multi-national process for an Integrated Coastal Management in the NBS-LME. The project recognizes the prevalence, socio-ecological importance and connectivity of mangroves in the retention and generation of key ecosystem services (fisheries, coastal protection and defense, water quality, blue carbon etc.) from which communities in the NBS-LME countries are beneficiaries. This project builds on, and supports, the antecedents and key elements of the regional agreement established within the CLME+ SAP for the NBS-LME region.

The objectives of the NBS Mangrove Project are:

1. To generate the necessary baseline knowledge and technical assessments as inputs towards a collaborative vision and a coordinated well-informed management of NBS-LME mangrove systems, with emphasis on the information needs of Guyana and Suriname.
2. To support development of transboundary coordination mechanism(s) between the countries of Guyana, Suriname, French Guiana, and Brazil (state of Amapá) towards the improved integrated coastal management of the extensive, ecologically connected yet vulnerable mangrove habitat of the NBS-LME region.

2.2 Mangrove Research Context

Mangroves refer to the constituents of tropical intertidal forest communities or to the community itself. The term ‘mangal’ has been used to refer to a community that contains mangrove plants (Tomlinson, 1986). The term mangrove can also be used to refer to an assemblage of tropical trees and shrubs that grow in the intertidal zone. It is used to describe a distinct group of plants adapted to a saline habitat (McKee, 1995). Mangroves have four (4) major roles that are recognized. They are facultative halophytes and they help in soil formation and help to stabilize coastlines. They may serve as filters for upland runoff. They may also serve as a habitat for marine organisms and invertebrates, and wildlife. They are producers of large amounts of detritus and may contribute to productivity in offshore waters. The classification of mangroves varies according to the classification system used.

Generally, mangroves are said to include approximately sixteen (16) families and forty to fifty (40 – 50) species. For the species to be studied for this research, three families will be considered. These families are Rhizophoraceae, Verbenaceae and Combretaceae to which Rhizophora mangle (Red Mangrove), Avicennia germinans (Black Mangrove) and Laguncularia racemosa (White Mangrove) belong to respectively (Gilmore et al, 1993; Simberloff, 1983; Tomlinson, 1986). There are three (3) main types of mangroves that are found in Guyana. These are the Black mangrove (Avicennia germinans), White mangrove (Laguncularia racemosa) and Red Mangrove (Rhizophora mangle). There is also a mangrove associate – the Buttonwood mangrove (Conocarpus erectus). The Black mangrove is commonly called ‘Cruda Bush’. It is also known as ‘Courida’. Through the intervention of the Guyana Mangrove Restoration Project (GMRP), the mangrove cover in Guyana increased.
A survey done in 2001 by the Guyana Forestry Commission (GFC), the estimated area in hectares (ha) of mangrove forest along the coast was estimated to be 91,000 hectares with Region 1 having the largest mangrove cover of 49,100 hectares or 61% of the total mangrove cover in Guyana. Region 2 had the second highest amount with 11,200 hectares or 14% of the total cover. Region 3 had 5,240 hectares or 7% of the total mangrove cover while Region 4 had 3,540 hectares or 4% of the total mangrove cover. Region 5 had 7,252 hectares or 9% of the total mangrove cover or 5% of the total mangrove cover. In 2011, an updated figure of 22,632 hectares of mangrove cover was presented by the Guyana Forestry Commission. Unlike the pattern found in parts of the world, mangrove distribution in the Guianas follows the pattern of Black mangroves dominant along coastal shorelines and Red mangroves further inland dominating riverine areas. Elsewhere, the pattern is Red mangroves, Black mangroves, and White mangroves. Climates, tidal and wave action, salinity and morphological processes usually influence the distribution of mangroves.

Coastal development, including cultural practices has led to the degradation, erosion and unsustainable use of mangroves locally. Over the years, there have been several efforts made to undertake research directly related to mangroves in Guyana. There have been notable attempts to examine areas of mangrove diversity and ecology, carbon storage potential and related strategies, community attitudes and perceptions towards mangroves, and factors affecting the distribution of mangroves. However, these attempts pale into insignificance to the larger arena where mangrove research has extended way beyond morphological examinations to examining crucial economic valuations, comparisons of results of various restoration techniques, and critical analyses of government policies and decision-making techniques.

Recognizing the existing information, we have related to mangroves, building a database related to same, and providing recommendations and suggestions to effect remedies, is a step in the right direction. Even in the case of surveys conducted among community members, there is a need for follow-up studies to be done. Bovell (2013) presented initial findings regarding gaps in mangrove research in Guyana. The gaps that were identified are listed summarily below:

i) Taxonomies of mangroves and associated species, and the temporal changes associated with each;

ii) Genotypic differences in mangroves locally and abroad;

iii) Effect of geomorphology on the distribution of mangroves along the coast of Guyana;

iv) Comparative studies and analyses of primary productivity of mangroves in Guyana;

v) Relationship between solid structures and coastal dynamics of mangroves;

vi) Amazon/Orinoco sedimentation inputs and the formation of mangrove ecosystems;

vii) Values of mangroves to fishes, birds, and wildlife;

viii) Role of mangroves in reducing wave energy;

ix) Total economic value of mangrove forests;

x) Mangrove rehabilitation/ restoration; and

xi) Community perceptions on the Mangrove Project.
2.3 Report Objectives

This Synthesis Report will serve to bridge the understanding of the current mangrove research gaps locally. The bulk of this assessment relied on secondary research which essentially utilised all primary research data that was collected in relation to the research topic.

Based on existing knowledge and data on mangroves, the following categorization was used in the synthesis:

- Brief history, classification, and distribution taxonomy and of mangroves locally
- Legal Framework for Mangroves in Guyana
- Flora and Fauna of mangrove forests in Guyana
- Mangroves and climate change
- Factors affecting mangrove ecosystems and responses to stresses
- Productivity of mangrove forests
- Community participation and conservation efforts
- The rehabilitation of mangroves in Guyana
- Economic valuation of mangrove forests

2.4 Methodology

Multiple sources of correlated information were reviewed using the following guiding questions:

a) What baseline knowledge on mangroves in Guyana currently exists?

b) In considering the objectives of the primary data sources, what do past, current, and planned research have in common?

c) What are the gaps that need to be filled as based on baseline knowledge and congruent objectives of the past, current, and planned research?
3 State of knowledge of mangroves in Guyana

3.1 Brief history, classification, taxonomy, and distribution of mangroves in Guyana

Dalton (1855) stated that in the 17th century, before the colonisation of Guyana by the Europeans, the coastal area was home to several indigenous (Amerindian) tribes and had a mangrove fringe measuring three (3) to five (5) km in width. Behind this fringed belt of vegetation, were swamp savannahs which were home to sedges and aquatic plants including mosses. Persons existing during the developmental and even pre-developmental stages of communities (1960 – 1970) indicated that the entire coast was home to mangroves – large belts of mangroves. Of notable mention, was La Jalousie, West Coast Demerara, which had one kilometre (1 km) deep of mangrove vegetation in the area.

Early baseline assessments showed that Region 1 (Waini Pomeroon) was composed mainly of *Avicennia* species along the coastal fringe. Shell Beach was a continuous mudflat which was low-lying and prone to erosion. Region 2 (Pomeroon-Essequibo) was the main area of *Rhizophora* dominance with *Avicennia* found on the belt inland to the sea dam. In the Southern part of the region, human activity removed all mangrove cover. Both the mouth of the Mahaica River mudflats and the Novar foreshore were dominated by patches of *Avicennia*. Over in Region 3 (Essequibo Islands and West Coast Demerara), *Avicennia* was found on the fringe with coastal erosion and upstream banks were covered in *Rhizophora mangle*.

However, due to human activity, it was replaced with other species but these offered no protection from flooding. Demerara Mahaica (Region 4) boasted seedlings of *Avicennia* and *Laguncularia* species on extreme edges of mudflats that were present there. *Laguncularia* was primarily found at odd points along the mudflat. At the Mon Repos beach, and at Lusignan, were mangroves behind a small raised beach. *Avicennia* was found at the seaward fringe and inland was *Laguncularia* densely populated. Anecdotal evidence showed that there were mangrove stands but all evidence of mangrove forest had disappeared. In Region 5 (Mahaica-Berbice), the mudflats near the mouth of the Mahaica River were colonised by *Avicennia*. The Novar foreshore was also colonised and dominated by *Avicennia* in patches. Belladrum and Profitt/Foulis hosted several *Avicennia* seedlings. At Trafalgar mangroves were destroyed due to lagooning which occurred as a result of rainwater accumulation.

By the early 1900’s onwards, mangrove descriptions and discoveries, along with taxonomies and classifications became imminent. Chapman (1976) reported that the species *Rhizophora harisonii* was present but could not be ascertained. At that time, two institutions responsible for specimen collection – the Jonah Boyan Herbarium at the University of Guyana, and the GFC did not have a record of collection or any identification of the said species.
There are several pieces of data which lend themselves to establishing key species of mangroves in Guyana. Hussain (1990) posited that there were two (2) principal species of mangroves in Guyana: *Avicennia germinans* and *Rhizophora mangle*. *Avicennia* was said to have been found in coastal mudflats while *Rhizophora* was found in sheltered areas near canals. Where pure stands of *Avicennia* were found, there were occurrences of *Laguncularia racemosa* and *Conocarpus erectus*. A small leguminous tree (*Machaerium lunatum*) was also found dwelling among the mangroves. Further work also solidified the types of mangroves found in Guyana (Pastakia, 1991). In his field work and via direct observation, Pastakia recorded seven species of mangroves found in Guyana. These were namely *Avicennia germinans*, *Avicennia schaueriana*, *Rhizophora mangle*, *Rhizophora harisonii*, *Rhizophora racemosa* and *Laguncularia racemosa*. The seventh is a mangrove associate scientifically called *Conocarpus erectus*. Pastakia mentioned four (4) mangrove families: Avicenniaceae, Rhizophoraceae, Combretaceae and Sonneratiaceae. The Black mangrove (locally called Courida or Cruda bush) dominated mangrove fringes. *Avicennia germinans* was confusingly referred to as *Avicennia nitida* and *Avicennia schaueriana*. 

Figure 1: Watercolour painting done by Sir Robert Hermann Schomburgk (1790 – 1814) depicting Guyanese flora (Rhizophora sp. in forefront of painting)
Therefore, only the genus *Avicennia* was used for the rest of the research by Pastakia. When compared to the distribution otherwise, the mangroves located locally followed the following pattern: *Avicennia* (Coast), *Laguncularia* (coast) and *Rhizophora* (not coast). *Laguncularia* and *Avicennia* were found as pioneers who provided new embryos for regeneration.

![Figure 2 tree and root system of the Rhizophora mangle](http://www.epaguyana.org/epa/downloads/environmental-education-publications/articles/category/11-articles)

Later studies and investigations (Van Maren, 2004; Bovell, 2011) also presented the species of *Avicennia germinans*, *Rhizophora mangle* and *Laguncularia racemosa* as being present in Guyana. Van Maren reported that the white mangrove was found on sandy soils and tended to persist on dry soils. The red mangrove was found in areas prone to flooding and the Black mangrove was found in clayey areas with hypersaline conditions, but only for a period of time. The red mangrove was the most dominant species while in some cases the red mangrove was entirely absent. The NMMAP offered, as a reason for the distribution of *Rhizophora* at riverside and estuarine areas, the effect of wave action. However, the *Rhizophora* is the species most adapted to wave activities so there is still some disparity and lack of clarity promoting this reason.

![Figure 3 The distribution pattern for mangroves in Guyana](extracted from NMMAP 2010-2012)
Based on the data collected the following research gaps currently exist:

<table>
<thead>
<tr>
<th>Research Gap #</th>
<th>Priority</th>
<th>Research Gap</th>
<th>Information lacking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (a)</td>
<td>Low</td>
<td>Anecdotal/empirical evidence of the early appearance of mangroves in coastal communities</td>
<td>There is sketchy information documented on the very early history of mangroves in the country. A survey particularly in rural areas should be carried out among persons age 50 and above would provide necessary information on early details surrounding mangroves locally.</td>
</tr>
<tr>
<td>1 (b)</td>
<td>High</td>
<td>Detailed taxonomy of mangal communities in Guyana</td>
<td>Detailed taxonomies of all mangrove species found locally along with the development of a taxonomic key(s) for their identification locally</td>
</tr>
<tr>
<td>1 (c)</td>
<td>High</td>
<td>Comprehensive database of biodiversity of mangroves in Guyana</td>
<td>The data collected from 1(b) would be useful in developing a database which could lead to greater or increased conservation and monitoring efforts.</td>
</tr>
<tr>
<td>1 (d)</td>
<td>High</td>
<td>Biochemical and biophysical analyses possibly responsible for distribution of mangroves in Guyana</td>
<td>Observations and comparisons have shown that the distribution pattern of mangroves in the Guianas region, differs from that in other parts of the world. There has been minimal specific research done locally to determine the exact reason for this. Biochemical analyses and biophysical analyses including soil comparisons (hydrology and geology), and plate tectonics would serve as a baseline for finalising reasons behind different distributions.</td>
</tr>
<tr>
<td>1 (e)</td>
<td>High</td>
<td>Differences in distribution of mangroves regionally and over time</td>
<td>What is the specific difference in distribution of mangrove species when comparing each region? Is there a difference in densities? How do yearly estimates in distribution of each species differ?</td>
</tr>
<tr>
<td>1 (f)</td>
<td>High</td>
<td>Dynamics of mangrove vegetation linked to geomorphology of the coast</td>
<td>Evaluation of changes in magnitude and frequency of coastal geomorphic processes can show how variable environmental conditions can determine colonisation by mangroves</td>
</tr>
</tbody>
</table>
3.2 Legal Framework for Mangroves in Guyana

Apart from the amended Forestry Act of 2010, which designates mangroves as protected species and therefore it is illegal to destroy mangroves without prior permission from the Commissioner, there are no direct legislations for governing mangroves locally. However, there are clauses in regulations that can be interpreted and used to govern the management and conservation of them. These rules and regulations indirectly refer to mangroves and are at best outdated. While the legislation provides command and control methods that could be utilised towards the sustainable management of mangroves, there is a notable lack of reinforcement of these legislations and some cases the effectiveness of these legislations is poor. In the National Mangrove Management Plan (2010- 2012), legislations that were related to mangroves were stated and have been identified below along with other legislations developed thereafter.

a) **Guyana Constitution Article 36** states that in the interest of the present and future generation, the state will protect and make rational use of its land, mineral and water resources, as well as its flora and fauna, and will take all appropriate measures to conserve and improve the environment.

b) **The Forests Act 2009 Part 3. 5.23. (1)** mandates the EPA to declare a specific area of state forest to be a specifically protected area for a period not exceeding 25 years (a) declare a specified area of State forest to be a specially protected area for a specified period not exceeding 25 years; Purpose of Part 3.5.22 (1) is to 1) conserve biological diversity 2) protect specific trees and plants 3) conserve soil and water reserves 4) protect forests from fires, pest, diseases and degradation.

c) **Forest Act 2009 Part 3. 5. 30** Minister can make order for protection of trees and plants any tree or plant, Part 3. 5. 31 Minister can declare private land to be a forest conservation area. Environmental Protection Act of 1996 mandated that the will provide for the management, conservation, protection and improvement of the environment,; danger of extinction; (2) any person who in any marine reserve without permission granted under subsection 3 (b) takes or destroys any flora and fauna other than fish is guilty of an offence.

d) **Fisheries Act 1957 Part 8 Marine Reserves and Fishing Priority Areas, Section 21. (1).** (a) to afford special protection to the flora and fauna of such areas and to protect and preserve the natural breeding grounds and habitat of aquatic life with particular regard to flora and fauna in danger of extinction; (2) any person who in any marine reserve without permission granted under subsection 3 (b) takes or destroys any flora and fauna other than fish is guilty of an offence.

e) **The Forests Act 2009, Part 1 5.2 (b) (1)** defines forest with reference to mangroves **Forest Act 2009. Part 1. 5.3.** states that the Minister can declare public forested land as state forest.
f) **Civil Act Article 4.1** defines foreshore of Guyana as the part of the shore of the sea and tidal navigable rivers which is covered by the medium high tide between the spring tides and the neap tide, the soil under tidal waters called land shall be deemed to be under state land.

g) **Sea Defence Act of 1998** declares that “sea defence includes – any shell bank or reef against the erosive action of the river current”. In Part 3 Section 12 of the Act declares that “all sea defences which are or shall be in existence in any district shall by force of this Act become the property of the state”.

h) Environmental Protection Agency states that their functions is to take steps necessary for the effective management of the natural environment so as to ensure conservation, protection, sustainable use of its natural resources; establish, monitor and enforce the environmental regulations; assessed environment impact of the project; and promote and encourage a better understanding and appreciation of the natural environment and its role in social and economic development.

i) **Sea Defence Act 1998** defined sea defence as (c, e)”All land fifty (50) feet landwards from the centre of any sea or river dam or sea or river wall and all land on the other side of such sea or river dam or sea or river wall in the direction of the sea or river to the toe of such sea or river wall; and declares that “sea defence includes – any shell bank or reef, sand bank or reef or other natural feature which serves as a protection of the sea coast against the erosive action performed by the Ministry or its agents at the expense of the Board.

j) **Guyana Land and Survey Commission Act** mandated the commission to take charge of and act as guardian over all public lands, rivers and creeks of Guyana.

k) **Municipal and District Council Act** Part II Sec. 7 (2) states that the jurisdiction of the City Council shall extend to low water mark of spring tide of the Demerara River and to all structure thereon (2) town council shall extend to low water mark of spring tides of the Berbice River and to all structures. Part IX 302 (19) to plant, trim, preserve or remove trees, flowers and shrubs in any public places.

l) **The Forests Act 2009** Part 3. 23 (b) prohibiting any disturbance of the soil, vegetation, rivers, or creeks in that specially protected area; and Part 3.31. (1) The Minister may by public notice make an order – (a) declaring any forest on private land to be a forest conservation area; and (b) prohibiting, restricting, or regulating all or any of the following - (i) entry into the forest conservation area (ii) cutting, damaging, taking, or removing any forest produce in the forest conservation area; (v) clearing, cultivating, or turning of soil in the forest conservation area; (vi) grazing or pasturing of livestock in the forest conservation area; (vii) setting of fire in the forest conservation area; (2) No order may be made except on the advice of the Commission that the order is necessary for – (a) conserving the forests of Guyana and securing the proper
management of forest land; (b) preventing soil erosion, coastal erosion, or erosion of the banks of rivers or creeks; (c) preventing the deposit of mud, stones, or sand in rivers or creeks or on agricultural land; (d) maintaining water supplies in springs, rivers, canals, reservoirs, aquifers, or water conservancies; (e) minimising the risk or mitigating the impact of storms, winds, floods, or landslides;

m) **The Environmental Protection Act of 1996** Part 10.68.1 Minister may make regulations for giving the effect to the provisions of this Act for the protection of particular species of prescribed fauna and flora (j.) protecting the coastal and marine resources and establish, monitor and enforce the environmental regulations

n) **Sea Defences Act of 1998** Sec.13 (1) and Sec. 16 (b) mandated to make regulations for (a) protecting the growth of Underwood, shrubs, and trees, on or near the foreshore or between high and low water marks (b) and the protection of the land and soil between high and low marks; and generally, conserving the foreshore; and require estate to protect the foreshore by sowing seed, planting shoots to promote the growth of or the other tree, underwood, or shrubs, between and low water marks on the foreshore Courida.

o) **Civil Act Article 4.3** states that no one shall remove any sand, shell, gravel, shingle or other mineral substances or any seaweed or vegetation from the lands without the permission of the Minister responsible for sea defences and are subject to the like penalties.

p) **The Forests Act 2009, Part 3.31.** prohibits the cutting, damaging, or taking any forest produce, or carry out any other kind of forest operation in a State forest; occupy or use any land in a State forest;

q) **Sea Defence Act of 1998 Sec.13 (1 Sec. 14, 15 and Sec. 16 (b) (a) (b) Sec, 26** states that everyone who infringes any of the provision of this Act shall be liable on summary conviction of twenty-two thousand five hundred dollars (G$ 22,500)

r) **Municipal and District Council Act sec. 302 (28).** states the power of the council to regulate the cutting of wood on land vested in the council.

s) **Local Government Act part IV sec 51.** Cutting of trees will have fixed fees

t) **The Forests Act 2009 Part 3.24., Part 3. 25 (2), Part 6. 68 b.(iv) section 25(2), section30(3), section 31(4), section 23(5)** - prohibits person in any State forest to throw down a lighted match or lighted or inflammable material; or do anything else likely to result in any forest produce being burnt or damaged. Penalty range from G$250,000 to $1,00000
u) Municipal and District Council Act sec. 287,290 28). States that the power of the council to regulate the grazing of animals; impounding the stray animal found in public places

v) Local Government Act Part IV sec 50 states that grazing of animals on common land of the village and in country district will be impound and sec.102 (1-5) straying animals

w) Guyana constitution Article 25 states that every citizen has a duty to participate in activities designed to improve the environment and protect the health of the nation. Article 74 (1) states that it is the duty of the Local Democratic to ensure in accordance with the law the efficient management and development of their areas and to provide leadership by example (3) to maintain and protect property, improve working and living condition and raise the level of civic consciousness

x) Local Democratic Organs Act Part II Sec. 7 states that duties of the local democratic organs is (a) maintain and protect property (b) protect and improve the physical environment (f) raise the level of civic consciousness (awareness).

y) National Biodiversity Action Plan was also developed (1999-2004) and recognizes biodiversity as an important national asset. The programme area has interventions that aimed to build a foundation for the conservation and sustainable use of biodiversity

z) ICZM Plan recognizes the coastal zone as an important part of the country but does not define the coastal zone for the purpose of integrated coastal zone management and resource use.

The following research gaps have been identified and are presented below.

<table>
<thead>
<tr>
<th>Research Gap #</th>
<th>Priority</th>
<th>Research Gap</th>
<th>Information lacking</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 (a)</td>
<td>High</td>
<td>Review of policy and legislation related to mangroves use and management in Guyana</td>
<td>There needs to be an overview of the key national policies, plans and legislations that would be related to the use, protection and management of mangrove ecosystems and mangroves specifically. The research can first analyse and assess policies, then offer possible options and recommendations for policy and law reform for consideration by the Government of Guyana.</td>
</tr>
</tbody>
</table>
3.3 Flora and Fauna of mangrove forests in Guyana

There are hundreds of species of flora and fauna found in mangrove communities. Mangroves provide the gradient that is needed between the sea and the land and serves as the perfect host for birds, fishes, wildlife, insects and other plant organisms and associates. Locally the situation is no different as there is a diverse array of these life forms.

A popular component of mangrove forests in Guyana is the Buttonwood mangrove (*Conocarpus erectus*). It is not considered as a true mangrove species because it lives predominantly on land and lacks the morphological and biological features associated with true mangrove species. It is found closely associated with the black mangrove and is found on open mudflats with new colonization of black mangrove seedlings. The grass (*Spartina brasiliensis*) is the first pioneer macrophyte and is considered as a stability species, and is also found closely associated with mangroves. There are several understory ferns including *Batis maritime*, *Acrostichum danaeifolium* and *Brachypteris ovate* among others. One of the most popular phytoplanktons found living near mangroves is diatoms. Most of the diatom assemblages are found attached to the prop roots of red mangroves (*Rhizophora species*) (Martyn, 1934; Pastakia, 1991).

There have been several studies done regarding avifaunal diversity. Previously, the number of avifaunal species was recorded at 720 for Guyana (Snyder, 1966). This work was built on by Braun, et al 2000 and Braun, et al 2007, with the numbers increasing from 786 species to 814 species. These 814 species (habitats and distributions) were recorded in the Field Checklist for Birds of Guyana. Prince and Bernard (1997) and Bayney and DaSilva (2005), both stated that there are twenty (20) bird orders in Guyana and nine (9) families that are shorebirds. Another unpublished study of the Waini-Shell Beach (Mendonca (2006)) documented ninety (90) species of birds.

Site specific work was done at Hope, East Coast Demerara by Dookram et al (2014). The study aimed to compare the effects of mangrove ecosystems (disturbed and undisturbed) on the populations of birds and fishes. Over a three month period, and by sampling birds using the point count method and binoculars Results of the study related to birds showed that disturbed sites had higher bird diversities and higher forest densities. Most birds were from the family Tyrannidae as compared to the undisturbed forest with most birds from the family Ardeidae. Additionally, the undisturbed forest had an increased population of birds, higher species richness, and more diverse bird species. For fishes, *Sciades couma* and *Anableps anableps* dominated the undisturbed site, while the disturbed site the habitat for one species, *Cichlasoma bimaculatum*, which had a very low population number. A total of 41 fish species were found at this location.

In the same year, DaSilva (2014) used observational and walking transect methods to examine the avifaunal diversity of the mangrove ecosystem at Wellington Park, Berbice. From this preliminary assessment, there were fourteen (14) families found from 27 species. In 2015 follow up work was also done by DaSilva, by use of a combination of desktop and field research and activities. He found that there were several families not only in Wellington Park but also at Golden Grove – Belfield, namely: Scolopacidae, Tyrannidae, Ardeidae, Accipitridae, Columbidae, Icteridae, Laridae, Cuculidae, and Trochilidae respectively. The WPMR was found to have a total of 14 families which was less than those
found in GGBMR (25 families). However, the GGBMR had greater occurrence of understory birds and more migrant species. Overall, both sites supported a fair diversity of avifauna.

King (2013) utilised two mangrove sites on the East Coast Demerara – Golden Grove Belfield (a standing forest) and Felicity-Chateau Margot (a restored site), to comparatively assess the avifaunal diversity there. The methodology included the use of point counts and mist nets. The GGBM reserve had greater number of species (93) identified that the Felicity-Chateau Margot reserve (72 species). However, the latter had greater avifaunal diversity. The order Passeriformes was justifiably most abundant since members of this order occupy ecosystems near coasts. Other notable families present were Characiformes and Scolopacidae.

Overall, the trends from the avifaunal assessments conducted locally show that there is a diverse array of birds (migrant, understory, etc) found within mangrove forests. As expected, there is a diverse range of marine life inhabiting mangrove zones including shrimp (*Xyphopoenus kroyeri*), crabs (*Uca* species including *rapax* and *macronai*). Turtles (*Chelonia mydas* and leatherback turtle *Dermochelys coriacea*), manatee (*Trichechus manatus*), caiman (*Caimam crocodylus*), waterfowl (*herms egret ibis*), and the Glossy ibis (*Plegadis falcinellis*) (Pastakia, 1991).

The WWF Guyana carried out a comprehensive one year study to identify and characterise wetland types in Guyana by using satellite imagery to identify the presence of these major wetland sites and to thereafter sample points. Secondary data collection was done using journals, reports research documents and datasets. In both the wet and dry seasons, transects were used to observe living organisms (presence and distribution). In the North-West wetlands, at the Waini, Baramanni and mouth of the lower Moruka Rivers and approximately 2 km from the shoreline, are mangrove swamps. All three mangrove species are found there. Characiformes, Perciformes and Siluriformes are popular fish species found there, Residents from the area also indicated that there are additional species present from direct observation including patwa (cichlids), mullet, gillbaker, and yarrow. Additionally, there are several bird species found there including but not limited to the attractive scarlet ibis, the black skimmers, ospreys and the greater yellowlegs. Hawks and eagles are among the generalists found there. There are several globally endangered species found in this vicinity including the giant otter (*Lontra kingicaudis*), and manatees (*Trichecus manatus*). The world’s largest river dolphin is also found there. Herepetofauna include the spectacled caiman, green anaconda, tree frogs and tree boa. More importantly, are the globally endangered sea turtles that nest on the beach annually including the leatherback, hawksbill, olive ridley and green sea turtles respectively. Aquatic insects being accommodated here are Embioptera, Arcrididae, Plecoptera, Diptera, Hymenoptera, and Orthoptera.

Ram (2017) investigated the effect of mangrove degradation along the coast on fish assemblages. In total, nine random plots were established at each site for habitat evaluation. Sampling was done during both wet and dry season, using cast nets, gills and hand nets of different mesh sizes. Twenty four (24) species from fourteen (14) families were recorded, with the sea catfishes, Ariidae, (6 species) being the most speciose family. The results indicated that the natural habitats had the greatest fish diversity in both the dry and wet season followed by the degraded and restored mangrove habitats respectively. Significantly higher fish abundance, biomass and mean length were observed in natural and restored
mangrove habitats in comparison to the degraded habitats. The results served as a clear indication that restored mangrove habitats restored fish diversity and abundance.

Based on the results of completed research, the following gaps in research have been identified:

<table>
<thead>
<tr>
<th>Research Gap #</th>
<th>Priority</th>
<th>Research Gap</th>
<th>Information lacking</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 (a)</td>
<td>Low</td>
<td>Effect of the use of <em>Spartina</em> grass as a means of recruiting mangroves</td>
<td>In each region, efforts should be made to use <em>Spartina</em> grass as a recruiter to determine and compare rates of recruitment and species recruited. Experiments with <em>Spartina</em> grass have been done locally and these results can serve as the precursor to similar studies in each region.</td>
</tr>
<tr>
<td>3 (b)</td>
<td>Low</td>
<td>Further studies in each mangrove region to determine flora and fauna present (establishment of a floral and faunal database)</td>
<td>Establishment of a biological database will lend itself to 3 (c) below</td>
</tr>
<tr>
<td>3 (c)</td>
<td>Low</td>
<td>Taxonomies of each species for in mangrove sites</td>
<td>Taxonomies per species will aid in differentiation of all species present and learning about 3 (d) below</td>
</tr>
<tr>
<td>3 (d)</td>
<td>High</td>
<td>Effect of salinity on variety and abundance of fishes</td>
<td>This would give clearer insight into mangrove fish habitats and their roles as nursery and feeding areas, refuges and migration routes.</td>
</tr>
<tr>
<td>3 (e)</td>
<td>High</td>
<td>Temporal patterns of occurrence of flora and fauna in mangrove communities</td>
<td>Once biodiversity indices are established, studies can be done at least twice yearly to determine species occurrence at specific times of the year.</td>
</tr>
<tr>
<td>3 (f)</td>
<td>High</td>
<td>Establishing keystone species of mangrove forests locally</td>
<td>Crabs are keystone species of mangrove forests. Their presence has a disproportionately large effect on its environment relative to their abundance. Studies can be done to determine how the presence of these keystone species affects the mangrove ecosystem. Research can also be done to determine how they serve as biological health of mangrove ecosystems.</td>
</tr>
<tr>
<td>3 (g)</td>
<td>High</td>
<td>Mapping migratory patterns and behaviours of migratory</td>
<td>Migratory patterns can be established and used as ecotourism promotional material; behaviours</td>
</tr>
</tbody>
</table>
birds through mangrove forests in Guyana of migratory birds can contribute to developing life history patterns and dependence on mangrove forests.

3.4 Mangroves and Climate Change

The Guyana Chronicle issue on October 26, 2013, quoted one resident, Theola Fortune, as having faced ridicule when initial attempts were made to warn persons about the importance of mangroves along the coast. They accused her, and by extension project members, of breeding mosquitoes in the community. With the impact of climate change in that same year, there were several breaches in the seawalls and this lead to flooding. It was then that residents realised the importance of mangroves in augmenting existing sea defense structures. This is just one of the numerous sentiments echoed by community members along the coast who have finally realised the importance of mangroves in combating climate change and its effects. There have not been many studies done directly examining the link between mangroves and climate change but there have been some brave attempts.

Hollowell (2009) documented the widespread impacts of fire across 50,000km square of mangroves in Region 1 in the North West of Guyana associated with the El Nino event in 1997-1998. However, one of the more serious implications of sea-level rise as a result of climate change, he indicated, is the presence of coastal hard sea defense structures which mars the movement of mangroves landward during flooding.

Dalrymple (2006) undertook an assessment to

(i) provide a conceptual model for the analysis of vulnerability of the areas
(ii) define the most important physical impacts of sea-level rise
(iii) recommend suitable adaptation strategies to reduce the impact of sea-level rise and
(iv) identify areas requiring further scientific investigation for reliable future sea-level rise assessment.

With the use of increased flood frequency probabilities, erosion, and inundation, various existing methodologies available for coastal vulnerability assessment were used and a site-specific procedure for the investigation was developed. Through the use of algorithms and equations of estimations (Brunn’s Rule), the results of the study found that there is a projected sea level rise of 3mm per year (1990 – 2020), small changes in the still water level result in significant increases in mean overtopping discharges, there is a high design risk (87.9%) for hard coastal structures, and that there is a high rate of erosion occurring. Additionally, like the results of Hollowell’s investigation, the results of the study also alluded to the fact that the ability of mangroves to move landward is restricted. Due to the clearing of lands for human settlement and development, it is likely that the buffer presented by mangroves may disappear and cause exposure along the coast to wave action and severe flooding.
Hickey et al (2012), attempted to understand the financial but practical challenges of adaptation by the use of in-depth qualitative interviews that were done with key experts both within the state bureaucracy and outside of it. The key informants were persons with knowledge of Guyana’s coastal infrastructure, hazards and disaster preparedness, climate change vulnerability and adaptation planning. The results of the study found that climate change affects everyday life. Sea defenses are old and in poor condition and are not well equipped to deal with the effects of climate change. Most of the hard structures are neglected and more than rehabilitation is needed. Rehabilitation includes drainage systems like kokers and conservancies. In some instances, mangroves are the sole form of protection. In some communities, some persons would remove the mangroves because bandits use them for cover or because they are of the opinion that the mangroves harbour mosquitoes. The overall findings of the study showed that mitigation efforts bring immediate financial rewards and urgent adaptation entails a prohibitive cost to defend against a future threat.

As an important investigative follow-up study to the latter mentioned, Saywack (2013) identified triple-win benefits and explored the depth of the identified synergies and challenges associated with mangrove restoration in Guyana in research entitled ‘Mangrove Management in Guyana: A case of Climate Compatible Development (CCD)’. The results of the research contributed to the ongoing discussion surrounding Climate Compatible Development which is essentially development which minimises the harm caused by climate change impacts but at the same time maximising human benefits and opportunities presented by a low emission, more resilient future and merging adaptation, mitigation, and development. Lower emissions would in turn build resilience and promote development. The main research question aimed to investigate the triple-win opportunities of adaptation, mitigation and development through mangrove restoration and protection. The methodology used was quantitative and utilised key informants and documented and anecdotal evidence. Data was collected using mainly secondary research from both published and unpublished data including grey literature. Direct observation in the form of site visits was also done to seven of the nine intervention sites of the GMRP. The results of the study proved that locally, mangrove restoration and protection have the potential to generate synergies and multiply benefits for climate change adaptation mostly in the form of shoreline protection, carbon sequestration and development.

Shoreline protection is afforded by the botany of the mangroves found locally, therefore minimising the need for hard structures such as seawalls and groynes. The protection of the shoreline is already at work. Carbon sequestration is a main mitigation benefit since mangroves are able to cycle carbon dioxide fifty (50) times faster than other tropical forests. Through the UNFCC, Guyana is committed to reducing all secretions into the atmosphere. By preserving the mangroves, there would be enhanced ecosystem services since a habitat for microorganisms would be afforded (including fishes and shrimps) along with crabs which are important in rural communities for food productivity and livelihood security. There are also improved livelihood operations of beekeeping, ecotourism and an overall possible benefit of alleviation of poverty (Bedasse, 2012).
While the concept of Climate Change Development sounded good in theory, Saywack identified several barriers for the tradeoff for a loss of land for alternative development. Firstly, there would be several interest groups that are opposed to change. Businessmen and other related occupations would be skeptical to give up their livelihoods all in the name of saving the environment and sacrificing their extractive based livelihood. Though mangroves would serve as good augmentation to existing solid structures they are however vulnerable to sea level rise. The sediment trapping to wave ratio is low and mangroves are not capable of shifting boundaries. The study concluded that it was indeterminate if benefits would outweigh the regrets or vice versa in promoting Climate Compatible Development.

A field visit carried out in 2013, in Regions 2, 3, 4, 5 and 6 highlighted the bewildering diversity of shoreline morphology, the deleterious effects of seawalls on mangroves, the reasons for the variability in alongshore mangrove regeneration and the success/failure reasons for mangrove replanting undertaken by the GMRP. Primarily, the shoreline diversity was related to coastal socio-economic development, degradation and fragmentation of the mangrove ecosystem and the presence of numerous river mouths, (Anthony et al, 2012). The recommendations of this report were the preparation of GIS based characterisation of the shoreline regionally, replanting in areas where banks are present, training in identifying and mapping of bank and interbank zones, and a holistic approach to mangrove replanting activities.

From the investigations of research related to mangroves and climate change locally, the following research gaps are identified below:

<table>
<thead>
<tr>
<th>Research Gap #</th>
<th>Priority</th>
<th>Research Gap</th>
<th>Information lacking</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 (a)</td>
<td>High</td>
<td>The effect of mangroves on the hydrodynamic processes along Guyana's coast</td>
<td>This information is very important since sea level is on the rise and the total suitability and possibility of mangroves being a crucial defense system is pertinent.</td>
</tr>
<tr>
<td>4 (b)</td>
<td>High</td>
<td>Distribution, phenology and abundance of mangrove forests in response to climate change</td>
<td>Climate change is causing a poleward shift in the distribution, phenology, and abundance of several species including mangroves. These changes are visible especially in wetlands. Research carried out on the latter can give useful insight into how biodiversity patterns and ecosystem structure and function are being altered.</td>
</tr>
</tbody>
</table>
Mangroves are sensitive to changes in sea level rise and salinities. These changes can lead to decreased productivity and untimely death. Understanding these processes and their timing can help in reducing vulnerability levels nationwide.

Factors contributing to mangrove resilience to sea level rise

Mangroves demonstrate significant resilience to climate change and sea level rise by sediment trapping and retention. Due to the different soil profiles regionally, retention and trapping capabilities can differ greatly. An investigation of this can show which regions are more resilient to climate change and steps that can be taken to effect these. The measurement of sediment accretion would prove to be a useful tool in this regard.

3.5 Factors affecting mangroves and their response to natural stresses

The functions of mangroves vary from shore protection, to habitat formation to carbon sequestration. In Guyana, mangroves serve as a major role in sea defence by breaking the action of waves and the tide. The factors affecting mangroves are natural and man-made. Natural threats include accretion and erosion while manmade includes rural agricultural activities such as over harvesting, urban construction on high rise buildings and other properties. Major (2011) assessed knowledge and use of mangroves. In the study, he aimed to assess the use and knowledge of mangroves by fishermen. A total of 50 questionnaires were used to gather information from fishermen at Mon Repos, Hope, Bee Hive and Mahaica. Most of the fishermen alleged to having used mangroves for firewood the most. However, 80% of them were aware of the benefits of mangroves and the work that the GMRP was doing. Therefore, even though use was unsustainable, knowledge existed on the importance of preserving the mangroves.

In the North West District, a study was carried out (Narine, 2011) to determine the level of compliance and issues related to mangrove bark harvesting. The Code of Conduct for Mangrove Harvesting was used to determine best practices for mangrove harvesting. The methodology involved the use of surveys and personal observation along with the use of primary data as a basis for comparison. The results of the study showed that there were three major issues in relation to mangrove harvesting: decrease in bark production over the years, the low price of bark and the importance of alternative tanning dyes as a substitute to mangrove bark. Additionally, it was found that the harvesting practices
do not fully conform to the standards set out in the Code of Practice by mangrove harvesting including disregard for felling distance, the felling of trees with thin barks and the use of chainsaws.

The ICZM Plan (2011) noted that poor growth rate is an important factor contributing to the depletion of mangroves in Guyana. Layne (2011) conducted research to determine the growth rate of black mangrove seedlings grown in a controlled environment and wildlings. Three sites were selected in three different communities along the East Coast Demerara (Min Repos, BV, Melanie), including one where regeneration was occurring and one where black mangroves had been replanted. Three plots and subplots were identified and saplings measuring 5cm and above were tagged for rechecking. Randomised Complete Block Design was also utilised in the methodology. Growth rate was recorded from examining measurements of height, leaf count and diameter. All three sites had favourable temperatures for the growth of the mangroves (15 degrees Celsius and 37 degrees Celsius). At the wildlings site, survival was the greatest as compared to poor survival at the replanted sites. A proposed reason for enhanced survival at wildlings site was that the already existing larger mangrove vegetation reduced the wave energy therefore reducing wave impact. The planted sites (BV and Mon Repos) were subjected to spring tides and heavy rains and may have altered nearby environmental salinity. The leaf production at the three sites was also different with the planted sites having greater production of leaves. Growth rate at Melanie was the highest with BV having the lowest. Once again, the absence of competing vegetation would have promoted faster growth rates. The monthly diameter increment increase followed the same pattern as was likely as a result of the absence of competing vegetation as mentioned earlier.

Erskine (2011) carried out research at Annandale, an area along the East Coast Demerara, to investigate the invertebrates’ population found in parallel mudflat and mangrove habitat, determine the suspended sediment concentration in each habitat respectively, and its influence on each habitat’s development; determine whether the invertebrate abundance influenced the suspended sediment concentration in each habitat and determine whether the invertebrates found and sediment shear stress in each habitat contributed to its erosion or accretion. Soil and water samples were collected, and soil was checked for presence and density of invertebrates, and turbidities of soil and water samples were measured. Overall, the suspended sediment concentration in both habitats was found to be high at the low tide which indicated that more sediment was leaving than coming in. Among the organisms observed in mangroves habitat the *A. anableps* were very prominent, both at low and high tides in abundance at all sites. Crabs were very common in both the mudflat and mangrove ecosystems, as they contribute to bioturbation, along with polychetes in the mudflat ecosystem. Overall, the mangrove habitat showed poor nutrient concentrations as compared to the mudflat ecosystem. It was concluded that erosion was occurring at outer mangrove habitats and the mudflat habitat. Other physical features proved to be more influential such as accelerating tidal velocity and invertebrate bioturbating activities. Several invertebrate species were present at both sites in Annandale, However, polychetes were distinctly present in the mudflat habitat. A high abundance of gastropods and malacostraca was observed in the mangrove ecosystem which contributed to nutrient cycling and its somewhat healthy nature. The low mean density of invertebrates indicated that they contributed to low rates of erosion. Additionally, the nutrient parameters were very satisfactory in all the sites.
Jack (2012) designed a timber brushwood design based on prior investigations of causes of erosion. Recommendations were made for future brushwood structures and a determination was made for an initial cost for the breakwater structure. The proposed work area was frequently visited, and level surveys were conducted by the WSG to determine elevation data and to obtain the required design elevation for the proposed structure. Theoretical work was conducted in the outline of a design of a suitable groyne and also in the determination of soil properties, geomorphology and hydrological investigation of the study area. Analysis of existing hydrographic data and Geomorphology was accomplished to determine the elevation of the foreshore depth of mud bed, wave climates and natural processing along the foreshore. Hydraulic data was collected in order to determine the size required. The main structure to be constructed at Victoria was that of a permeable timber piling groyne with bamboos or gabion as a screening mechanism. The aspects of the environment primarily susceptible to impacts due to the development of the project were stated as the water environment including surface and ground water quality; and marine environment with special emphasis on parameters such as currents, bathymetry, sedimentation and erosion.

Duncan (2013) investigated the survival of planted mangroves along thee (3) sites that were previously the subject of mangrove planting activities (Mon Repos, Hope Beach, and Village #8). Using transects and plots, diameter and height measurements were taken from selected plants three months after these transects and plots were set up. There were significant differences at each of these three sites. Village #8 and Hope showed high survival rates (80% and 78% respectively) while Mon Repos showed 50% survival rate. The results from this study confirmed that of Gratiot’s (2010) who purported that Village #8 and Hope were sheltered and offered stable shorelines for mangrove growth, and that the elevation of mudflats at Mon Repos was not facilitating for the survival of mangroves. Hope and Village #8 both had higher diameter and growth increments than Mon Repos.

Omacharan (2013) investigated the effect of human influence in the presence of coastal mangrove forests in Region 5. The densities of mangrove stands adjacent to nearby villages were measured over an eight month period and it was found that the major human activities were rice cultivation, housing and animal rearing. There was a positive correlation between degraded mangroves and human activities ($R^2 = 0.9821$).

Mangal (2013) carried out a study to determine how the physical parameters influenced the distribution of mangroves in Region 5 (West Coast Berbice). Collection of data was carried out for one month and triplicate field measurements of pH, temperature, turbidity, and dissolved oxygen were taken at predetermined sites. This was done at two areas of a particular location, these being within the mangrove stands and with the water channel before it entered into the stand. Site characteristics along with anthropogenic influences were also recorded. Temperature, ph and dissolved oxygen were measured by the use of probes, and turbidity was measured by use of a turbidimeter. Overall the water temperature was found to be lower in the mangrove areas than in the channels as supported by the
cover provided by the mangrove forests. The pH tested was found to be in a neutral range which is attributed by the presence of acid reducing bacteria in the soils of mangroves. The older stands of mangroves were found to have higher dissolved oxygen.

At twelve (12) different areas in Region 5, a study was done to determine relationships between mangrove population densities and soil parameters (soil organic content, soil pH and soil texture). With the help of existing maps, samples were collected and tested for these parameters and the results showed that there was no significant relationship between mangrove population densities and each of the parameters tested. Extremely weak relationships were found (Harry, 2013).

Edwards (2013) tested salinity to determine if there was a correlation between soil salinity and mangrove populations in Region 5. With the use of existing maps, sixteen sites were selected and over a six (6) month period, observations were made and tests were done to analyse salt content. Population densities were also recorded for each site. Additional parameters tested included pH, soil texture, cation content, phosphorous and organic matter content. There were no significant correlations between population density and salinity levels.

In 2013, Gopaul similarly investigated inland sediment outflow along the coastline of region 5 to determine if there was a relationship between the presence or absence of mangroves and the nature and concentration level of soil sediments present there (density). Existing maps were used to determine drainage areas and sites of mangrove forests. A reconnaissance survey was also done to obtain baseline information about the area. The final sites were selected (nine outfalls from six villages) and laboratory analysis was done at GUYSUCO to determine overall sediment concentration and determination of the chemical nature of the soil. The results, like the latter study, also showed that there was no relationship between sediment concentration and the density of mangroves found in the area. However, useful information was gained for sediment concentration per area. Even in the testing of individual soil parameters, there was still a weak relationship that was obtained.

Robertson (2015) investigated the wave attenuation due to mangroves and assessed existing numerical models used to predict sea wave attenuation in mangroves. The site chosen for this research was Chateau Margot which consists of wide mudflats which are made from large alluvial sediments. Theoretical data collection was done through literature reviews and existing data and practical work was done by deploying gauges to collect wind and wave data. Transects were also cut to collect tree height, canopy, root diameter and leaf count. The overall results of the study showed that a three year old black mangrove forest with a bandwidth of 50m can reduce a 0.43 m wave at open sea to 0.001 m of the coast. Modelled wave heights prove that a 50 m mangrove forest can reduce a 0.43 m wave to approximately 0.2 m.

Three species of mangroves found in Guyana were assessed for in-situ salt tolerance and endophytic diversity during the wet and the dry season. These species were A germinans, R mangle and L
Other parameters measured included sodium and chlorine content in soil, soil water and leaf tissue. This was done using prescribed methods from the Standard Methods for the Treatment of Waste and Wastewater, 20th Edition. The results showed that when cultured in-situ, the plates with no salt added were more promoting to the growth of fungal endophytes. The Aspergillus species, Mucor and Penicillium were representative in the preliminary set of results in the study. *Rhizophora mangle* had the most number of diseased leaves while *Laguncularia* had the least number of diseased leaves thus making *Rhizophora* the most vulnerable to foliar disease. These results were statistically significant. The Post Hoc tests showed that the results between *Rhizophora* and *Laguncularia* and *Rhizophora* and *Avicennia* were statistically significant. *Laguncularia* leaves were found to have the highest sodium content while *Rhizophora* leaves were found to have the lowest sodium content. The highest number of colony forming units (CFUs) was from *Rhizophora mangle* both in the dry season (39) and in the wet season (84). These results were not statistically significant. From the results of the second phase of the study, out of a total of sixty (60) leaf fragments in total, from which there were two hundred and two (202) CFUs obtained. *Rhizophora mangle* dominated in both of the seasons. The results showed that the dry season had greater diversity and abundance than the wet season. The results for the greatest number of diseased leaves correlated positively with the number of taxa formed on each of the mangrove species. The greater the abundance of the diseased leaves, the higher the number of endophytic fungal taxa found. Dominant species found were *Aspergillus flavus* and *niger*, *Penicillium*, and *Mucor*. The similarity of fungus between the dry season and the wet season was 61.54 % which is a significant similarity. The highest similarity between species was found in *Avicennia germinans* and *Laguncularia racemosa* with 62.5% similarity (Craig, 2016).

Toorman et al. (2018) examined the interaction of mangroves, coastal hydrodynamics, and morphodynamics along the coastal fringes of the Guianas, and found that quantitatively, three processes govern the coastal dynamics: the interaction between mangroves, hydrodynamics and sediment mechanics. Discrete mudbanks are transported westwards by waves and currents, and once dumped, mud is trapped and the colonisation of mangroves occurs. Afterwards, waves attack the shores again and a cycle of erosion and accretion occurs. The occurrence of flooding is more likely in areas where there is little to no mangroves occurring. Even hard structures, like seawalls and groynes, are not fully sustainable. As a precautionary method, prediction models are often used to make estimations so as to evade threats to the coastal zone and develop implementation and integrated procedures to remedy the same.

Based on the findings of the completed research, the following research gaps are mentioned below:
<table>
<thead>
<tr>
<th>Research Gap #</th>
<th>Priority</th>
<th>Research Gap</th>
<th>Information lacking</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 (a)</td>
<td>Low</td>
<td>Relationship between sedimentation and the presence/absence of mangroves</td>
<td>There have been significant strides taken in this research area. However, greater effort needs to be placed into understanding background dynamics e.g., dredging, associated with the presence or absence of mangroves</td>
</tr>
<tr>
<td>5 (b)</td>
<td>High</td>
<td>Relationship between coastal development (structural engineering) and the presence/absence of mangroves</td>
<td>Regionally, a characterisation of the shoreline can be done, and GIS mapping can be used to draw relationships between shore structures and other sea defenses. This data would be combined with studies of near shore bathymetry along the Guyanese shoreline.</td>
</tr>
<tr>
<td>5 (c)</td>
<td>High</td>
<td>Movement of mud banks and erosion cycle</td>
<td>Erosion is a great threat to Guyana's mangroves and when coupled with other environmental stresses, can prove too hazardous to the life of mangroves. Research in this area would therefore help to take precautionary moves before these environmental stresses cause disaster.</td>
</tr>
<tr>
<td>5 (d)</td>
<td>High</td>
<td>Mapping and modelling of coastline retreat and advance</td>
<td>The coastline is very important to the preservation of mangroves. Due to cyclic processes, the coastline can either retreat or advance depending on geologic processes and activities. Mapping and modelling of these activities will help in gathering key data which would holistically contribute to mangrove restoration, conservation and protection.</td>
</tr>
</tbody>
</table>
3.6 Productivity of mangrove ecosystems

Mangroves are said to be among the most highly productive ecosystems in the world and are comparable to coral reefs on several accounts. Measuring the litterfall is the most important way of measuring net primary productivity. Estimating biomass and net primary productivity are valuable contributors to ecosystem management and the evaluation of carbon stock. Leaf turnover in particular provides an indication of the contribution as a major energy source to consumer organisms and as such is a popular method of estimating primary productivity. Records of primary productivity rates also contribute to determining the overall health of the ecosystem. Notable efforts have been made locally to determine primary productivity in mangrove ecosystems through leaf fall dynamics.

Sharma (2006), Smith (2007) and Hodge (2008) measured litterfall in a "restricted" forest (in a restricted 5km stretch of mangroves at Ruimzeight, West Demerara). The methods used in these three studies utilised litter fall traps to collect all components of litterfall followed by drying then weighting. The forest (made up mainly of *Avicennia germinans*) had similar rates of litter production for the three contiguous years 0.11kg/m²/year; 0.10kg/m²/year and 0.073kg/m²/year respectively.

Crook (2013) proposed that the destruction of the mangrove ecosystem could result in the rapid release of carbon. Therefore, the ‘blue carbon’ concept was presented. This concept is widely used to recognize the importance of improved management of coastal ecosystems in terms of climate change mitigation. Case studies on ‘blue carbon’ around the world was done and discussions on how it can potentially be applied locally as a means of introducing a sustainable means of financing, in order to support ongoing and future efforts to manage and restore Guyana’s mangroves, was undertaken.

Jaikissoon (2013) estimated the carbon storage capacity of the major mangrove species in two regions of Regions #1 and #2 and found 3390.94 kg/ha and 809.09kg/ha respectively. Along the same line, specific work was done by Jaikishun, Ansari et al (2013) on the carbon storage potential of mangrove forests in Guyana. In their research, the carbon storage in mangrove forests in Guyana was estimated. Carbon and other phytochemical properties of soil in mangrove forest were quantified in six (6) regions of Guyana: Region 1 to Region 6 in the fringe forests. Transects were set up from inland to shore and plots were subdivided and selected for random carbon assessment. The diameter at breast height and overall tree height for each mangrove tree species was tested using DBH tape and Laser Technology Laser Range Finders. Non-tree vegetation above ground was measured by using harvesting techniques and forest floor litter was sampled using the oven drying technique. Aboveground and belowground biomass was determined by destructive harvesting while soil carbon variables (depth, bulk density, and concentrations of organic carbon were analysed using the Walkley-Black method). Two species, *Rhizophora mangle* and *Avicennia germinans* were found to have the highest carbon stock capacity (481 Mg/ha). Out of over 18 million hectares of forest cover, mangroves account for approximately 22,000 hectares of forest cover (MNRE, 2012). The results of the study indicated that mangroves account for less than 1% of the total carbon storage potential in Guyana’s mangrove ecosystems. The
global estimates for carbon storage potential are at 3% thereby reflecting that this level of carbon storage potential is very low.

Primo (2017) focused on research to estimate litter production by mangrove forests in an effort to understand the energy contribution made by mangroves to neighbouring ecosystems and the factors that can influence this production. There were three study sites that were used: Village #7, West Coast Berbice, Wellington Park, East Coast Berbice and Hope/Victoria East Coast Demerara. All the sampled plots were previously developed by the Guyana Mangrove Restoration Project by the use of transect lines. Forest assessment and measurement was done to assess parameters that have an effect on litter fall production. There were seven (7) litter fall traps in total and the overall results showed that the soil structure and composition could have affected the growth and the level of nutrients available to surrounding ecosystems. The differences in soil structures could have been as a result of natural topography of the area, limited freshwater flushing, and nutrient input into the sites. There were noticeable differences in production of leaf litter between sites and seasons (wet and dry). It was concluded that the maximum leaf litter production was during the dry season and continuous fluctuation in leaf production in the degraded forest beginning at the end of the dry season and throughout the wet seasons. At the degraded site, leaf composition held the greatest account in leaf litter, followed directly by twigs, flowers, fruit and other unidentified components. Though the results of the study were inconclusive, it paved the way for more recent primary productivity studies locally.

Based on completed studies, the following research gaps have been identified:

<table>
<thead>
<tr>
<th>Research Gap #</th>
<th>Priority</th>
<th>Research Gap</th>
<th>Information lacking</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 (a)</td>
<td>Medium</td>
<td>Regional studies investigating primary productivity in the form of leaf litter dynamics</td>
<td>Studies of biomass and leaf litter production to establish baseline information perhaps using trial plots and established sites by the Mangrove Department</td>
</tr>
<tr>
<td>6 (b)</td>
<td>Medium</td>
<td>From 7a above, a comparison of the variations in primary productivity within each region</td>
<td>A comparative analytical report region by region to assess rates of primary productivity</td>
</tr>
<tr>
<td>6 (c)</td>
<td>Medium</td>
<td>Investigation of temporal changes in primary productivity</td>
<td>The influence of time on rates and status of primary productivity</td>
</tr>
<tr>
<td>6 (d)</td>
<td>Medium</td>
<td>Assessment of levels of environmental stress interference with primary productivity</td>
<td>Indicators of primary productivity in mangrove forest types e.g. disturbed, undisturbed</td>
</tr>
</tbody>
</table>
3.7 Community participation and efforts in conservation

At the community level, participation is crucial to the management of mangrove forests. The message of protecting the resources in a community usually resonates well once person’s livelihoods are not affected and they are taught how to use their resources in a sustainable manner. The idea of protecting resources rolls over into the protection of mangroves. Over the years, there have been several efforts in mangrove awareness and conservation at the local level.

Evans (1998) investigated how mangroves could be restored along the coast and in part reported that large areas of mangrove forest were destroyed to control mosquitoes. Additionally, mangroves were used unsustainably for fuel wood, and bark collection for tannins. He found that most people had beliefs that the mangrove forests were harbours of mosquitoes.

In the Buxton/ Friendship area, an exploratory study was carried out on a sample of 136 community members including key informants with the objectives of determining attitudes and willingness of community members to promote mangrove restoration and sustainability, and identify the familiarity level of community members towards the latter mentioned. Based on the results of the study, it was found that many of the members were familiar with mangroves but not with the local Mangrove Action Committee which promoted social and educational activities in the community. Additionally, members were highly familiar with destructive cultural practices affecting mangroves, how mangroves should be planted, and when they should be planted (Thomas-Holder, 2013).

Due to land tenure arrangements, insufficient knowledge of mangrove habitats, and Government interaction, some coastal dwellers indicated via a survey that these were the primary reasons for their lack of involvement in the management of mangroves. However, they indicated that they were willing to actually get involved and increase their awareness. Stakeholders also noted that there was a need for stronger enforcement of regulations (Williams, 2013). Another study conducted in 2013 by Bhola in Region 6, noted that land tenure issues were a major constraint to sustainable management of mangroves, as many of the remaining mangroves in that part of Guyana were located on private lands. Nevertheless, individuals were willing to transfer ownership and power over mangrove areas if there suitable options presented to them.
In 2013, Murray assessed the level of mangrove awareness amongst secondary schools in Region 4, along with their knowledge of the Guyana Mangrove Restoration Project. The research was done using questionnaires which had questions related to the students’ and some teachers’ knowledge of mangroves and the Mangrove Project. It was concluded that students had favourable knowledge on mangrove awareness, but more work was needed to be done in improving awareness in secondary schools. A high percentage of the sample (43.8%) was willing to participate in conservation activities even though the actual knowledge of the then GMRP was poor overall.

A similar study was undertaken in 2015 by DaSilva to determine the extent of teachers’ awareness of the importance of mangroves as an important ecosystem in Guyana. One hundred and twenty participants (120) from Region 4 and Region 6 were exposed to mangrove conservation training workshops and were later on subjected to one hundred ‘yes or no’ questions. They were tested on their perceptions and awareness, current sources of information and stakeholders and roles. The results of the study showed that teachers were knowledgeable about mangroves and displayed favourable attitudes toward the conservation and management of mangroves. The researcher recommended that more should be done to pass on knowledge to students through field trips, training workshops and lectures. It was also recommended that the Ministry of Education and the GMRP engage in continuous professional development.

Kalamadeen (2013) through the GMRP developed a mangrove management plan for the Golden Grove Belfield Mangrove Reserve. Importantly, the key components of the plan, were (1) agreed management goals and objectives for the site (community involvement); (2) a delineation process which included data collection and community resource mapping and the collection of on socioeconomic and biological data on the status of mangroves and fauna of the site, and (3) institutional arrangements for management of the site including mangrove restoration, protection and economic activities. This plan integrated several pertinent aspects of mangrove management and community participation – both necessary precursors to effective conservation.

Based on the completed research, the following research gaps have been identified:

<table>
<thead>
<tr>
<th>Research Gap #</th>
<th>Priority</th>
<th>Research Gap</th>
<th>Information lacking</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 (a)</td>
<td>Medium</td>
<td>Updated community perceptions of mangroves: benefits and uses</td>
<td>How have perceptions of mangrove forests and their usefulness/benefits changes since the inception of the GMRP?</td>
</tr>
<tr>
<td>7 (b)</td>
<td>Medium</td>
<td>Updated assessment of students and teachers</td>
<td>How have students and teachers knowledge of mangroves and</td>
</tr>
</tbody>
</table>
knowledge of mangroves and conservation efforts | conservation efforts been enhanced since widespread dissemination of information on mangroves through the inception of the GMRP?

| 7 (c) | Medium | Community involvement: goals and objectives | What do communities require to benefit sustainably from mangrove forests but at the same time contributing to community knowledge and management of these forests?

| 7 (d) | High | The development of additional management plans for communities adjacent to mangroves | Plans similar to that developed by Kalamandeen (2013) should be developed so as to better effect management of mangrove communities and enhance community participation.

### 3.8 The rehabilitation and restoration of mangroves in Guyana

There have been notable efforts in the rehabilitation and restoration of mangroves locally. At the end of 2012, there were more than 330,000 black mangrove seedlings along 5.59km of the coastline at ten locations, equating to approximately 35ha in area that were planted. Topper (2012) assessed the year two achievements of the Mangrove Action Project by a brief desk review, meetings with stakeholders, and field observations. The report found that public awareness and development of a monitoring system for coastal mangroves were satisfactorily achieved. The monitoring system, though functional, was not fully operational. Although the 11km target of protection of the shoreline was not reached, there was still effective protection given the setbacks of limited technical assistance and limited understanding of shoreline dynamics.

The 2017 Annual Report of the Mangrove Department, NAREI, presented the overall results of the activities of the department in the said year. From a total of nine (9) sites, the overall states of the sites were presented as follows: Lima – planted with black mangrove seedlings had extensive natural regeneration and growth of planted seedlings; Anna Regina – breakwater structure installation had natural regeneration of mangroves; Devonshire Castle – fitted with a geotextile tube had natural regeneration; Victoria – fitted with geotextile tube at naturally occurring mangrove sites had rapid recruitment; Hope – planted with black mangrove seedlings had erosion occurring; Green Field – planted with black mangroves had erosion occurring; Better Hope – planted with black mangroves had extensive natural regeneration; the two sites at Village #6 - #8 had extensive natural regeneration, and the three sites at Wellington Park suffered from extensive erosion due to sawdust build-up along the foreshore and natural erosion activities.
An interpreted time-series satellite data of 1990, 2000 and 2010 using a semi-automated Geographical Information System and Remote sensing approach was done in order to look at regeneration and loss in forested areas (Mahaica-Berbice) over specific periods (Hamwant, 2011). The time periods used were 1990 to 2000, 2000 to 2010, and 1990 to 2010. The overall findings were consistent within all three temporal periods. There was an average loss of forested area of 26.57ha/yr for the twenty year period. The first ten (10) years of the assessment saw a rate of deforestation of 7.86 ha/yr and increased to 45.32 ha/yr in the second assessment period. The rates of deforestation differed spatially and temporally. Greater regeneration occurred between the 1990 –2000 period, in comparison to the 2000 –2010 period. It was observed that for the period 1990 there was reforestation in forest at a rate of 15.61ha/yr whilst there was a loss of 31.08 ha/yr. The rate of reforestation decreased for the period 2000 to 2010 to 8.76ha/yr. while the rate of forest loss increased to 54.07 ha/yr. Assessing the 1990 to 2010 period it was observed that the regeneration was at a rate of 11.61ha/yr. and on the contrary, there was forest loss at a rate of 34.39 ha/yr.

In a presentation entitled, ‘Restoring mangroves in a challenging environment’, Machin (2013) indicated that in optimal environmental conditions, the recovery of the coastal protective belt can be rapid with mean growth rate of 200cm per year at the most successful field site and canopy closure one year after planting. The sediment conditions and wave energy were the main attributing factors determining the success rate of planted seedlings. Site selection procedures were done using (1- macro scale, using Satellite imagery and Aerial photography from the GIS database to identify presence of mud banks and predict their movements) and 2) Micro scale at each potential planting site to assess suitability of different locations within planting sites in terms of known tolerance limits of mangroves to variation in mud elevation, soil conditions and wave action. Machin (2013) also examined field results of ten locations across 5.59 kilometres of shoreline comprising 35 hectares on the East Coast of Demerara coastline. An average growth rate of 200cm/year was found. Ecological natural restoration methods were also utilised including planting of coastal grasses (e.g. *Spartina*) to facilitate stabilisation of sediments in areas subject to heavier wave energy, as well as natural recruitment of mangrove seedlings through entrapment of propagules, fencing to enable natural recruitment by naturally available mangrove seeds without pressure from grazing animals, trials of techniques to restore natural hydrological processes in degraded mangrove forest areas to again allow for natural recovery of these mangrove areas and establishment of coastal engineering structures.

Along this line, Giovannozzi et al (2013) recognised that hard sea defense structures hamper the ability of mud to build up to a level suitable for mangrove colonization and propagule movement. For example, sea walls disrupt the normal wave-energy flow onto the land, and restrict the ability of mangrove stands to shift their boundaries as sea levels rise. Even during periods of seawall construction, existing stands of mangroves are damaged. Importantly, sea defense structures also limit the flow of fresh water into mangrove ecosystems.

Libourd (2013) carried out research to compare survival rates of mangroves wildings planted using open planting and encasement techniques and to assess the comparative costs of replanting mangroves using open planting and encasement. Six hundred black mangrove seedlings were collected from Ann's Grove and Victoria village respectively on the East Coast Demerara. Plots were
demarcated at Mon Repos, Greenfield and Village #8 along the shore and four (4) treatments were replicated at each site. These treatments were open planting, bamboo pipe, half length PVC pipe, and full length PVC pipe. The plots were monitored for three (3) weeks for a total of fifteen (15) weeks. In order to calculate costs, factors taken into consideration were acquisition costs and transport costs for materials and payment for planting. Survival rates were found to be low overall with all treatments. The full PVC and half PVC had comparable survival rates. Mon Repos had the lowest survival rates which was not surprising as Gratiot (2010) expressed possible reasons for this. Overall, there was a 70% survival rate at Greenfield. PVC accounted for the highest cost per treatment but this was no statistically significant.

Through the GMRP, now Mangrove Department, NAREI, there has been significant strides in mangrove restoration. However, more research is needed to better understand underlying dynamics so as to choose the best restoration and monitoring techniques.

The following research gaps have been identified below.

<table>
<thead>
<tr>
<th>Research Gap #</th>
<th>Priority</th>
<th>Research Gap</th>
<th>Information lacking</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 (a) High</td>
<td>Detailed survival rates and factors affecting their survival at each replanted site in Guyana</td>
<td>There have been several studies done to assess survival rates at replanted sites but a comprehensive study needs to be done to determine survival rates at all replanted sites and comparisons should be done to see if survival rates follow a trend or have increased/decreased over the years.</td>
<td></td>
</tr>
<tr>
<td>8 (b) High</td>
<td>A comparative assessment of the use of hard structures locally to effect mangrove as sea defenses</td>
<td>With the implementation of breakwaters, geotextile tubes, brush dams etc. a comparative assessment should be done to determine levels of effectiveness of each treatment type in promoting the growth of mangroves.</td>
<td></td>
</tr>
<tr>
<td>8 (c) High</td>
<td>Local role of mangroves in reducing wave energy</td>
<td>Studies of change in wave energy reaching the sea defence infrastructure over time as restored forest areas develop</td>
<td></td>
</tr>
</tbody>
</table>
| 8 (d) Medium   | Effect of herbivory on restoration and subsequent survival of mangroves          | Cattle grazing is very dominant in restored mangrove sites. Key documentation of this is needed at each site and a link between herbivory and rates of survival along with effects on
restoration is pertinent to developing methods to remedy any situations of exiting herbivory in mangrove forests.

8 (e) High Investigation of alternative hard structures to augment mangrove forests Apart from the alternative hard structures that have been implemented locally, research should be undertaken to determine how geologically similar areas are using other hard structures as support systems to mangroves.

### 3.9 Economic valuation of mangrove forests

Mangroves are highly valuable forests and their valuation ranges from habitat, food source, goods and products and coastal zone defense systems. Locally, persons are dependent on mangrove forests for their livelihoods including honey production and harvesting of the wood and bark. Generally, mangroves are useful for fisheries due to enhanced primary productivity and refuge from predation. In fact, mangrove forests are virtually impenetrable to large boats and other machinery and equipment (Spalding et al, 2015). There is a diverse array of fishes and other marine organisms found within these highly protected forests. Many fish species, example snapper, use mangrove forests as juveniles before heading out into the sea as fully grown and mature adults. Though there are studies that point to the diversities of organisms in mangrove forests, there are no studies deeply examining the economic value of these forests locally.

The services provided by mangrove forests and its surrounding ecosystems can be estimated by calculating the value of these goods or services per unit area. For example, mangroves acting as a complete sea level rise defense system can be calculated by considering the amount of money saved from preventing damage from sea level rise. Ileiva (2013) conducted a preliminary study at the Golden-Grove Belfield area and estimated the total economic value of mangroves at USD1209 per hectare incorporating direct use values (fishing, ecotourism and apiculture indirect use values (carbon sequestration, biodiversity). This study did not evaluate the benefits in terms of coastal protection and non-use values of mangroves.

The research gap for the economic valuation of mangroves in Guyana has been identified below.
<table>
<thead>
<tr>
<th>Research Gap #</th>
<th>Priority</th>
<th>Research Gap</th>
<th>Information lacking</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 (a)</td>
<td>High</td>
<td>Total Economic Value of mangrove forests in Guyana</td>
<td>This is a high priority research area that can contribute information on cost/benefit analysis, environmental costs and management actions.</td>
</tr>
</tbody>
</table>
4 Ongoing, Planned and Inaccessible Studies For Mangrove Research In Guyana

CLME + Sub-regional project being implemented by EPA
This project aims to identify, analyse, and agree upon major issues, root causes and actions required to achieve sustainable management of the shared living marine resources, including mangroves, in the Caribbean LME and its adjacent regions; and to improve the shared knowledge base for sustainable use and management of transboundary living marine resources.

CH&PA/IDB project on Climate Resilience Support for the Adequate Housing and Urban Accessibility Program
This project supports the Government of Guyana with the integration of climate adaptation and resiliency aspects into the Adequate Housing and Urban Accessibility Program, which is a proposed reformulation of GY-L1028 - "Road Network, Upgrade and Expansion Program. Though this project is not directly related to mangroves, the modelling and coastal data can be used to inform mangrove management.

The EU/SRDD Project to update the Sea Defence Act
The overall objective of the programme is to support climate change adaptation through an Integrated Coastal Zone Management approach and thereby protect the population in vulnerable, flood prone areas under sea level. One of the expected results is to update the Sea Defence Bill and the harmonised legal framework governing the executive agencies with responsibilities for disaster risk management, ensuring that an integrated coastal zone management approach is covered comprehensively. The results would also be useful in informing mangrove management.

Marine Spatial Planning Project (funded by European Union)
This project aims to identify and propose key coastal and marine areas for conservation status. By the use of a participatory approach, spatial data will be developed and used to make decisions regarding aspects of marine management and protection. The knowledge gained will help in the decision-making process in increased marine protection and human uses. The overall outcomes will conserve biodiversity and improve the complete health of the ocean. Of direct benefit to mangroves, the project will map related spatial data of mangroves and serve as a stimulus for conservation and restoration options.

EU Integrated Coastal Zone Management Project
The overall objective of the programme is to support climate change adaptation through an Integrated Coastal Zone Management approach and thereby protect the population in vulnerable, flood prone
areas under sea level. One of the expected outputs related to mangroves includes suitable mangrove sites established with conditions conducive to their protection and natural regeneration.

**Academic research**

The EPA Guyana indicated that they have no direct projects that were done by researchers relating to mangroves in Guyana. However, upon direct and official request by the NBS-LME Mangrove Project, a list of another facilitated research could be generated and presented. Contact made with the Guyana School of Agriculture also indicated that there were no direct projects or research done by students related to mangroves locally.

The list for undergraduate and graduate research projects by students of the University of Guyana has not been released as yet but is expected to be released by the end of December 2018, by which time, it will be comprehensive and accessible. Project proposals are currently in preparatory stages. However, direct access regarding project topics will only be made accessible once project proposals are completed and presented, approved, then accepted. However, there has been one confirmed study for undergraduate mangrove research so far for the upcoming year. This is expected to commence in January 2018, by Kimberly Duncan, a final year Biology student at the University of Guyana, Turkeyen Campus. The title of the thesis is ‘Anecdotal and empirical investigations of mangroves in Region 5, Guyana’. It is expected to be completed in June 2019 and proposes to examine anecdotal and empirical evidence from the older population, regarding the presence of mangroves during prescribed periods. Additionally, the study intends to use surveys, personal interviews, and questionnaires to gather information about situations that existed in a pre-Georgetown or early Georgetown era.

**Inaccessible completed undergraduate research by students of the University of Guyana**

The following list of research theses were not able to be accessed by the consultant due to property rights issues by their owners. However, the table presents (in cases where obtainable), the researchers and their affiliations, year of research and title of research.

<table>
<thead>
<tr>
<th>Researcher/ Affiliation</th>
<th>Year</th>
<th>Title of Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ayana Isaacs, University of</td>
<td>2002</td>
<td>Insect diversity in the black and white mangrove ecosystems</td>
</tr>
<tr>
<td>Guyana</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study Title</td>
<td>Author(s)</td>
<td>Year</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Abundance and distribution of avifauna in two black mangrove ecosystems</td>
<td>Kevin Cornette, University of Guyana</td>
<td>2012</td>
</tr>
<tr>
<td>along the East Coast Demerara</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investigating how the macroinvertebrate and microbial population influences</td>
<td>Shaneen Gillis, University of Guyana</td>
<td>2012</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification of insect pests and functional diseases in mangrove nurseries</td>
<td>Marvin Monize, University of Guyana</td>
<td>2012</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy-metal accumulation in leaf eating insects in three mangrove ecosystems</td>
<td>Kewena Stewart, University of Guyana</td>
<td>2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The predation on mangrove seedlings by herbivourous animals</td>
<td>University of Guyana</td>
<td>2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5 Recommendations

Based on the research gaps and priorities identified in this report, the following recommendations are proposed to fill these gaps in a timely manner:

1. Generate a full list of research topics and utilise the skills of researchers, academics etc. to undertake these topics as research;
2. Partner with neighbouring universities to develop strategies for undertaking research gaps;
3. Set a goal of a fixed amount of research topics to be completed in an academic year by willing and capable research students of the University of Guyana;
4. Circulate the main findings of the Synthesis Report so as to disseminate knowledge on the current state of mangroves in Guyana to garner support for researchers;
5. Involve all relevant stakeholders in the dissemination of research projects; and
6. Prioritise the hiring of relevant staff/ personnel at the Mangrove Department of NAREI for the purpose of undertaking or assisting in the supervision of research/ scientific studies.
6 References

5. Bovell O. 2010. A Situational Analysis of Coastal Mangrove Sites in Guyana (Shell Beach to Mahaica)


26. Giovannozzi, M. and Robertson, R., 2013. *Coastal engineering approaches applied through the Guyana Mangrove Restoration Project to protect existing stands of mangroves to facilitate natural recruitment*. Guyana Mangrove Restoration Project, Presented at the


32. Ilieva. 2013. The socio-economic importance of mangroves in Guyana Ecosystem services valuation, Ca'Foscar University of Venice, Italy. Poster presented at the Guyana mangrove Forum, April 11-13, Georgetown, Guyana, Guyana Mangrove Restoration Project.


35. Johnson-Bhola, L. 2013. Land tenure issues as a constraint to the sustainable management of Guyana's mangroves, SEES, University of Guyana, Presented at the Guyana mangrove Forum, April 11-13, Georgetown, Guyana, Guyana Mangrove Restoration Project.

36. Kalamadeen, M. 2013, Development of a management plan for the Golden Grove-Belfield Mangrove Reserve, lessons learnt in and potential for application to other mangrove reserve areas, University of Guyana, Presented at the Guyana mangrove Forum, April 11-13, Georgetown, Guyana, Guyana Mangrove Restoration Project
37. King T. 2013. **A comparative Assessment of Avifaunal Diversittyyin the Golden-Grove Belfield and Felicity-Chateau Margot Mangrove Reserves on the East Coast Demerara, Guyana.**


41. Mangal R. 2013. **An investigation of the physical parameters of water quality associated with mangrove stands along the Western Coast of Berbice (Region 5).** Unpublished.

42. Major R. 2011. **Fishermen use of mangroves & their knowledge of the GMRP.** Unpublished.

43. Murray O. 2012. **An Examination of Mangrove Conservation Awareness amongst Secondary Schools Students in Region Four.** Unpublished.


52. Persaud, H. 2011. Spatio-Temporal Analysis of Guyana’s Coastal Zone (Study site Region # 5 - Mahaica- Berbice). Guyana Mangrove Restoration Project