STATE OF THE WELLINGTON PARK MANGROVE FOREST

Report on Data Collected and Analysed for Wellington Park, East Berbice-Corentyne, Guyana

Submitted to

ENVIRONMENTAL PROTECTION AGENCY, GUYANA

By

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April 16, 2020

Synopsis

The main aim of this report is to provide information on the data collected and analysed at Wellington Park in East Berbice-Corentyne, Guyana. It is hoped that the data collected, analysed and reported here will provide the baseline information that is needed to assess the state of this mangrove system. Wellington Park is one of the mangrove restoration intervention sites in Guyana. It is in the East Berbice-Corentyne of the Mahaica-Berbice Region (Region 6) of Guyana and one of the sites where the success of mangrove restoration project was initially recorded. However, the noticeable extensive erosion driven by natural forcing and observable pollution of the mangrove environment with sawdust in the Canje Creek have contributed to the significant loss of the mangrove forests in this restoration site with is effects on sediments, water, vegetation and vertebrate/invertebrate species. A total of thirteen (13) surface sediment short cores (length < 30 cm) were collected from the intertidal zones and within the mangrove areas of Wellington Park using a 65 mm diameter tube. The specially designed pipes were used for the sediment extraction so as to maintain the structure and arrangement of the sediment profiles. The extracted short core (< 30 cm) sediment samples were then sliced into 0- 10 cm, 11 – 20 cm and 21 – 30 cm respectively maintaining the profile of the extracted sediments and these were stored at low temperature (+4^{0}C) from the field and during their transportation to the laboratory.

The surface sediments of the thirteen (13) sampling sites had a pH range of 6.0–8.27 with an average of 7.18, which indicated that the sediments were mainly alkaline. The sampling sediments also contained higher levels of Mn, and Fe than the other heavy metals. For the other metals (trace) analysed. Co, Se, Mo, Ag, Sn, Sn, W, Bi, and U were not detected in the samples, whereas V, Ni, Cd, Hg, Pb, Bi and Th are of negligible amounts, even to the depth of 30 cm. Le (Lanthanum) is a trace metal that is significantly detected in all of the samples, from 0 – 30 cm and in all of the 13 short core samples analysed. This ranged between 92 and 96.6 mg La/kg with the average of 95.3 mg La/kg with a Standard Deviation of 0.84. Although the presence of La may be beneficial to plants and organisms, however, the excess of La could be toxic to soil invertebrates at concentrations slightly above the natural background levels of 6.6 - 50 mg La/kg found in most soils, suggesting that effects of La on the soil community may already occur following relatively minor extra inputs from industrial, agricultural or domestic emissions in the area.

Although Cd concentration observed is negligible, Cd has a relatively high risk due to its strong toxicity characteristic. Roads are considered to be line sources of lead (Pb) pollution, even in areas away from cities. Wellington Park has the main road not far from the mangrove system and minor road that leads to the environment, which could be a line source of Pb pollution. The sources of the limited As detected in samples could be attributed to both natural or anthropogenic sources. Hg and Zn were also detected metals in sediments. However, most of the sediment samples from inside mangrove environment and the sediment profiles were comparative in metals with the samples from outside mangrove systems, respectively. The only difference is at the 0 – 10 cm of the profile which has deposits of loose sawdust in the profiles. The minor variations in metal concentrations with depth or between areas appeared to result from diagenetic processes rather than from anthropogenic inputs. However, anthropogenic activities can also contribute towards the presence of Fe, Mn, Zn, Cu, Ni, Ag, Pb and Cr. Other studies may be needed to establish the link.

The normalized concentrations of microplastic materials found within the sediments were between 155 pellets of plastics and 2256 of plastic fragment /kg of dry sediment, with the highest concentrations in the stations near to the 0 – 10 cm layer of the sedimentary core. The most abundant types of microplastic were the films from the fragmentation of food bags and wrappings, fragments of hard plastics and disposable utensils, the foams, mainly of expanded polystyrene, rope fragments and fishing nylon, etc. (which are defined as irregular plastic fragments here), followed by fragments of fibres (fabrics) and pellets of plastics of materials which could not be categorised as plastic fragments nor fabric. The reported microplastics composition in sediments from the Wellington Park Mangrove environment are examples of fragments of plastic pollution on mangrove sediments.

The results of bio-chemical parameters study of surface water showed some of the parameters are higher than the normal range indicating the pollution status of the water. This observation, in the Wellington Park mangrove forest at the time of sampling, indicated a possible pollution as a result of human activities, high organic matter deposition or due to domestic wastewater disposal, which all eventually affect the water quality of mangrove forest. The present study gives important information about the current features of the surface water found in and around the mangrove system along with their assessment with extant literatures and in the view of the impact of human

activities. Considering the presence of E-coli found in the surface water sampled although not significant, there is the need for general awareness about this microbial contamination (*E-Coli*). Monitoring systems should be established for the food being harvested and sold locally to investigate of any possible transfer of this contaminant in food consumed in the community.

A total of 37 plant species were identified in the study area and all of which are native to Guyana. Regarding the conservation status of the species that were identified, 27 species are of least concern according to the International Union for Conservation of Nature (IUCN) Red List, and 9 species were not evaluated. None of the species that were identified are listed on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) database. A total of 21 plant families are found in which the Cyperaceae family has the highest number of species present in the area. The second most abundant plant families found in the area are Fabaceae, Euphorbiaceae, and Poaceae, which all had 2 species present in the area. For fish, a total of 10 species from 7 families were identified. The most abundant family found is the Sciaenidae, which had 3 species inhabiting the area. The conservation status of the fish species found during the survey was also considered. It was found that the majority of the species are of least concern (LC), and there is on species, *Arius (Sciades) parkeri*, the IUCN classified it as vulnerable (VU) according to a 2011 evaluation. None of the species were found on the CITES list.

The high rate of erosion in the study area has not only affected the mangrove stand. Fish communities in nearshore marine habitats are negatively affected when there is a loss of mangrove and other vegetation that fish species depend on for reproductive and protective cover. It has been shown by numerous studies that once the mangrove stand is negatively affected the fish community starts to decline and the fisheries area also declines

Effective measures to control the direct disposal of the domestic waste in the mangroves and surrounding environment need to be implemented and ascertained in order to protect the system.

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1 Introduction

The mangroves are critical coastal forest systems for many reasons. They play essential roles in regional and global blue carbon cycle processes along tropical and sub-tropical coastlines (Bouillon et al., 2008; Kristensen et al., 2008; Jardine and Siikamäki, 2014; Wang, et al. 2019); they are forest systems with relatively high primary productivity (Saenger and Snedaker, 1993; Komiyama et al., 2008); they have a rapid sediment carbon sequestration (Chmura et al., 2003; Alongi et al., 2005) and they are carbon-rich sediment in comparison with other coastal wetland ecosystems (Donato et al., 2011;; Perera, et al. 2018;). Also, mangrove forests are critical productive ecosystems that play crucial role in coastal area protection as well as in maintaining diverse marine ecosystems (Veettil et al., 2019; Veettil and Quang, 2019). Various ecosystem services of mangrove forests include coastal protection against cyclones and tsunamis, protection of shoreline and inland natural resources and carbon sequestration (Sandilyan and Kathiresan, 2014). Although mangrove forests only account for <0.1% of earth continental surface, they are responsible for about 10% of global carbon burial and export (Wang, et al. 2019). They account for >15% of the global carbon pool (Bouillon et al., 2008; Pérez et al., 2017). However, the recent assessments of global mangrove systems suggests that about one-third of mangrove areas around the world have already been lost over past decades as a result of reclamation, deforestation, pollution, engineering, illegal logging, climate change, and urbanization (Lewis et al., 2011; Peixoto et al., 2011; Perera, et al. 2018; Fent, et al. 2019; Veettil and Quang, 2019), as well as transformation of the mangrove areas to provide aquaculture ponds (Alongi, 2002; Ward, et al. 2016).

Mangroves are among the world's most threatened ecosystems disappearing at an annual rate of 2% (Valiela et al., 2001; Liu and Lai, 2019) due mainly to deforestation, climate change, and sea-level rise (Duarte et al., 2013; Hamilton and Friess, 2018; Lovelock et al., 2015). The destruction of global mangroves can lead to a substantial loss of Carbon dioxide to the atmosphere with a magnitude equivalent to about 2.5 times of the annual anthropogenic CO_2 emissions (Siikamaki et al., 2012; Liu and Lai, 2019). Given that mangroves have a high Carbon sequestration potential and a restricted spatial distribution confined to the coastal zone, they should be conserved with top priority, especially in regions like tropical country like Guyana with extensive coastlines, for meeting the commitments of the Paris Agreement (Taillardat et al., 2018).

Although many factors are behind mangrove loss, humans largely contribute to the vulnerable state of the loss (Gallup, et al., 2020). In describing anthropogenic degradation of mangroves globally, six distinct categories have been found: (1) degradation resulting from extractive uses of mangrove trees and fauna (Ellison and Farnsworth, 1996; Romañach, et al., 2018); (2) degradation of mangroves associated with reclamation for non-extractive uses (including the harvesting of fish, crab, shellfish, honey, wood, charcoal and tannins); the conversion of mangroves for agricultural, industrial and urban developments; and to create salt flats and shrimp ponds (Alongi et al., 2016; Cisse et al., 2004; Diop and Soumare, 1999; Ellison and Farnsworth, 1996; Romañach, et al., 2018; Valiela et al., 2001); (3) degradation resulting from the pollution of mangroves (Ellison and Farnsworth, 1996; Fall et al., 2009; Romañach, et al., 2018); (4) degradation resulting from human-driven climate change (Ellison and Farnsworth, 1996); (5) degradation resulting from anthropogenic hydrological changes (Dahdouh-Guebas et al., 2004); and, (6) degradation resulting from overgrazing by livestock (Dahdouh-Guebas et al., 2006). Many countries have placed mangrove protection firmly into policy guidelines or framework legislation. Laws that govern land use and the management of mangroves vary significantly across nations and even within nations (Lavieren et al., 2012; Weigel et al., 2011; Weigel and Dahou, 2007).

In Guyana, mangrove is one of the coastal-marine ecosystems considered strategic for the development and protection of abundant resources in the coastal areas of the country. Unfortunately, in Guyana, mangroves degradation is a big concern, the leading causes are related to urban expansion, climate change, pollution, changes in the use of the soil and overexploitation of the natural elements, among others (e.g. CI, 2018; Bovell, 2013; 2019). Specifically, urban expansion towards the mangrove areas has generated pollution due to the wastewater and solid waste, which are improperly handled and dumped into the ecosystem, thereby turning solid waste into marine litter.

Guyana's marine ecosystem is part of the North Brazil Large Marine Ecosystem and is considered a highly productive ecosystem with moderately diverse food webs. The high productivity of marine habitats of the Guianas is related to the high diversity and abundance of marine species it contains. Additionally, many river plumes including that of the Amazon River and other major rivers, such as the Corentyne and Essequibo Rivers enrich the marine habitats along the coast of the Guianas with nutrients. The entire coastal zone of Guyana lies below sea level and is protected

by 370 km of sea defences, 80 km of which are defensive structures that range from earthen banks to concrete walls, the rest being natural / mangroves and mudflats. The vulnerability of the coastal zone is made more acute by predictions of a rise in mean sea level driven by climate change (STAC, 2018: page 10, paragraph 3 of the project document).

Therefore, the main aim of this report is to provide information on the data collected and analysed at Wellington Park in East Berbice-Corentyne, Guyana. It is hoped that the data collected, analysed and reported here will provide important environmental baseline information of what is needed to monitor the state of this mangrove system along time.

2 Approach and Methodology

2.1 Study Site: Wellington Park

Wellington Park (Figure 1) is one of the mangrove restoration intervention sites in Guyana. It is in the East Berbice-Corentyne of the Mahaica-Berbice Region (Region 6) of Guyana and one of the sites where the success of mangrove restoration project was initially recorded (GoG, 2012). However, the noticeable extensive erosion driven by natural forcing and observable pollution of the mangrove environment with sawdust in the Canje Creek have contributed to the significant loss of the mangrove forests in this restoration site (Bovell, 2019). Recent research and academic work on Wellington included the works by Da Silva (2014 and 2015) and Primo (2017). While Da Silva (2014 and 2015) observed, examined and identified fourteen (14) families of species diversity of mangrove ecosystem at the Park; Primo (2017), on the other hand, examined litter production by mangrove forest in three different study sites which included Village #7, Wellington Park and Hope respectively. According to the Guyana National Bureau of Statistics Census (2012), Wellington Park (No. 33 Village) area has an estimated seventy-seven (77) inhabitants with the major livelihood activity being agriculture. Farmers use pesticides and herbicides which are sources of metals pollution as well as Nitrogen, while animal husbandry is a source of Phosphorous non-point pollutants.

At Wellington Park Mangrove Restoration site, sediments/soils, surface water, vegetation and vertebrate/invertebrate samples were collected and analysed, the results of which are presented in this report.

Figure 1 Wellington Park Mangrove Forest in East Berbice-Corentyne, Guyana showing the site where data were collected for various analysis (Image Courtesy of Google Earth Pro. © Image 2020 CNES/Airbus)

2.2 Data Collection: Sediment Sampling

This section described the methods used for the sampling of the soil/sediment at the study site. A total of thirteen (13) surface sediment short cores (length < 30 cm) were collected alongshore at regular intervals from the intertidal zones and within the forested mangrove areas of Wellington Park (See Figure 2 for the sample locations of the sediments) using a 65 mm diameter tube. The samples extracted using the pipes were immediately sliced and packed in bags. The specially designed pipes were used for the sediment extraction so as to maintain the structure and arrangement of the sediment profiles. The extracted short core (< 30 cm) sediment samples were then sliced into 0- 10 cm, 11 – 20 cm and 21 – 30 cm respectively maintaining the profile of the extracted sediments and these were stored at low temperature ($+4^0$C) from the field and during their transportation to the laboratory. Sample locations (in Figure 2) were positioned using a hand-held Global Positioning System (± 3 m rms error). The erosion, transportation, entrainment or deposition of sediments by any medium/fluid are controlled not only by the physical properties of the particles themselves but also that of driving mechanisms (Molinaroli, et al. 2009; Oyedotun, 2016). The sediment characteristics (e.g. chemical and physical properties) may be significantly influenced during the transport processes (Pye, 1994). Therefore, sampling alongshore the system was conducted with the hope of it revealing important information about the sources of sediment compositions, the sediment transport history and their depositional situation (Holland and Elmore, 2008; Oyedotun, 2016).

Indeed, many marine and coastal systems are increasingly affected by the release and deposition of heavy metals and various forms of non-point pollutants from different anthropogenic activities (Popadic, et al. 2013; Wang, et al. 2015). These materials do always settle and become incorporated into the sediments, thereby making sediments the reservoir of heavy metals and pollutants in a coastal-marine environment (Young, et al. 2013; Wang, et al. 2015). The short sedimentary cores (length < 30 cm) obtained from the thirteen (13) sampling sites (Figure 2) using a 65 mm diameter tube at the mangrove system were sliced into 10 cm interval into sub-samples for investigation into their geochemical components and composition.

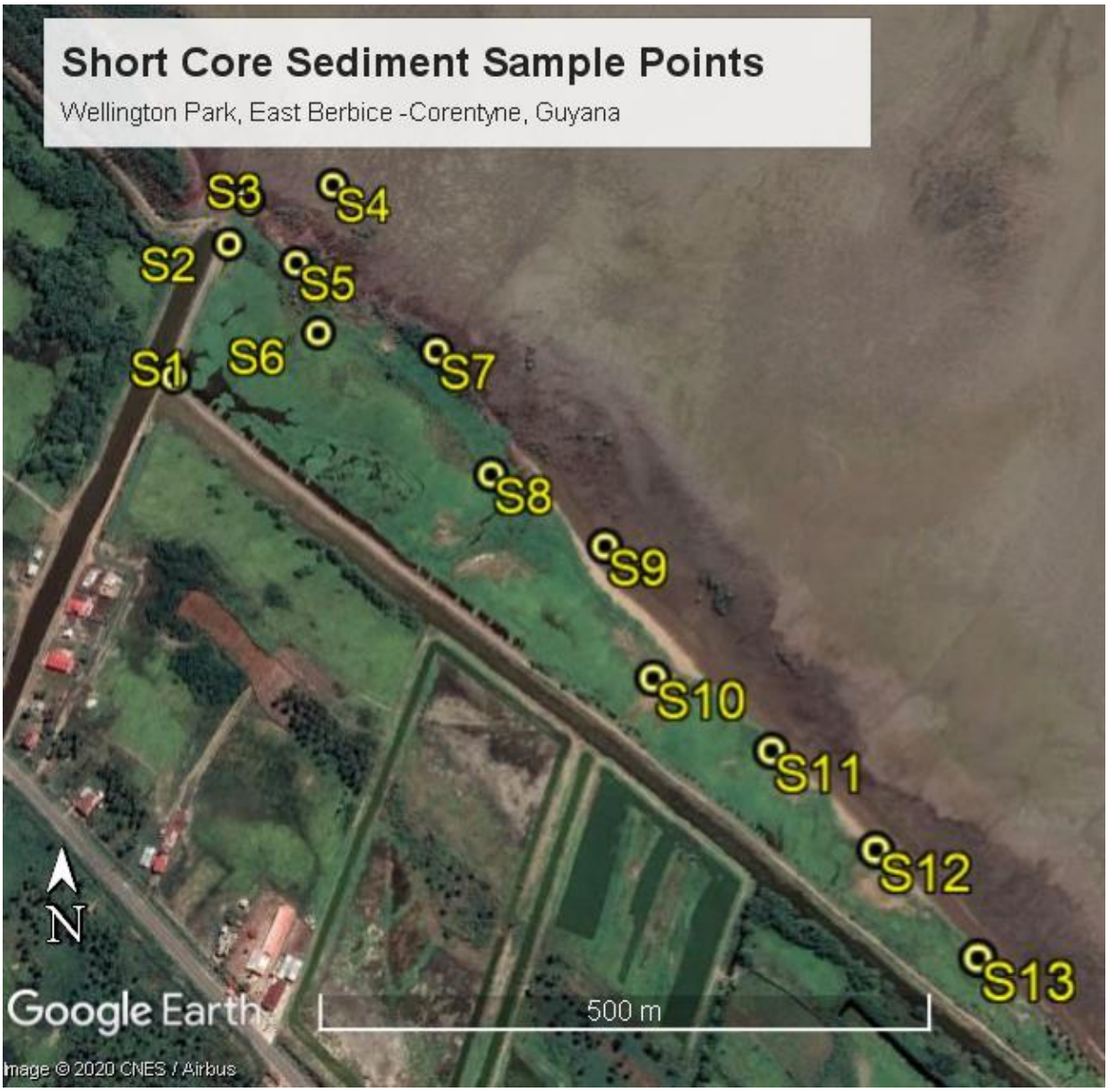


Figure 2 Sediment (Short Core) Sample Points (S1 – S13) at Wellington Park Mangrove Forest in East Berbice-Corentyne, Guyana showing the site where data was collected for various analysis during the 14 – 17 January 2020 fieldwork (Image Courtesy of Google Earth Pro. © Image 2020 CNES/Airbus)

Figure 3 Example of sediment (Short Core) extracted from the site (A) and how it is bagged into 0 – 10 cm, 11 – 20 cm etc. (C).

2.3 Data Collection: Water Sampling

A multi-parameter metre probe (HI9829/10-02) was used to measure surface water quality at nine (9) locations within and outside the Mangrove Restoration site by the channel that connects with the Canje River. Figure 3 provides location where the surface water variables were measured *in-situ* and 27 water samples (3 per each of the 9 sites) were collected for laboratory analyses. With the aid of Hanna HI9829 multi-parametre probe (Figure 5A and D), some surface water quality parameters measured in triplicates on sites for their pH, Temperature, Total Dissolved Solids

(TDS), Dissolved Oxygen (DO), Conductivity and the HACH 2100P turbidimeter (Figure 5C) was used to measure the turbidity in each of the locations on site (in-situ). At each of the nine (9) sampled locations identified before and within the mangrove restorated areas and the coastal shoreward side of the mangrove forest, sterilised bottles were used to collect three (3) samples which were sent for laboratory (off-site) analyses. The spatial location of the sampling points were marked with the aid of GPS during the fieldwork executed between 14 and 17 January 2020. The collected samples which were stored in sterilised bottles were transported for laboratory analyses. The methods of data collection and the analyses for this work are well documented in academic literature (e.g. McCullough, 2015; Søndergaard, et al. 2018; Williams, et al. 2019).

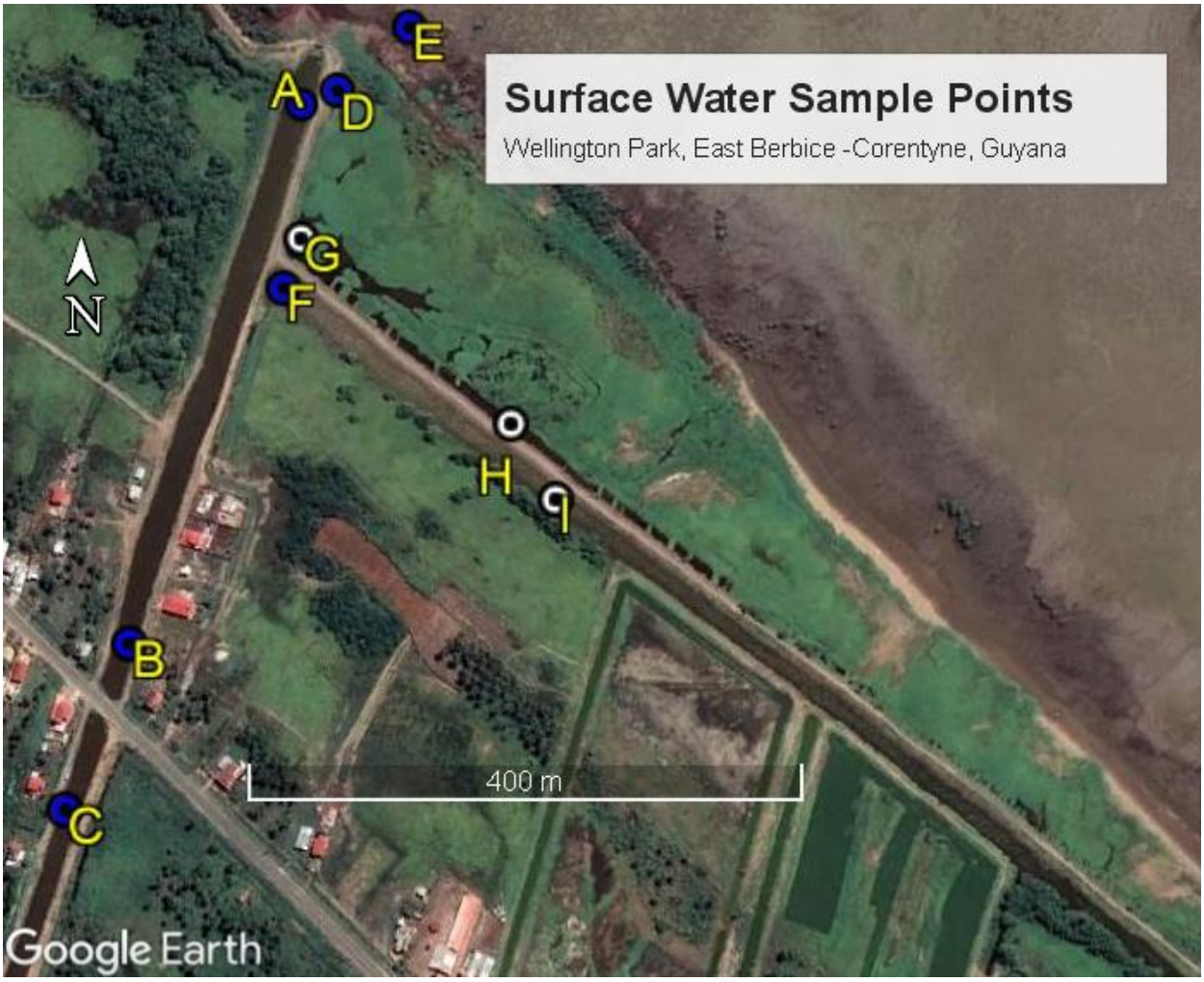


Figure 4 Surface Water Sample Points (A – I) at Wellington Park Mangrove Forest in East Berbice-Corentyne, Guyana showing the site where water samples were collected for various analyses during January 14-15, 2020 Fieldwork (Image Courtesy of Google Earth Pro. © Image 2020 CNES/Airbus)

Figure 5 Example of surface water sampling on the field for multiparameter testing and labs (A) Hanna HI9829 multi-parametre probe used at the field (B) and HACH 2100P turbidimeter (C). Examining water quality parameter using HI9829 multi-parameter probe on the field and recording the observations (D).

2.4 Data Collection: Vegetation Sampling

A regular design along-shore was used to survey the vegetation in the study area used the transect survey method. The transect ran from the shoreward side of the mangrove forest to the seaward side (in West to East direction) (See Figure 6). Transects were spaced in 120 m apart going from west to east direction. All plants for the vegetation types that intersects each transect were identified, and the number of individual plants was recorded.

Figure 6 Transects for Vegetation Survey at Wellington Park Mangrove Forest in East Berbice-Corentyne, Guyana showing the site where data was collected for various analysis (Image Courtesy of Google Earth Pro. © Image 2020 CNES/Airbus)

Field Work Procedures

The starting point of the transects was marked using a GPS. The transects were oriented perpendicular to the seashore start point (90^{o} bearing) using a compass, which was adjusted to compensate for magnetic declination.

2.5 Data Collection: Vertebrate and Invertebrate Survey

To determine the vertebrate and invertebrate species present in the Wellington Park mangroves, the following procedures were followed:

- Observations – observations were made along the transects for signs and physical sightings of vertebrates and invertebrates
- Informal Interviews – the resident in the surrounding community were interviewed to ascertain what species were present within the mangroves in the area

- Sampling – nets were swiped along each transect (See Figure 7 for the example of how the nets were swiped along each transect). The species caught were identified, and the individuals counted. Morphological data such as length and height were taken and photographs taken for all specimen, both known and unknown.

Figure 7 Setting nets for the vertebrate sampling

2.6 Data Analysis: Sediment Analysis

Sediment's mineralogical or geochemical analysis are very useful in metal pollution investigation as studies have been found that they have long residence time in marine-coastal-estuarine environments (e.g. Antizar-Ladislao, et al. 2015; Oyedotun, 2016). The samples preparation, after the collection from the field, involved them being oven-dried at either 70°C (for XRF) and 50°C (for microplastic investigation) in Oven Drier for three (3) days before the dried samples were pulverised into fine powder using an agate mortar and pestle. Each pulverised ground sample were

then weighed and measured prior to analysis. The pulverised samples weighed between 4 – 6 grams. For the sampled sediments analysed, X-ray Fluorescence Spectrometry (XRF) was used to determine the major oxide and trace element composition of sediment samples (after Bloemsma, et. al., 2012; Oyedotun, 2016; 2018) which allowed the X-ray intensity to quantitatively analyse the elements present in the sediment sub-samples. The micro-plastic investigations within the sediments were examined using the Leica Microsystems' stereoscope following the procedures described by Bodin, et. al. (2013), Kovač Viršek et al. (2016) and Garcés-Ordóñez, et al. (2019). These methods of data analysis are summarily described as follows:

XRF – The major and trace elements in their oxidised state were determined/measured as percentage of composition for the major elements (after Norrish and Chappell, 1977) while trace/minor elements were measured to obtain data in concentrations of one to several tons and parts per million (microgram-mg or a gram g, μg/g). Major geochemical elements of the sediments that was analysed (through X-ray Fluorescence Spectrometry, XRF) were: Ca (Calcium), Si (Silicon), Al (Aluminium), Fe (Iron), Cl (Chlorine), Mg (Magnesium), Na (Sodium), K (Potassium), Ti (Titanium), S (Sulphur), P (Phosphorus), Mn (Manganese), V (Vanadium), and Cr (Chromium). The trace elements that were considered in the XRF analysis are: Ti (Titanium), Cr (Chromium), Co (Cobalt), Sr (Strontium), Se (Selenium), Sb (Antimony), U (Uranium), Zn (Zinc), Br (Bromine), Zr (Zirconium), Ba (Barium), Ce (Cerium), Pb (Lead), (Copper), Ga (Galium), Ce (Cerium), As (Arsenic), Rb (Rubidium), Y (Yttrium), Mo (Molybdenum), Ag (Silver), Sn (Tin), Te (Tellurium), I (Iodine), Cs (Caesium), La (Lanthanum), Hf (Hafnium), Ta (Tantalum), W (Tungsten), TI (Thallium), Bi (Bismuth), and Th (Thorium) possibly. The samples analysed were obtained from 0-10 cm, 11-20 cm, and 21-30 cm of the 13 core samples respectively. These subsamples were analysed using a Handheld Delta X-ray Fluorescence Spectrometry to produce the high X-ray intensity, which permits the quantitative analysis of elements (Coccato et al., 2017; Margui et al., 2016; Young et al., 2016).

Figure 8 Example of sediment preparation in the lab after the fieldwork. Weighing the sediments (A and B) before being put into the oven for oven dried for three days (C). The dried samples were pulverised into fine powder using an agate mortar and pestle (D and E). Each pulverised ground sample were then weighed and measured prior to analysis using Handheld X-ray Fluorescence Spectrometry (XRF) to determine the major oxide and trace element composition of sediment samples (F).

Microplastic investigation/analysis – The samples were loosened up and then put into a 1000ml measuring cylinder. A predetermined weight, 10g, was then put into the beaker and zinc chloride solution was then added to the beaker and thoroughly mixed with the sample using a glass rod. The mixture was then left standing for 15 minutes and then thoroughly mixed again using the glass rod and then left standing for another 15 minutes. The surface of the water was then skimmed (exactly 1 ml using a glass pipette) and put into a gridded Sedgewick-Rafter counting chamber and placed on the microscope stage and left standing for another 15 minutes. The particles suspended in the counting chamber is then quantified via manual counting using the microscope which was also used in sorting into their various categories (fibres, film, foam, pellets, fragments and microbeads). This procedure is well documented and accepted in literature (e.g. Imhof, et al. 2012; Kovač Viršek et al. 2016; Coppock, et al. 2017; Garcés-Ordóñez, et al. 2019; Rodrigues, et al. 2020)

Soil moisture investigation/analysis: Soil moisture content is expressed "through the weight as the ratio of the soil sample which contains water mass as opposed to the dry weight of the soil sample" (Klute, 1986). In order to determine the soil moisture content, the soil sample containing water mass were oven dried to constant weight. The soil samples were weighed before and after drying to compute the loss in water mass. The water mass, here, was considered as "the difference between the weights of wet and oven dry samples" (Klute, 1986). After weighing the wet soil, it was placed in an oven at 105^0C. At this temperature, the soil sample was left to dry and weighed initially after 24hrs. and then at regular intervals every three hours until constant weight was achieved. The employment of the Gravimetric Method was used to calculate the soil moisture content in this work.

The following formula that was used to compute the soil moisture content:

$$MC\% = \frac{W_2 - W_3}{W_3 - W_1} x100$$

Where: W1 = Weight of tin (g) W2 = Weight of moist soil + tin (g) W3 = Weight of dried soil + tin (g)

2.7 Data Analysis: Water Analysis

The evaluated parameters which were quantified in-situ using multi-parameters are: pH, Dissolved Oxygen (DO), Conductivity, Absolute Conductivity, Total Dissolved Solids (TDS), Temperature and Salinity. These were quantified with a multi-parametric probe HANNA® HI9828; all probes were calibrated *in situ* (See Figure 5), according to the manufacturer's instructions, before every use. Nitrite of the water samples were also tested on the field as well as Turbidity of the surface water using turbidimeter as described in Section 2.3. Biological Oxygen Demand (BOD) and *Escherichia coli (E-coli),* analyses were performed by an external accredited laboratory (Kaizen Environmental Services, Guyana). Total Suspended Solids (TSS), Electrical Conductivity (ECw), Total Nitrogen (TN), Total Phosphorus (TP), Chemical Oxygen Demand (COD), Salinity, and fats, oil and grease, analyses were performed by another external laboratory (Guyana Sugar Corporation, GuySuco, Incorporated).

2.8 Data Analysis: Vegetation Analysis

At each observation point (described in Section 2.3), the degree of impact was be assessed on a scale from 0 to 5, where 0 is *no impact* and 5 is *severely impacted* (Table 1). This was done by observing the area in a 15 - 20 m radius. Observations were made to assess how many trees were at that level where the crowns touch and overlap (code 0) or whether there are unnatural gaps between them (code 5).

Table 1 Code used to Assess the Human Interference on Mangrove Forests at the Study Site

Code	Impact	% Canopy Cover	Example
0	No impact	96-100	Even canopy of trees. No gaps. No evidence of human interference.
1	Slight impact	76-95	The canopy of trees fairly continuous but some gaps. Some regrowth. Isolated cutting/stripping of trees or some evidence of pigs digging up saplings.
2	Moderate impact	51-75	The broken canopy of trees with lower regrowth and recruitment areas. Some trees cut and stripped.
3	Rather high impact	31-50	Tree canopy is uneven, the majority of the area is not showing regrowth, and there is bare mud.
4	High impact	11-30	Only a few trees remain at canopy height. Extensive clearance and some recruitment, large areas of bare mud.
5	Severe impact	0-10	Extensive clearance to bare mud, little recruitment, few trees remain alive.

The type of impact also was considered and recorded. This was recorded on each datasheet using the following codes:

Table 2 The Types of Impact on Vegetation

Code	Type of Impact
CO	Infrastructure including, piggeries, garbage dumps, developments
ER	Erosion - shown by uneven mud surfaces or little scarps/ cliffs
EC/BS	Extensive cutting or Bark stripping (for tannins/ dyes)
MU	Multiple impacts. Note codes of multiple impacts in Remarks
FD	Others, e.g. Foraging damage by pigs, goats, sheep, cattle, etc

Data Analysis Plan – After the taxonomic identification of species, the following Diversity Indices will be considered in quantifying them:

Shannon-Wiener Index $(H') = -\sum_{n=1}^{n} (pi * \ln pi)$

Maximum diversity possible $(H_{max}) = \ln(\text{Total number of species found})$

Pielou's Evenness Index */Equitability/Evenness* $(E) = H' / H_{max}$

3 Results and Discussion

3.1 Results: Moisture Content and other Descriptions

A total of thirty-nine (39) water content tests were performed before the XRF analyses were carried out on the sediments. Table 3 shows the detailed information about the soil moisture content at each of the layers (0-10, 11-20, 21-30 cm respectively) in addition to the description of colour and texture of the sediment samples in each of the sub-sedimentary short core (< 30cm) samples examined. The table also provides the pH content of each of the core sampled.

The sites vary slightly in terms of spatial heterogeneity of patter of soil colour downcore between brown, black and gray, with variation being either very dark grayish brown, dark yellowish brown, reddish brown, dark brown, etc. (See Table 3). Differences in this soil typologies within the sites, based on colour could be as a result limited or no canopy coverage. In terms of soil texture and other descriptions, the general textural pattern observed is that sediment core within the mangrove system are of majorly clayey pattern, compact and smooth. However, the observation of sawdust within the soil texture could be an indication of alteration of biophysical environment of this mangrove system by other land uses, affecting sediment compositions. The presence of sawdust within the sedimentary core could be an indication of flux dynamics of anthropogenic land uses which are then returned to this mangrove system either through natural colonization or via assisted rehabilitation. For this inference to be fully ascertained, more data and investigation would be needed to assess and quantify this juxtaposition.

The ratio of the soil dry weight and wet weight is soil moisture content and the values of each of the layers of the sedimentary core are presented in Table 3. Most of the averages of soil moisture

contents in all of the sample sites are of 0.24±3.2. These values could indicate the state of ventilation in each core and the ability of the system to support microorganisms. However, further investigation of the influence of the moisture content on other soil physiochemical parameters are recommended to be able to establish if there is any correlation with these other parameters. It could, however, be clearly inferred that this mangrove system is well ventilated which could encourage higher soil humidity, soil organic carbon accumulation by influencing plant growth and soil microbial decomposition, if the issue of influx of anthropogenic sawdust which are observed to be colonizing the sedimentary cores are mitigated or prevented.

Table 3 Colour, Texture, Organic Matter (OM), PH and Moisture Content description of the sediment sampled and analysed. (Note: S – Sample Points as identified in Figure 2)

Sediment Samples	Colour Description	Soil Texture and other Description	Presence or Absence of other Organic Material	pH	Moisture Content
S1				8.27	
0-10	Very Dark Grayish Brown	Clayey texture			2.74
11-20	Dark Yellowish Brown	Clayey and Smooth Texture			0.59
21-30	Dark Yellowish Brown	Clayey and Smooth Texture			0.62
S2				7.68	
0-10	Dark Greenish Gray	Loose Wet Clay			0.64
11-20	Dark Greenish Gray	Less Wet, More Compact and Smooth			0.63
21-30	Black	Grainy Texture			0.72
S3				8	
0-10 OH	Brown	Wet and Loose (Sawdust)			1.88
0-10	Black	Slightly Compact			0.34
11-20	Dark Greenish Gray	Slightly Compact and Very Smooth	Root Particles		1.37
21-30	Dark Greenish Gray	Smooth, Wet and Slightly Compact			0.51
S4				8.05	
0-10 OH	Darkish Redish Brown	Loose (Sawdust)			2.53

0-10	Light Reddish Brown	Compact and Smooth	Plant Particles		0.92
11-20	Light Reddish Brown	Compact and Smooth			1.08
21-30	Very Dark Gray	Silty			0.85
S5				6.21	
0-10 OH	Brown	Loose and Wet and Grainy (Sawdust)			2.95
0-10	Dark brown	Wet and Loose (Sawdust)			3.2
11-20	Black	Dry and Loose (Sawdust)			2.01
21-30	Reddish Brown	Dry and Loose (Sawdust)			2.75
S6				6	
0-10 OH	Reddish Brown	Clayey Texture, Wet and Loose, Mixed with Sawdust			1.52
0-10	Very Dark Brown	Slightly Wet	Root Particles		2.04
11-20	Dark Brown	Slightly Wet and Loose	Root Particles		2.9
21-30	Very Dark Gray	Compact (Sawdust)	Root Particles		2.91
S7				7.94	
0-10	Very Dark Gray	Wet and Loose			2.62
11-20	Black	Wet and Sticky with very Fine Grains	Root Particles		1.68
21-30	Black	Wet and Sticky with very Fine Grains	Root Particles		1.34
S8				6.72	
0-10 OH	Brownish Yellow	Loose and Grainy, Wet Sand			0.29
0-10	Yellowish Brown	Loose and Grainy, Wet Sand			0.29
11-20	Dark Reddish Brown	Wet and Loose (Sawdust)			2.55
21-30	Dark Brown	Wet and Loose (Sawdust)			2.11

S9				7.19	
0-10 OH	Dark Brown	Wet and Loose (Sawdust)			0.88
0-10	Dark Brown	Sandy-Clayey Texture, Compact			0.38
11-20	Very Dark Gray	Sticky and Smooth			0.93
21-30	Very Dark Greenish Gray	Clayey and Smooth			0.93
S10				6.8	
0-10 OH	Brownish Yellow	Sandy-Clayey Texture, Loose and Wet (Sawdust)			0.43
0-10	Very Dark Gray	Clayey and Smooth, Sticky			0.95
11-20	Dark Greenish Gray	Clayey and Smooth, Sticky			0.78
21-30	Yellowish Red	Clayey, Dry and Compact			0.66
S11				6.62	
0-10 OH	Dark Yellowish Brown	Sandy Texture			0.27
0-10	Dark Yellowish Brown	Sandy-Clayey Texture, Very Sticky, Loose			0.64
11-20	Yellowish Brown	Sandy - Clayey Texture, Sticky			0.67
21-30	Light Yellowish Brown	Clayey and Compact			0.64
S12				6.85	
00:10	Brownish Yellow	Sandy and Loose			0.19
11:20	Brownish Yellow	Sandy and Loose			0.24
21:30	Brownish Yellow	Sandy and Loose			0.24
S13:				7	
0:10 OH	Brownish Yellow	Sandy, Wet and Loose			0.28
00:10	Brownish	Sand mixed with Sawdust, Wet and Loose			0.74
11:20	Dark Greenish Gray	Sandy-Clayey Texture, Loose			0.3

21:30	Dark Gray	Sandy-Clayey Texture, Smooth and Sticky			0.64

3.2 Results: XRF of Sediment

The results of the major geochemical element detected (using XRF) from each of the samples are presented in Table 4. These elements are Fe (Iron), Mn (Manganese), V (Vanadium), and Cr (Chromium). The minor (trace elements) detected from the samples are presented in Table 5. These are Ti (Titanium), Co (Cobalt), Sr (Strontium), Se (Selenium), Sb (Antimony), U (Uranium), Zn (Zinc), Zr (Zirconium), Pb (Lead), (Copper), As (Arsenic), Rb (Rubidium), Y (Yttrium), Mo (Molybdenum), Ni (Nickel), Cu (Copper), Nb (Niobium), Cd (Cadmium), Hg (Mercury), Le (Lanthanum), Ag (Silver), Sn (Tin), W (Tungsten), Bi (Bismuth), and Th (Thorium). Each of these samples were obtained from 0-10cm, 11-20cm and 21-30cm of the sedimentary core respectively

Table 4 Major Geochemical Elements Detected from the Sediment Samples (Note: S – Sample Points as identified in Figure 2)

Sediment Samples	Co-ordinates of the Samples	V (%)	Cr (%)	Mn (%)	Fe (%)
S1	N 06.18000^o W 057.23642^o				
0-10		0.0115	0.0041	0.5521	4.0901
11-20		0.0194	0.0077	0.068	4.8717
21-30		0.022	0.0055	0.0864	4.8155
S2	N 06.18121^o W 057.23611^o				
0-10		0.0221	0.0077	0.0388	4.6891
11-20		0.0233	0.0073	0.0593	4.7563
21-30		0.0239	0.0069	0.0544	4.6081
S3	N 06.18121^o W 057.23611^o				
0-10 OH		ND	ND	0.2791	3.7449
0-10		0.0168	0.0074	0.1306	4.5803
11-20		0.0186	0.0039	0.0668	4.8272
21-30		0.0271	0.0055	0.0554	4.8457

S4	N 06.18177° W 057.23528°				
0-10 OH		0.0088	ND	0.4046	4.9094
0-10		0.0176	0.006	0.1415	4.8054
11-20		0.0183	0.0058	0.0942	4.9464
21-30		0.0223	0.0058	0.0675	4.4049
S5	N 06.18134° W 057.23607°				
0-10 OH		0.0083	ND	0.199	4.2682
0-10		0.0118	0.0042	0.3327	4.6217
11-20		0.0147	0.0046	0.2622	4.6235
21-30		0.0128	0.0052	0.1593	3.9595
S6	N 06.18073° W 057.23528°				
0-10 OH		0.0208	0.0056	0.1077	4.8132
0-10		0.0153	0.0037	0.449	4.9352
11-20		0.0138	0.0063	0.2546	7.0551
21-30		0.0171	ND	0.0907	3.8763
S7	N 06.18006° W 057.23442°				
0-10		0.0218	0.0081	0.0636	4.3717
11-20		0.021	0.0069	0.076	4.5031
21-30		0.026	0.008	0.0695	4.5374
S8	N 06.17932° W 057.23361°				
0-10 OH		0.0135	0.0051	0.0534	3.4006
0-10		0.0104	0.0038	0.0735	3.4379
11-20		0.0119	0.0039	0.0898	3.7407
21-30		0.0126	0.0037	0.1549	4.1752
S9	N 06.17847° W 057.23295°				
0-10 OH		0.0156	0.0038	0.095	3.0896
0-10		0.0108	0.0038	0.0419	3.048
11-20		0.0145	0.004	0.0954	4.3092
21-30		0.0199	0.0046	0.078	4.5533
S10	N 06.17766° W 057.23219°				
0-10 OH		0.0135	0.0042	0.0827	3.1315
0-10		0.0236	0.0076	0.071	4.5053
11-20		0.018	0.0063	0.0696	4.5921
21-30		0.0247	0.0061	0.0599	4.321

S11	N 06.17691^{o} W 057.23139^{o}				
0-10 OH		0.0112	0.0032	0.041	2.9339
0-10		0.0119	0.0054	0.1072	4.1549
11-20		0.0143	0.0052	0.0444	3.8257
21-30		0.0247	0.0078	0.0624	4.5178
S12:	N 06.17616^{o} W 057.23058^{o}				
00:10		0.0145	0.0055	0.0365	3.1092
11:20		0.0123	0.0038	0.0414	3.1936
21:30		0.0183	0.0037	0.0444	3.8394
S13:	N 06.17537^{o} W 057.22980^{o}				
0:10 OH		0.0204	0.0047	0.0462	2.8613
00:10		0.0139	0.0025	0.0425	3.8702
11:20		0.0246	0.0068	0.0832	4.6519
21:30		0.0175	0.0044	0.0667	3.7848

Table 5 Minor Geochemical Elements Detected from the Sediment Samples (Note: S – Sample Points as identified in Figure 2; ND – No Data; OH – O Horizon)

Soil Samples	Co-ordinates	Ti (μg/g)	Co (μg/g)	Ni (μg/g)	Cu (μg/g)	Zn (μg/g)	As (μg/g)	Se (μg/g)	Rb (μg/g)	Sr (μg/g)	Y (μg/g)	Zr (μg/g)	Nb (μg/g)
S1	N 06.18000° W 057.23642°												
0-10		0.217	ND	0.0024	0.0021	0.0109	0.0013	ND	0.0111	0.0474	0.0016	0.0094	0.0016
11-20		0.2972	ND	0.0045	0.0026	0.0143	0.0019	ND	0.0135	0.0126	0.0029	0.0148	0.0025
21-30		0.3069	ND	0.0038	0.0024	0.0135	0.0022	ND	0.0138	0.0125	0.0031	0.0147	0.0028
S2	N 06.18121° W 057.23611°												
0-10		0.3005	ND	0.0039	0.0031	0.0133	0.002	0.0002	0.0139	0.012	0.0027	0.0153	0.0027
11-20		0.2987	ND	0.0052	0.003	0.0146	0.0019	ND	0.0144	0.0124	0.003	0.0145	0.003
21-30		0.3158	ND	0.0046	0.0026	0.0144	0.0014	0.0002	0.0139	0.0115	0.0029	0.0149	0.0027
S3	N 06.18121° W 057.23611°												
0-10 OH		0.1174	ND	ND	0.0015	0.0064	0.0064	ND	0.0071	0.0114	0.0016	0.0106	0.0008
0-10		0.2603	ND	0.0042	0.0028	0.0109	0.0052	0.0002	0.0117	0.012	0.003	0.0178	0.0023
11-20		0.3053	ND	0.0032	0.0025	0.0138	0.002	ND	0.0136	0.0122	0.003	0.0153	0.0025
21-30		0.2819	ND	0.0036	0.0023	0.0133	0.0027	ND	0.0133	0.0124	0.0027	0.0153	0.0027
S4	N 06.18177° W 057.23528°												
0-10 OH		0.1595	ND	0.0016	0.0035	0.0078	0.0111	ND	0.0101	0.0189	0.0025	0.0125	0.001
0-10		0.304	ND	0.0026	0.0026	0.0133	0.0031	ND	0.0132	0.0139	0.003	0.014	0.0024
11-20		0.2971	ND	0.0036	0.0026	0.0138	0.0028	ND	0.0139	0.0137	0.0029	0.0144	0.0025
21-30		0.288	ND	0.0034	0.0025	0.0129	0.002	ND	0.013	0.0127	0.003	0.0151	0.0024
S5	N 06.18134° W 057.23607°												
0-10 OH		0.1341	ND	0.0028	0.0037	0.0077	0.0093	0.0002	0.0111	0.0136	0.0031	0.0125	0.0012
0-10		0.1345	ND	0.0035	0.0038	0.0072	0.0107	0.0002	0.0094	0.0191	0.0034	0.0159	0.0012

11-20		0.1808	ND	0.0026	0.0035	0.0094	0.0088	0.0002	0.0117	0.0146	0.0034	0.0145	0.0016
21-30		0.1744	ND	0.0036	0.0037	0.0098	0.0069	0.0003	0.0114	0.0124	0.0031	0.014	0.0017
S6	N 06.18073^{o} W 057.23528^{o}												
0-10 OH		0.2396	ND	0.0053	0.0033	0.0121	0.0058	0.0002	0.0128	0.0132	0.0033	0.0144	0.0021
0-10		0.1469	ND	0.0029	0.0042	0.0086	0.0116	0.0003	0.0118	0.0149	0.0034	0.0142	0.0015
11-20		0.1477	ND	0.005	0.0046	0.0099	0.0147	0.0004	0.0132	0.0151	0.0022	0.0109	0.0015
21-30		0.1602	ND	0.0029	0.0036	0.0083	0.0081	0.0003	0.0113	0.0123	0.0034	0.0119	0.0013
S7	N 06.18006^{o} W 057.23442^{o}												
0-10		0.2783	ND	0.0049	0.0026	0.0129	0.0023	ND	0.0127	0.0115	0.0031	0.0155	0.002
11-20		0.2527	ND	0.0048	0.0027	0.0126	0.003	ND	0.0128	0.0125	0.0029	0.014	0.0023
21-30		0.2861	ND	0.006	0.0025	0.0132	0.0026	ND	0.0139	0.013	0.0032	0.0145	0.0025
S8	N 06.17932^{o} W 057.23361^{o}												
0-10 OH		0.0959	ND	0.0026	0.0012	0.0059	0.0028	0.0002	0.003	0.0065	0.0014	0.0103	0.001
0-10		0.0963	ND	0.0022	0.0012	0.0054	0.0031	0.0002	0.004	0.0068	0.0014	0.0104	0.0011
11-20		0.1497	ND	0.0043	0.0045	0.0084	0.0056	0.0003	0.0127	0.0136	0.0025	0.0124	0.0017
21-30		0.2035	ND	0.0034	0.0036	0.01	0.0044	0.0003	0.0125	0.0134	0.0028	0.0164	0.0018
S9	N 06.17847^{o} W 057.23295^{o}												
0-10 OH		0.1009	ND	0.0029	0.0015	0.0061	0.0029	0.0002	0.0037	0.0075	0.0012	0.0087	0.001
0-10		0.1252	ND	0.0023	0.0009	0.0057	0.0021	ND	0.0042	0.0055	0.0015	0.0092	0.0011
11-20		0.2419	ND	0.0029	0.0019	0.0108	0.0022	ND	0.0105	0.0105	0.0023	0.0115	0.002
21-30		0.2728	ND	0.0028	0.002	0.0119	0.0024	ND	0.0109	0.0151	0.0025	0.0158	0.0022
S10	N 06.17766^{o} W 057.23219^{o}												
0-10 OH		0.1369	ND	0.0034	0.0015	0.006	0.0026	0.0001	0.0034	0.0069	0.0014	0.0133	0.0011
0-10		0.2817	ND	0.005	0.0026	0.0124	0.0019	0.0002	0.013	0.0114	0.0027	0.0133	0.0025
11-20		0.2944	ND	0.0038	0.0024	0.0127	0.002	0.0001	0.0122	0.0133	0.0026	0.0129	0.0023

21-30		0.3043	ND	0.0052	0.0031	0.0136	0.002	ND	0.0131	0.0125	0.0033	0.0171	0.0027
S11	N 06.17691^{o} W 057.23139^{o}												
0-10 OH		0.1081	ND	0.0022	0.0008	0.0051	0.0023	ND	0.0025	0.0042	0.0012	0.0139	0.0011
0-10		0.2636	ND	0.0021	0.0019	0.0088	0.0031	ND	0.0077	0.0084	0.0022	0.0196	0.0019
11-20		0.1685	ND	0.0034	0.0019	0.0075	0.0026	0.0001	0.0063	0.008	0.0018	0.0102	0.0014
21-30		0.324	ND	0.0057	0.0029	0.0149	0.0014	ND	0.0149	0.0131	0.0032	0.0145	0.0027
S12:	N 06.17616^{o} W 057.23058^{o}												
00:10		0.1051	ND	0.0029	0.0011	0.0048	0.0024	0.0002	0.0016	0.0034	0.0013	0.0202	0.0014
11:20		0.1118	ND	0.0027	0.0013	0.0045	0.0026	ND	0.002	0.0033	0.0011	0.0123	0.0011
21:30		0.1094	ND	0.0024	0.0012	0.0057	0.0033	0.0002	0.0022	0.0058	0.0015	0.0319	0.0014
S13:	N 06.17537^{o} W 057.22980^{o}												
0:10 OH		0.154	ND	0.0033	0.0014	0.0052	0.0023	0.0002	0.0032	0.0051	0.0013	0.018	0.0011
00:10		0.2147	ND	0.0027	0.0017	0.0098	0.0016	ND	0.0096	0.0095	0.0025	0.0128	0.0019
11:20		0.3041	ND	0.0055	0.0035	0.0123	0.0025	0.0002	0.012	0.0115	0.0031	0.0228	0.0025
21:30		0.2085	ND	0.0031	0.0018	0.0085	0.002	ND	0.0073	0.0094	0.0021	0.0127	0.0017

Continuation of Table 5.

Soil Samples	Co-ordinates	Mo (μg/g)	Ag (μg/g)	Cd (μg/g)	Sn (μg/g)	Sb (μg/g)	W (μg/g)	Hg (μg/g)	Pb (μg/g)	Bi (μg/g)	Th (μg/g)	U (μg/g)	LE (mg La/kg)
S1	N 06.18000^{o} W 057.23642^{o}												
0-10		ND	ND	0.0021	ND	ND	ND	0.0006	0.002	0.001	0.0012	ND	95.0305
11-20		ND	ND	0.0032	ND	ND	0.0011	0.0006	0.0037	ND	0.0018	ND	94.6563
21-30		ND	ND	0.0029	0.0023	ND	0.0016	ND	0.0034	ND	0.0016	ND	94.683

S2	N 06.18121^{o} W 057.23611^{o}												
0-10		0.0003	ND	0.0026	ND	ND	0.0022	0.0011	0.0032	ND	0.0021	ND	94.8611
11-20		ND	ND	0.0031	ND	ND	ND	0.0011	0.0033	ND	0.0024	ND	94.7733
21-30		ND	ND	0.0047	0.0027	ND	ND	0.0009	0.0032	ND	0.0022	ND	94.9082
S3	N 06.18121^{o} W 057.23611^{o}												
0-10 OH		ND	ND	0.0021	ND	ND	ND	ND	0.0035	0.0018	ND	ND	95.8055
0-10		ND	ND	0.0039	ND	ND	0.0013	0.0007	0.0041	ND	0.0012	ND	94.9233
11-20		ND	ND	0.0022	ND	ND	ND	ND	0.0032	ND	0.0019	ND	94.7028
21-30		ND	ND	0.0035	ND	ND	ND	0.0008	0.0033	ND	0.0019	ND	94.7066
S4	N 06.18177^{o} W 057.23528^{o}												
0-10 OH		ND	ND	ND	ND	ND	ND	ND	0.0056	0.0026	ND	ND	94.4406
0-10		ND	ND	0.0031	ND	ND	0.0012	ND	0.0036	ND	0.0015	ND	94.648
11-20		ND	ND	0.0021	ND	ND	ND	0.0007	0.0036	ND	0.0014	ND	94.5601
21-30		ND	ND	0.0043	ND	ND	0.0017	ND	0.0033	ND	0.002	ND	95.1331
S5	N 06.18134^{o} W 057.23607^{o}												
0-10 OH		ND	ND	0.0024	ND	ND	ND	ND	0.0068	0.0022	0.0011	ND	95.3127
0-10		ND	ND	0.0027	ND	ND	ND	ND	0.0069	0.0017	0.0012	ND	94.8082
11-20		ND	ND	0.0018	ND	ND	ND	0.0007	0.006	0.0022	0.0008	ND	94.8327
21-30		ND	ND	0.0046	ND	ND	ND	ND	0.0058	0.0017	0.0014	ND	95.6083
S6	N 06.18073^{o} W 057.23528^{o}												
0-10 OH		ND	ND	0.0031	ND	ND	ND	0.0007	0.0049	0.0016	0.001	ND	94.7293
0-10		ND	ND	0.0046	ND	ND	ND	ND	0.0069	0.0024	0.0013	ND	94.3613
11-20		ND	ND	0.0036	ND	ND	ND	ND	0.0065	0.0019	0.0013	ND	92.4316
21-30		ND	ND	0.003	ND	ND	ND	0.001	0.0059	0.002	0.001	ND	95.7795

S7	N 06.18006^{o} W 057.23442^{o}												
0-10		ND	ND	0.0039	ND	ND	ND	0.0009	0.0036	ND	0.0015	ND	95.1792
11-20		0.0003	ND	0.0031	ND	ND	0.0013	0.0007	0.0036	ND	0.0016	ND	95.0622
21-30		ND	ND	0.0041	ND	ND	ND	0.0011	0.0037	ND	0.0026	ND	94.9901
S8	N 06.17932^{o} W 057.23361^{o}												
0-10 OH		0.0003	ND	0.0029	ND	ND	ND	0.0007	0.0013	ND	0.0008	ND	96.3906
0-10		0.0002	ND	0.003	ND	ND	0.0011	0.0007	0.0019	ND	0.0007	ND	96.3345
11-20		ND	ND	0.003	ND	ND	ND	0.0011	0.0057	0.0021	0.0013	ND	95.9248
21-30		ND	ND	0.0023	ND	ND	ND	0.0007	0.0048	ND	0.0018	ND	95.372
S9	N 06.17847^{o} W 057.23295^{o}												
0-10 OH		ND	ND	0.0033	ND	ND	0.0011	ND	0.0022	ND	ND	ND	96.6528
0-10		ND	ND	0.0036	ND	ND	0.0011	0.0005	0.0015	ND	0.0008	ND	96.7302
11-20		ND	ND	0.0024	ND	ND	ND	0.0005	0.0025	ND	0.0016	ND	95.2735
21-30		ND	ND	0.002	ND	ND	0.0013	ND	0.0027	ND	0.0018	ND	94.998
S10	N 06.17766^{o} W 057.23219^{o}												
0-10 OH		0.0004	ND	0.0034	ND	ND	0.0012	0.0007	0.0015	ND	0.0011	ND	96.5833
0-10		ND	ND	0.0034	0.0023	ND	0.0018	0.0006	0.0033	ND	0.0018	ND	95.0325
11-20		ND	ND	0.0037	0.0016	ND	0.0011	0.001	0.003	ND	0.0019	ND	94.9429
21-30		ND	ND	0.0035	ND	ND	0.0015	0.0014	0.0032	ND	0.0025	ND	95.1993
S11	N 06.17691^{o} W 057.23139^{o}												
0-10 OH		0.0003	ND	0.0028	ND	ND	0.0013	ND	0.0012	ND	0.0009	ND	96.8629
0-10		ND	ND	ND	ND	ND	ND	ND	0.0022	ND	0.0013	ND	95.3976
11-20		0.0004	ND	0.0032	ND	ND	0.0015	ND	0.0022	ND	0.001	ND	95.8904
21-30		ND	ND	0.003	ND	ND	0.0014	0.0012	0.0036	ND	0.0023	ND	94.9787

S12:	N 06.17616^{o} W 057.23058^{o}												
00:10		0.0005	ND	0.0023	ND	ND	0.0017	ND	0.0012	ND	ND	ND	96.6843
11:20		0.0004	ND	0.0034	ND	ND	0.0012	ND	0.001	ND	ND	ND	96.6
21:30		ND	ND	0.0045	ND	ND	ND	ND	0.0012	ND	0.0009	ND	95.9226
S13:	N 06.17537^{o} W 057.22980^{o}												
0:10 OH		0.0005	ND	0.0037	ND	ND	0.0016	0.0006	0.0013	ND	0.0013	ND	96.8634
00:10		ND	ND	0.0022	0.0023	ND	ND	0.0008	0.0026	ND	0.0015	ND	95.7946
11:20		ND	ND	0.003	ND	ND	0.0016	0.0012	0.0033	ND	0.0024	ND	94.8419
21:30		0.0002	ND	0.0025	ND	ND	0.0012	0.0006	0.0021	ND	0.0015	ND	95.8615

Mangrove ecosystems are exposed to a variety of contaminants and anthropogenic agents. Wastewater run-offs, industrial effluents, atmospheric and marine activities are major contributors in this regard. Heavy metals such as copper (Cu), zinc (Zn), manganese (Mn), cadmium (Cd), chromium (Cr), lead (Pb) and mercury (Hg) are particularly important in these ecosystems (Silva et al., 1990; Kulkarni, et al. 2018). Such metals are generally persistent and tend to accumulate in food chains. Their contents are higher in sediments where they form complexes with particulate organic carbon; iron oxyhydroxides and sulphides (Chapman, et al., 1998; Ranjan et al., 2008). The level of heavy metal contamination in an ecosystem may be measured by analysing water, soil, sediment and/or biological samples. However, to determine the extent of anthropogenic impacts on a certain ecosystem, heavy metal analyses in sediments has become a standard method to elucidate this impact (Chatterjee et al., 2009; Bastakoti, et al. 2018). Analysis of pollutants in sediments may also provide critical information to identify anthropogenic water pollution (Senten, 1989; Buajan and Pumijumnong, 2010), since some pollutants are absorbed by fine grained particles that may be continuously re-suspended and deposited. Since mangrove sediments do act as sinks for heavy and trace metals by sequestering allochthonous organic matter from terrigenous sources (Lewis, et al., 2011; Maiti and Chowdhury, 2013), hence the presentation of both heavy (major) and trace metals of sediments sampled from the study sites at Tables 4 and 5 respectively.

In general, heavy metal pollution in this study of the mangrove environment is associated with human-related processes, such as non-point agriculture pesticides and herbicides, untreated domestic wastewater, sewage effluent, and surface run-off, as similar to other mangrove systems that have been studied in other parts of the world (e.g., Chen et al., 2012; Usman et al., 2013; Shi, et al. 2019, etc.). Mangrove sediments appear to be a reliable indicator of local heavy metals contamination and may reflect regional pollution levels and their possible ecological risks (Ribeiro et al., 2018; Shi, et al. 2019). Sediments carried out by the marine current draining the Guianas from the Amazon River can also transport mercury from mining as well as other metals which are product of the metal extraction and processing along those coasts.

The surface sediments of the thirteen (13) sampling sites had a pH range of 6.0–8.27 with an average of 7.18 (Table 3), which indicated that the sediments were mainly alkaline. This represents an unfavourable physical property of soils, especially in soils with smectite-type clay content

(Blaskó, 2011). It becomes unfavourable because in any very alkaline soil, some certain micronutrients such as zinc and copper may become chemically unavailable to plants.

The thirteen (13) sites also contained higher levels of Mn, and Fe than the other heavy metals (Table 4), which suggested that the current heavy metal detected along the coastline in Wellington Park may be mainly dominated by Mn and Fe. Silt and clay are mainly responsible for retaining heavy metals in aquatic sediments. Therefore, the higher concentrations of these major metals in the sampled sediments could be partially attributed to its large clay fraction observed (see Table 3).

For the other metals (trace) analysed. Co, Se, Mo, Ag, Sn, Sn, W, Bi, and U were not detected in the samples analysed, whereas V, Ni, Cd, Hg, Pb, Bi and Th are of negligible amounts in all of the samples, even to the depth of 30 cm. Le (Lanthanum) is a trace metal that is significantly detected in all of the samples, from 0 – 30 cm and in all of the 13 short core samples analysed (Table 5). This ranged between 92 and 96.6 mg La/kg with the average of 95.3 mg La/kg with a Standard Deviation of 0.84, indicating that there is no significant difference across the sites and in regard to the depth. Lanthanum was one of the dominating elements in the soils near the mining area studied by Li et al. (2010), with concentrations of between 40 and 140 mg La/kg in agricultural soil but as high as 1800 - 6905 mg/kg in spots of wasteland closest to the mining area (Li et al., 2010; Liang et al., 2014; Li, et al. 2018). The average La concentration in the Earth crust is approximately 30 mg/kg (Henderson, 1984), with average soil concentrations of 6.6 - 50 mg La/kg dry soil for most countries (Ramos et al., 2016; Li, et al. 2018). The findings from this study indicate the La toxicity of soils in the sampled areas. Although the presence of La is beneficial to plants and organisms (e.g. Fastovets, et al. 2017), however, the excess of La could be toxic to soil invertebrates at concentrations slightly above the natural background levels of 6.6 - 50 mg La/kg of the dry soil found in most soils. The excess here suggests that effects of La on the soil community may already occur following relatively minor extra inputs from industrial, agricultural or domestic emissions in the area. This emphasises the importance of considering local background levels of La and possible use of an added concentration approach in order to assess if anthropogenic inputs of La can provoke adverse effects to soil organisms, disrupting plan photosynthesis, reduce the content

of important elements, etc. Further studies would be needed to investigate this scenario and possibilities.

Many previous studies have reported that Cd pollution was mainly derived from human activities (Ranjan et al., 2008; Harikumar and Jisha, 2010). Cadmium pollution was not significantly detected in all of the sample sites nor in all of the sediments across the 30 cm depth. Although Cd concentration observed is negligible, Cd has a relatively high risk due to its strong toxicity characteristic. In general, Cd is mainly derived from land-based anthropogenic sources, such as urban/domestic and industrial wastewater, traffic, road construction, mining, and other industrial activities (Ranjan et al., 2008; Harikumar and Jisha, 2010).

Roads are considered to be line sources of lead (Pb) pollution, even in areas away from cities (Ward et al., 1975; Stewart, 1989). Wellington Park has the main road not far from the mangrove system and minor road that leads to the environment, which could be a line source of Pb pollution.

Similar to other metals, the sources of the limited As detected in samples could be both natural or anthropogenic (Mandal and Suzuki, 2002). Naturally, As is present in both sedimentary and igneous rocks with average concentrations of 2 mg/kg (Mandal and Suzuki, 2002). Various researchers have reported that natural processes could be the main reason for elevated As in uncontaminated marine sediments (Reimann et al., 2009; Mirlean et al., 2011; Mirlean et al., 2013). Naturally, carbonate materials also play an important role in retaining As in marine sediments (Mirlean et al., 2013). Many marine algae, especially brown macroalgae accumulate huge amounts of As, especially during their growth stages, and this could result in elevated, or presence of, As in marine sediments (Farías et al., 2007; Mirlean et al., 2011).

Most of the sediment samples from inside mangrove environment and the sediment profiles were comparative in metals with the samples from outside mangrove systems, respectively (Tables 3 – 5). The only difference is at the 0 – 10 cm of the profile which has deposits of loose sawdust in the profiles. Mangroves of Guyana are situated in the proximity of the Amazon River and are generally considered to be pristine; Wellington Park is not an exception. Hg and Zn were also detected metals in sediments. The minor variations in metal concentrations with depth or between areas appeared

to result from diagenetic processes rather than from anthropogenic inputs. However, anthropogenic activities can also contribute towards the presence of Fe, Mn, Zn, Cu, Ni, Ag, Pb and Cr (e.g. Silva et al., 2001, 2003; Jara-Marini et al., 2008). Other studies may be needed to establish the link. The exploration of Principal Component Analyses (PCA) is also other possibilities of further studies that can also be considered. Example of this is presented in Annex 7 for analyses per horizon which give an idea of differences from sites in the right to sites in the left (those towards Courantyne in opposition to those towards the canal that connects with the Canje Agricultural area)

3.3Results: Microplastic of Sediment

The normalized concentrations of microplastic materials were between 155 pellets of plastics and 2256 of plastic fragment / kg of dry sediment, with the highest concentrations in the stations near to the 0 – 10 cm layer of the sedimentary core (Table 6). The most abundant types of microplastics were the films from the fragmentation of food bags and wrappings, fragments of hard plastics and disposable utensils mainly of expanded polystyrene, rope fragments and fishing nylon, etc. (which are defined as irregular plastic fragments here), followed by fragments of fibres (fabrics) and pellets of plastics of materials which could not be categorised as plastic fragments nor fabric but which are present in the sediments sampled in the mangrove environment identified in Figure 2. The concentration of microplastic materials in each of the short core samples, demarcated by layers is presented in Table 7.

Table 6 Concentration of microplastic in sediment samples based on classes and layers

Microplastic Classes	0-10 cm	11-20 cm	21 – 30 cm	Total
Fibre	122	72	73	267
Fragments	835	792	629	2256
Pellets	78	27	50	155
Microbeads	0	0	0	0
Film	0	0	0	0
Foam	0	0	0	0
Total	1035	891	752	2678

There are few studies that relate to the quantification of the abundance of marine litter and microplastics on mangrove soils in Guyana, possibly due to the difficulties in the sampling activities. Oyedotun and Johnson-Bhola (2019) assessed the marine litter in five (5) sampling sites along Guyana coastline in three (3) Administrative Regions (Regions 4, 5, and 6) Guyana based on fieldwork carried out in January 2018. The study showed that the litter contents varied considerable among the sampling sites. However, out of all the categories of beach litter items in all of the sample sites, plastic materials accounted for most of the litter followed by metal, paper/card, glass, wood fragments, clothing materials, organic materials, and pottery at 48.2%, 20.8%, 11.5%, 6.8%, 4.7%, 4.6%, 3.2%, and 0.2% respectively. The average grading of the beaches showed that none could be graded A (very good), without cleaning up of such areas of litter. Rosignol and Georgetown coastal areas were the only beaches with average grade C (fair) while the other three (3) samples sites could only be graded D, very poor. Apart from this study on marine litter and that of Primo (2017), no study in the country has been carried to identify the microplastic composition in sediment. Although this study did not focus on marine litter, there are, however, the evidence of this environment being littered at the surface waterways and at the mangrove environment (Figure 9).

Figure 9 Examples of marine litters beside the surface water and at the mangrove environment

In this study, the majority of the microplastics analysed presents characteristic peaks found in polymeric materials (See Table 7), specifically they were similar to the synthetic copolymer used in the fabrication of various polymeric materials (after, Li et al., 2016; Garcés-Ordóñez, et al. 2019). Other identified materials are of polyethylene pellets and secondary microplastics (Table 7). Plastics in general are hazard to marine environments and, unfortunately, these have all become too common in coastal environment, including but not limited to mangrove environment. The reported microplastics composition in sediments from the Wellington Park Mangrove environment are examples of fragments of plastic pollution on mangrove sediments. However, microplastic poses others forms of dangers to other users of mangrove environment, including marine fauna and humans that use the environment. Further studies on the impacts of microplastic deposition on the living organisms, including fish and humans are recommended as these can easily entire food chain of the inhabitants of this environment.

Table 7 Concentration of microplastic in sample sediments based on categories, layers and sample points (Note: S – Sample Points as identified in Figure 2)

Samples	Microplastics	01-10 cm	11-20 cm	21 -30 cm	Total	Total per Sample
	Fibre (Fabric)	5	3	3	11	
S1	Fragments (Irregular)	42	26	32	100	
	Sphere (pellets) of other materials	1	0	3	4	
						115
	Fibre (Fabric)	12	4	7	23	
S2	Fragments (Irregular)	128	114	132	374	
	Sphere (pellets) of other materials	20	4	6	30	
						427
	Fibre (Fabric)	11	7	4	22	
S3	Fragments (Irregular)	26	37	49	112	
	Sphere (pellets) of other materials	3	3	2	8	
						142
	Fibre (Fabric)	7	6	6	19	
S4	Fragments (Irregular)	25	10	14	49	
	Sphere (pellets) of other materials	0	1	0	1	
						69
	Fibre (Fabric)	9	1	3	13	
S5	Fragments (Irregular)	37	22	33	92	
	Sphere (pellets) of other materials	2	0	0	2	
						107
	Fibre (Fabric)	17	10	0	27	
S6	Fragments (Irregular)	36	126	0	162	
	Sphere (pellets) of other materials	2	9	0	11	
						200
	Fibre	19	12	15	46	
S7	Fragments	180	144	104	428	
	Sphere (pellets) of other materials	2	2	10	14	
						488
	Fibre (Fabric)	9	10	7	26	

S8	Fragments (Irregular)	93	64	49	206	
	Sphere (pellets) of other materials	5	3	3	11	
						243
	Fibre (Fabric)	7	2	3	12	
S9	Fragments (Irregular)	24	17	22	63	
	Sphere (pellets) of other materials	3	0	0	3	
						79
	Fibre (Fabric)	12	3	11	26	
S10	Fragments (Irregular)	188	152	127	467	
	Sphere (pellets) of other materials	12	5	12	29	
						522
	Fibre (Fabric)	8	8	4	20	
S11	Fragments (Irregular)	44	34	33	111	
	Sphere (pellets) of other materials	3	0	0	3	
						134
	Fibre (Fabric)	3	3	5	11	
S12	Fragments (Irregular)	24	23	17	64	
	Sphere (pellets) of other materials	1	0	1	02	
						77
	Fibre (Fabric)	3	3	5	11	
S13	Fragments (Irregular)	24	23	17	64	
	Sphere (pellets) of other materials	0	0	0	0	
						75

3.4 Results: Surface Water Quality Parameters

The bio-chemical variables of the surface water analysed from and around Wellington Park mangrove area are listed in Tables 8 and 9 respectively. Analytical results for Nitrite, oil and grease in all of the samples were below the detection limits. The pH, as a measure of acidity or alkalinity, of the surface water in all of the samples indicate that they are slightly alkaline (with values that range from 7.03 to 7.8). Any pH below 7 is considered acidic while any value greater than 7 is considered alkaline or basic. The pH measurements observed at the study sites could be classified as being acceptable for the environment as the pH value of between 6.5 and 8.5 considered an

acceptable range (e.g. SOCAR 2019). This kind of alkalinity of the natural waters is within the normal range in mangrove forest areas and this is mostly controlled and attributed to salinity and hydroxide (Lotfinasabasl, et al., 2018).

The temperature of surface waters is influenced by latitude, altitude, season, time of day, air circulation, flow and depth of the water body (Lotfinasabasl, et al., 2018). In turn, temperature affects physical, chemical and biological processes in water bodies. If temperatures exceed 35 °C, root structures, seedling establishment and photosynthesis of the mangrove trees will be negatively affected (Kathiresan and Bingham, 2001). The surface water temperature ranged between 29.11 and 34.26 °C. The mean value of 31.78 and a Standard Deviation of 1.72 could suggest that the environment provides the mangrove ecosystems with a mesophilic to thermophilic temperatures. Similar results in another environment have also reported temperatures of this range (e.g. Rajasekar, 1998; Saravanan, 1999; Rajaram, et al. 2005).

The measured dissolved oxygen (DO) concentration of the water samples indicates a high percentage at sites A, B, C, D and I which are samples taken from surface water outside the mangrove systems but within the environment. However, the DO values for the samples taken within the mangrove system are of lower value compared to that is around the system. (See Figure 10). Using the Particle Per Meter (PPM) of the Dissolved Oxygen (DO), samples sites A, B, C, D, H and I respectively could be assessed as good, while sites E, F and G can be classified as fair respectively (See Table 8). This is based on the SOCAR report that stated that the surface water status could be classified as "good (> 5 mg.l-1); yellow: fair (5- 2 mg.l-1); red: poor (< 2 mg.l-1)" (SOCAR, 2019: 83). In terms of percentages, the sites E, F and G also recorded percentages below what healthy water should be, that is the DO is expected to be between 80 and 120%. This is an indication that the water in these areas are polluted.

Although in the SOCAR report, the Land-based Sources (LBS) Working Group did not make provision for other forms of nitrogen and phosphorus assessment. If the assessment range of dissolved inorganic nitrogen and phosphorous respectively as used in the report is applied here, all the samples could be classified as being of poor status in terms of nitrogen and phosphorus nutrients. The assessment range of < 0.1 mg/l is classified as good, 0.1 – 0.5 mg/l as fair and >

0.5 as poor for dissolved inorganic nitrogen and < 0.01 mg/l for good, 0.01 – 0.05 mg/l as fair and > 0.05 mg/l for phosphorous. If there is consistent inputs of excessive of nutrients to this mangrove systems, it could give rise to eutrophication and contribute to the increasing growth of benthic macro-vegetation and phytoplankton as with other similar coastal eco-systems as indicated in the Index of Coastal Eutrophication Potential (ICEP) (SOCAR, 2019).

Phosphorus is one the most necessary nutrient for organisms which exists in the water resources in the forms of particulate and dissolved both. The phosphate concentrations were found lying in the range of 0.07 and 1.33 mg/l with a mean level of 0.49 mg/l. The standard deviation (0.47) shows a significant variation between the concentrations of Phosphorus in the different sampling sites. It can also be observed that the concentration of 1.25 and 1.33 in sites which are close to settlements suggesting the increase in this value could be attributed to domestic and homemade sewages. Apart from these two outliers that higher concentration, most of the phosphorus concentration ranged between 0.07 - 0.047 mg/l.

Pureness of water is directly related to the total dissolved solids (TDS). High TDS levels generally indicate hard water (Lotfinasabasl, et al., 2018). Total dissolved solids in the water samples were found at a mean level of 18.64 ppt between the range of 10.33 (ppt) to 31.45 (ppt). The TDS results presented in Table 8 shows that TDS values are higher than $40e^{-8}$ (0.00000004) ppt which is expected to be the normal range – this may be due to the surface water in the mangrove environment being at the downward of the township area, thereby indicating high content of TDS.

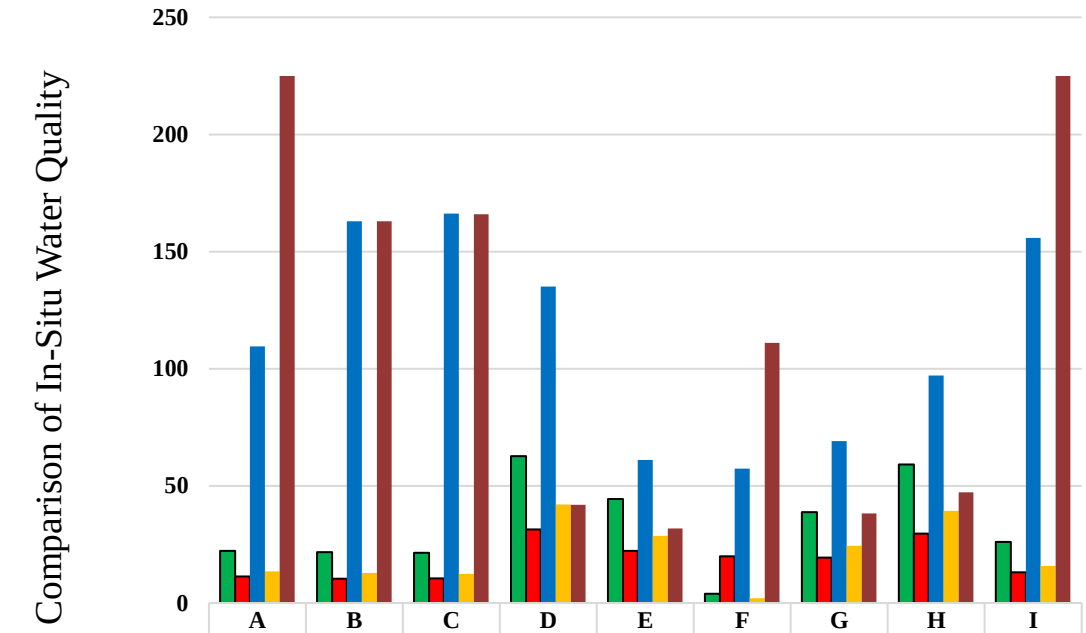
Salinity is defined as the total concentration of dissolved salts present in aquatic ecosystems. Apart from at site F, the value of salinity majorly ranged between 12.46 and 42.02 ppt and the mean value was found to be 11.01 ppt. The standard deviation (13.37) suggests there is high variation in the concentration of salinity in the study area. The within mangrove environment sample ranged between 28.33 and 42.07 while those of the surface water that is not within the mangrove system ranged between 12.46 and 15.85 ppt and an outlier of 2.09 at site F (Table 8). This observation indicates that the mangrove planting area is in the normal range of salinity and only some parts in the stream section outside the mangrove area and close to waterway, are not suitable to life of mangroves systems.

Table 8 Results (Average) of the in-situ water quality parameters (Sample points identified in Figure 4)

Samples	Coordinates		pH	% DO	PPM DO	Conductivity	Absolute Cond.	TDS (ppt)	Temperature (ºC)	Salinity	Nitrite (ppm)	Turbidity (NTU)
A	N06.18138	W057.23618	7.8	109.6	7.57	22.27	25.17	11.26	31.2	13.47	0	225
B	N06.17709	W057.23738	7.03	163	10.86	21.65	25.21	10.33	33.81	12.83	0	163
C	N06.17590	W057.23783	7.03	166.2	11.04	21.39	24.66	10.53	32.77	12.46	0	166
D	N06.18121	W057.23611	7.03	135.1	7.59	62.73	74.00	31.45	34.26	42.07	0	41.9
E	N06.18179	W057.23594	7.8	61.1	3.73	44.36	48.03	22.28	29.11	28.67	0	31.8
F	N06.17984	W057.23656	7.41	57.3	4.31	3.93	66.00	19.92	29.96	2.09	0	111
G	N06.18006	W057.23644	7.11	69.1	4.41	38.82	44.14	19.41	32.41	24.50	0	38.2
H	N06.17892	W057.23488	7.11	97.1	5.70	59.18	66.87	29.59	31.87	39.33	0	47.2
I	N06.17888	W057.23505	7.11	155.8	10.14	26.13	28.91	13.07	30.63	15.85	0	225

Table 9 Results of the Water Quality Parameters Analysed in the Lab (Sample points identified in Figure 4. nd – not detected)

Samples	Coordinates		TSS (mg/l)	Ecw (ms/cm)	COD (mg/l)	N (mg/L)	P (mg/L)	Oil & Grease (mg/L)	BOD (mg/L)	E.Coli (CFU/100mL)
A	N06.18138	W057.23618	84	21.3	360	4.09	1.25		< 1.68	9
B	N06.17709	W057.23738	48	20.3	560	4.93	0.07	nd		
C	N06.17590	W057.23783	14	18.9	960	9.81	0.45	nd		
D	N06.18121	W057.23611	1	59.2	1240	4.97	0.21	nd	< 3.00	4
E	N06.18179	W057.23594	nd	41.3	1000	10.1	0.15			
F	N06.17984	W057.23656	nd	4.41	440	1.58	0.47		< 3.00	nd
G	N06.18006	W057.23644	nd	40.7	840	4.89	0.27	nd	< 300	nd
H	N06.17892	W057.23488	12	58.7	2240	8.34	0.18	nd	< 3.00	7
I	N06.17888	W057.23505	72	24.3	1080	4.50	1.33			



	A	B	C	D	E	F	G	H	I
Conductivity	22.27	21.65	21.39	62.73	44.36	3.93	38.82	59.18	26.13
TDS (ppt)	11.26	10.33	10.53	31.45	22.28	19.92	19.41	29.59	13.07
% DO	109.6	163	166.2	135.1	61.1	57.3	69.1	97.1	155.8
Salinity	13.47	12.83	12.46	42.07	28.67	2.09	24.50	39.33	15.85
Turbidity (NTU)	225	163	166	41.9	31.8	111	38.2	47.2	225

Figure 10 Comparison of some of the in-situ water quality parameters across the sampling points

In terms of turbidity (water clarity) of the water sampled that was measured on the field, sites A, B, C, F and I recorded high Nephelometric Turbidity unit (NTU) than that of the other sites. However, across all the samples, the Nephelometric Turbidity unit (NTU) for the samples indicated that there was high level of suspended particles in the water. Turbid water does not pose any threat to the fringing mangrove along the coastline since they thrive in a muddy environment (mud flat). However, turbidity can affect the growth rate of micro algae, high percentage of suspended particles may cause a decrease in the amount of sunlight for photosynthesis because an increase in suspended particles leads to increase water temperature since the particles caused more heat to be absorb. The assessment of the turbidity value for the samples here could be categorized as unacceptable. Only two assessments are used to denote the status with respect to turbidity in SOCAR report and these are: acceptable or non-acceptable. The acceptable range for turbidity is 0 – 1.5 NTU (SOCAR, 2019: 83).

Electrical conductivity (EC) in natural waters is the ability to conduct electric current. This is mostly influenced by dissolved salts such as sodium chloride and potassium chloride. Electrical conductivity of water ranges between 0.11 and 16.174 ms/cm with a mean value of 13.678 ms/cm. EC in one samples was below the normal range in, that is in samples sites F (which is not within the Mangrove environment) but others exceed the normal range in all the other samples within and around mangrove forests (Table 9). This observation can be attributed to, high concentration of organic matter, dissolved salts, anions and cations and maybe as a result of low freshwater flow. Table 9 shows that EC values of water from the study area, mostly ranged between 18.9 – 59.2 ms/cm which indicates a high content of anions and cations present in the study area due to possibly sewage disposal of domestic activities and may be some agricultural runoff. Data of the EC (Table 9) shows that EC values of the water in all the part of study area (except one), in approximation, are not in the normal range but all were in higher than the normal range. The high conductivity of water may be as an indication of the high pollution present (Harun, et al. 2010) or it could be as a result of the increases in salinity.

A rapid indicator for indirect measurement of the amount of organic pollution, which cannot be oxidized biologically is Chemical Oxygen Demand (COD) ((Lotfinasabasl, et al., 2018). The amount of COD in different sites was detected between the range of 360–2240 mg/l and the mean value of COD was found to be 968.89 mg/l (Table 9). The concentration of COD was observed 4–5.6 times higher than the normal range in mangrove forests which indicates high load of waste. The results from the surface water samples show that the concentration of COD in the study area, except at sample points A, exceeded the normal range (400 mg/l) indicating high pollution present (See Waziri and Ogugbuaja, 2010 on physico-chemical water pollution indicators).

The high BOD value of < 3.00 mg/l (see Table 9) in observed at the sites within the mangrove environment during January 2020 fieldwork could be due to utilisation of oxygen for the oxidation and biodegradation of the organic matter (e.g. Gandaseca, et al., 2011; Kumara and Vijaya Kumar, 2011). Whereas the significantly lower BOD values (< 1.68 mg/l) which was recorded at Site A (see Table 9) during the period of investigation could be attributed to the passive distribution of domestic sewage into the creek and to the circulation pattern of low tide and high tide water in the creek (e.g. Zingde and Sabnis, 1994; Pawar, 2013).

Any material recovered as a substance in the form of an organic solvent from soil and water samples is defined as Oil and grease (O&G). In all the samples analysed, oil and grease were not detected.

Studies have reported the occurrence of pathogenic microorganisms namely, *Vibrio cholerae*, *Staphylococcus aureus*, *Salmonella*, *Shigella*, *Escherichia coli* (*E-coli*) in mangrove ecosystems (Grisi and Gorlach-Lira, 2010; Rodrigues et al., 2011; Poharkar, et al. 2014). *E. coli* is a dominant bacterium in sewage, which can compete with the native microflora (Ramaiah, et al., 2007). The presence of fecal indicator bacteria like *E. coli* primarily suggests sewage contamination in mangroves. The prevalence of *E. coli* in water bodies due to anthropogenic activity has been previously reported (Chandran, et al., 2013). This study also revealed the occurrence of *E. coli* strains (of 9 CFU/100ml in site A, 4 CFU/100ml in site D and 7 CFU/100ml in site H respectively) at the mangroves water system of Wellington Park, suggesting the contamination of mangrove areas by domestic discharge. This may also suggest the fact that the mangroves may act as a reservoir for pathogenic strains. Unknowingly, the local population may consume the food harvested from such areas. Values however are negligible if we follow the standards for polluted waters.

3.5 Results: Vegetation Species

A total of 37 plant species were identified in the study area and all of which are native to Guyana. Regarding the conservation status of the species that were identified, 27 species are of least concern according to the International Union for Conservation of Nature (IUCN) Red List, and 9 species were not evaluated. None of the species that were identified are listed on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) database. A total of 21 plant families are found in which the Cyperaceae family has the highest number of species present in the area (Figure 11). The second most abundant plant families found in the area are Fabaceae, Euphorbiaceae, and Poaceae, which all had 2 species present in the area.

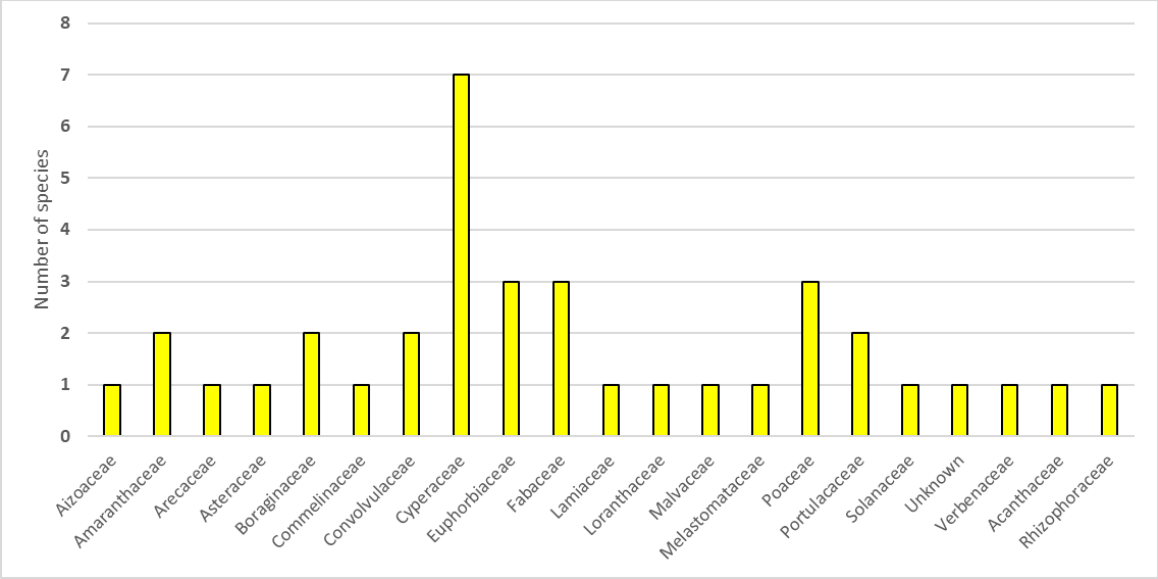


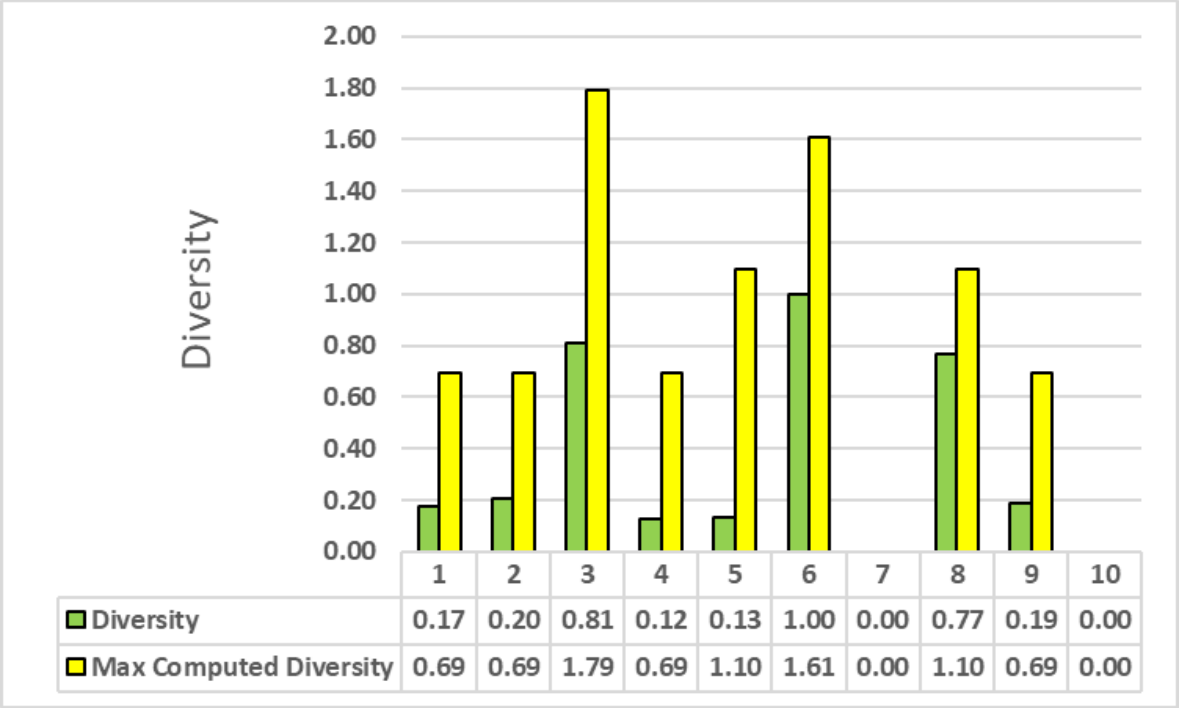
Figure 11 Number of plant species identified per family (abundance)

Within all the transects that were surveyed, the level of disturbance was all classified as severe (code 5). Erosion (ER) was found to be the leading cause of disturbance in each of the transects. There was also evidence of littering in all the transects and in the environment (See Figure 9 as example).

In terms of species diversity, the Shannon-Weaver Diversity Index was used to quantify the species diversity and evenness of the species found in the transects. The following equations were used:

Species Diversity $\boldsymbol{(H')} = -\sum \boldsymbol{n=1n\ (pi*ln\ pi)}$
Maximum diversity possible $\boldsymbol{(H_{max})} = \boldsymbol{ln(Total\ number\ of\ species\ found)}$
Equitability/Evenness $\boldsymbol{(E)} = \boldsymbol{H'/H_{max}}$

With the Shannon-Weaver Diversity Index, the higher the number, the higher the diversity. It usually falls between 1.5 to 3.5 but rarely reaches 4. So, any values that fall below the 1.5 to 3.5 range, the diversity is considered to be low. $\boldsymbol{H_{max}}$ is a computation of the maximum possible species diversity if all of the species found were equally likely to occur, and $\boldsymbol{E}$ is based on species abundance probabilities or proportion and ranges from 0 to 1 with 1 being perfect equitability or evenness and 0 being no equitability or evenness.



	1	2	3	4	5	6	7	8	9	10
Diversity	0.17	0.20	0.81	0.12	0.13	1.00	0.00	0.77	0.19	0.00
Max Computed Diversity	0.69	0.69	1.79	0.69	1.10	1.61	0.00	1.10	0.69	0.00

Figure 12 Species diversity (H') and maximum theoretical diversity (H_{max}) in each survey transect

The highest computed species diversity was found in transect 6 with a diversity value of 1.00, followed by transects 3 and 8 (0.81 and 0.77 respectively) (Figure 12). However, for all the transects surveyed, the computed species diversities were all below the normal range, so we can conclude that the species diversity was very low. For transect 7 and 10, species diversity values could not be computed because, in transect 7, only 1 species (*Sesuvium portulacastrum*) with a very high abundance was found (500+ individuals). In transect 10, no species found within the transect.

In terms of species evenness when the computed values for each of the transects, transects 8 and 6 had the highest evenness values, which were both greater than 0.50 (0.70 and 0.62 respectively). The other transects are below 0.50, which means that the species evenness/equitability is very low (Figure 13).

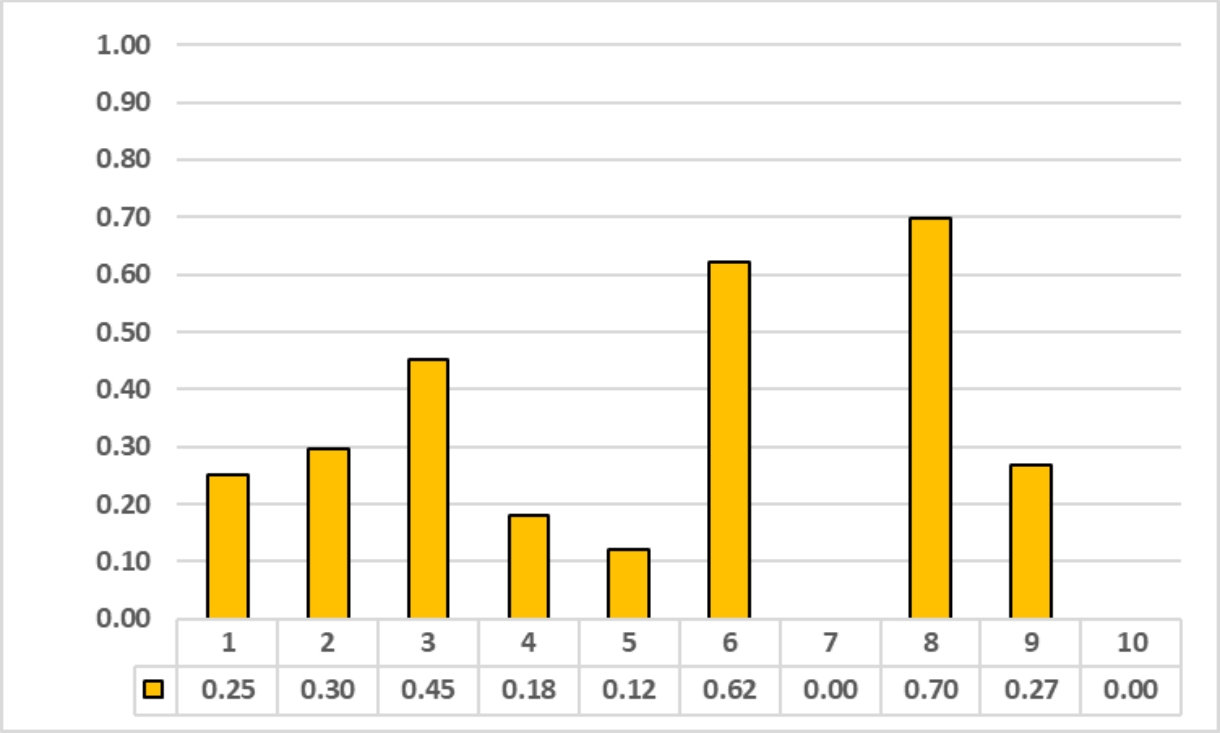


Figure 13 Species evenness/equitability per transect

Further investigations carried out on the study area reveal that the area has long been going through drastic changes in the vegetation from as far back as 2009. This was also found to be as a result of the longshore drift process.

How is longshore drift affecting the study area vegetation?

Within the study area, the type of coast found there can be characterized as an intertidal or muddy coast. Intertidal or muddy coasts can be characterized as a soft coast (FAO, 2007). The area is comprised mostly of fine sedimentary deposits which are predominantly silt and clay particles. The silt and clay particle origination from the highlands of the amazon basin and are brought out into the Atlantic Ocean by the Amazon River. The particles are then moved and deposited along the Atlantic Coast of South America going westward toward Venezuela by various nearshore processes. When these particles are deposited, mudflats are formed which are then colonized saltmarshes, mangrove forests and other types of vegetation which are adapted to growing in this type of environment (Masselink & Russell, 2013; Thammasittirong, et al., 2014).

However, because of the thixotropic gel like fluid nature of the mudflats, they are easily washed away by the various nearshore processes such as longshore drift, which is also helps by the northeast Tradewinds, the oblique wave approach and nearshore cell circulation currents. The aforementioned process causes continuous erosion and accretion events which are very evident within a short space of time and is suspected to be increasing in magnitude because of anthropogenic climate change. The increasing sea surface temperatures are suspected to be increasing the velocity of not only nearshore processes (currents, wave energy, etc) but also larger scale marine processes (Prevedel, 1997; Anthony et al., 2010; Masselink & Russell, 2013; Thammasittirong et al., 2014).

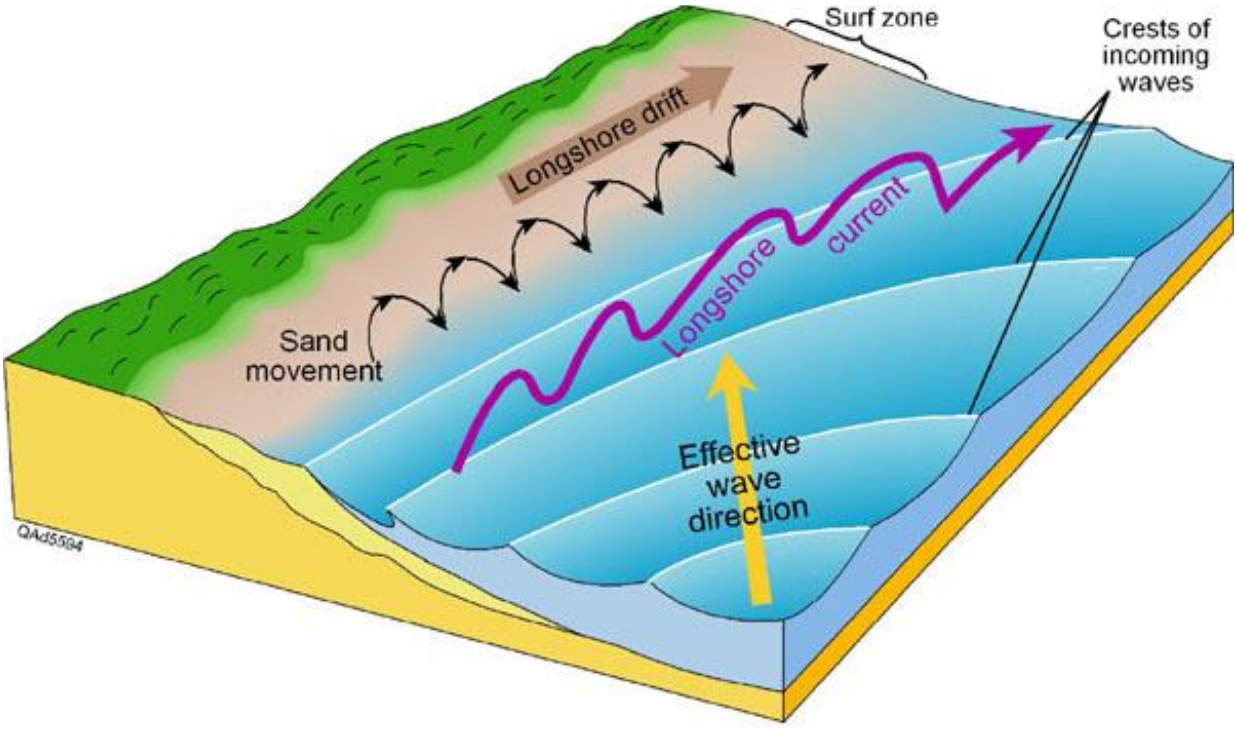


Figure 14 The effective wave direction is aided by the Northeast Tradewinds. The wave breaks when hits the beach and washes silt and clay particles on to the beach. While the water is running off the beach back into the ocean, particles are pulled back into the ocean, particles are pulled back into the sea via backwashing and are caught and transported west by the longshore current (Illustration used here taken from: https://revisionworld.com/gcse-revision/geography/coastal-landscapes/coastal-processes/longshore-drift. Accessed on 15 April 2020)

As a result of the high erodibility of the mudflats, they are constantly migrating west toward the northwestern coast of Guyana when they are eroded from the northeast coast. In many cases due to the nearshore processes, the mudflat increases in elevation and the conditions start to favour colonization of coastal vegetation (mostly mangroves) as was observed in previous years in the study area, notably 2013 and 2016 (see Figure 15). In other cases, the elevation of the mudflat decreased significantly and caused the study area to be severely eroded which caused the mangrove vegetation to be severely undermined. Evidence of the mangrove stand being undermined and toppling over in the study area (Anthony et al., 2010).

In Figure 15 A, the mudflat was at a higher elevation and much more stable which encourage seedlings to become established since they were subjected to significantly less wave action which would wash them away. In plate B, there is a less extensive mudflat due to erosion from the longshore drift current which would also lower the elevation of the mudflat and make it less stable causing vegetation establishment to be difficult.

Using the year 1969 as the baseline year, analysis showed that the shoreline in the area went through drastic changes, accretion and erosion events (Figure16). From 1969 to 2009, there was an estimates loss of 7.7 ha of land dues to erosion. So, within the same time period, 0.2 ha of shoreline was lost annually. However, between 2009 and 2013, the area had a massive accretion even which saw the area gaining 8.6 ha of land and this signaled an estimate net gain of 0.9 ha of land. This resulted in mangrove gains that was concentrated on the Northwestern side of the study area of approximately 4.2 ha. From 2013 to 2016, an estimated 4.8ha of land was lost to erosion and this saw the mangrove stand being reduced to an estimated 3.7ha. This is a net loss of land of about 1.6ha. During the 2016 to 2020 period, 5.2 hectares of land was lost (annual rate of land loss due to erosion is estimated at 1.6ha). The mangrove stand reduces to approximately 0.48ha in 2020 which is a loss of 3.22ha when compared to 2016.

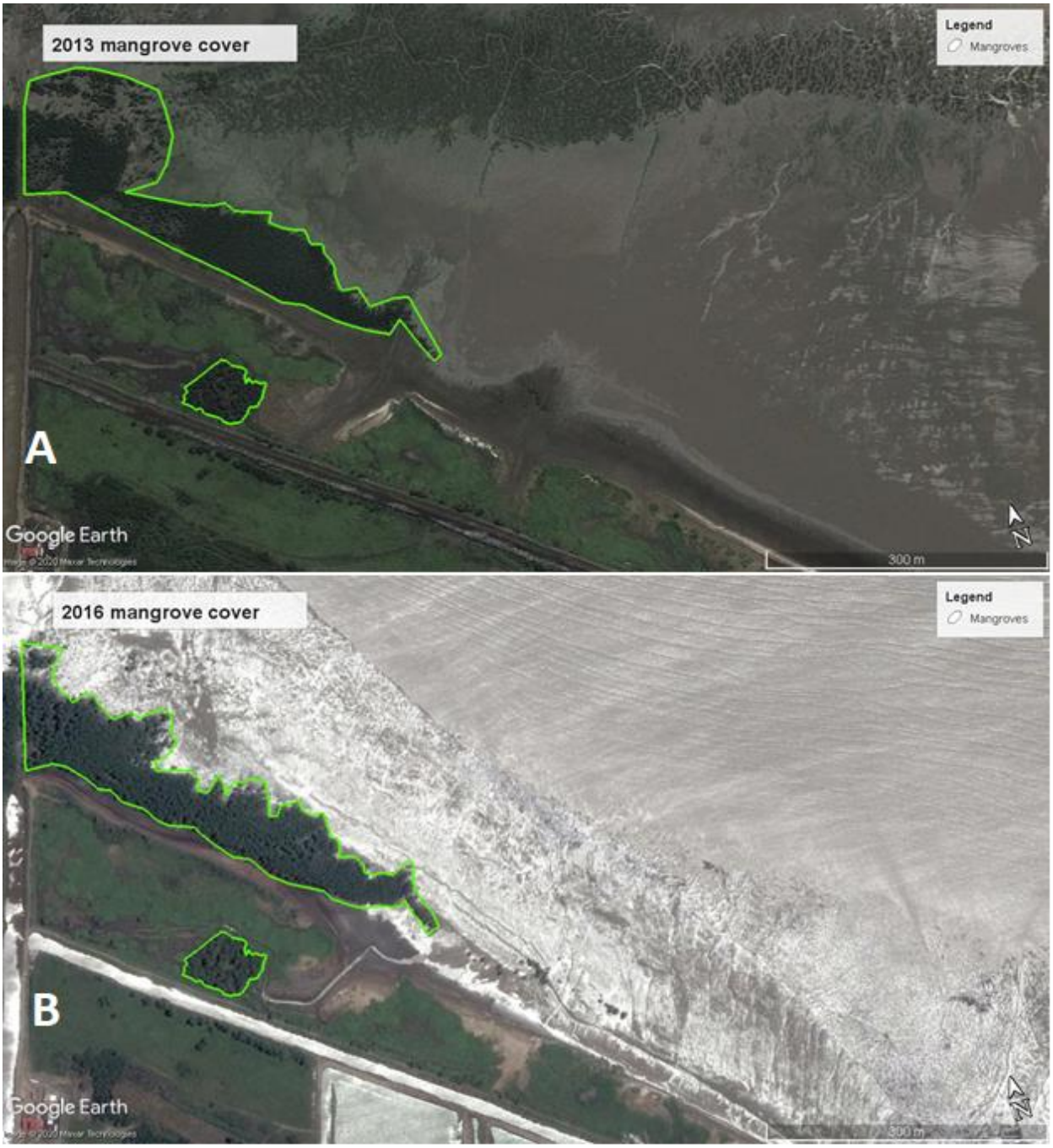


Figure 15 The extent of mangrove cover 2013 and 2016 (Image Courtesy of Google Earth Pro. ©CNES/Airbus)

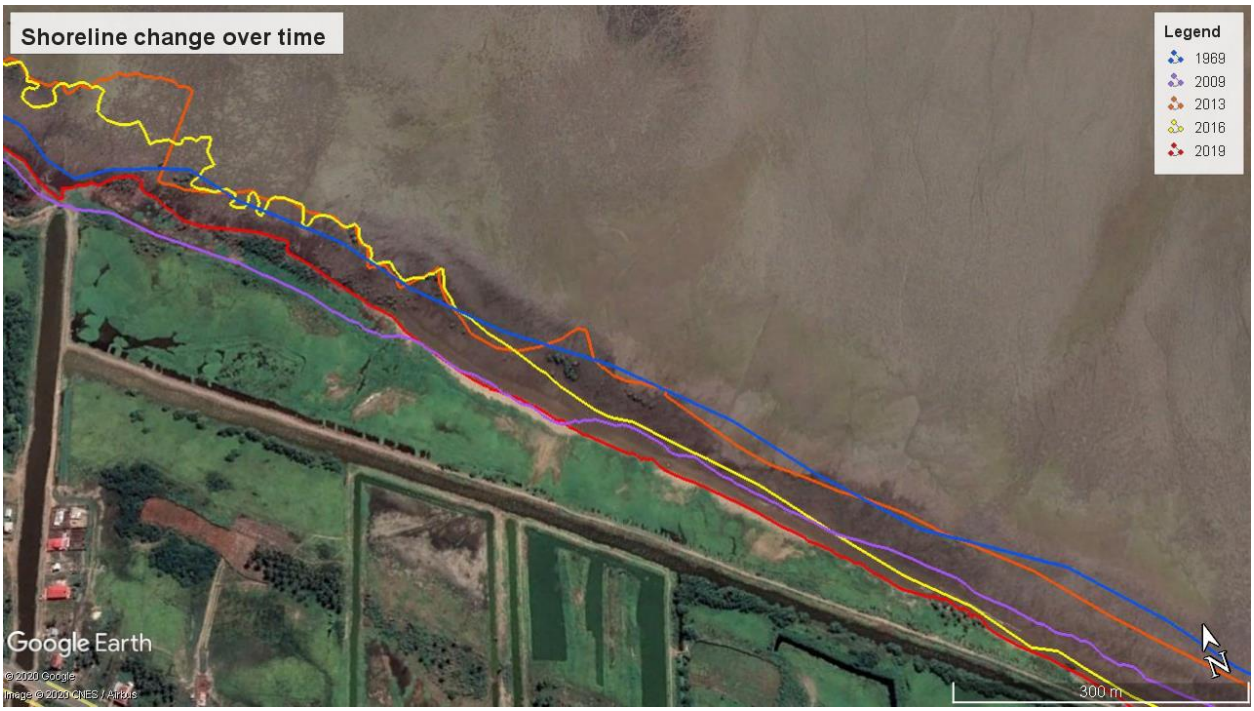


Figure 16 Changes in the shoreline at the study area from 1969 and 2019 (Image Courtesy of Google Earth Pro. ©CNES/Airbus)

3.6 Results: Fish and Invertebrates

For fish, a total of 10 species from 7 families were identified at the time of sampling (Figure 17). The most abundant family found is the Sciaenidae, which had 3 species inhabiting the area. The species diversity of the fish community at the site was computed at 1.7, which indicates that the fish community at the site, although not highly diverse, does fall within a normal range. The computed species equitability was calculated at 0.95, which is high. The entire area has suffered from severe disturbances, and this 1.70 diversity may be a result of species still frequenting the area from an adjacent mangrove stand, which is intact.

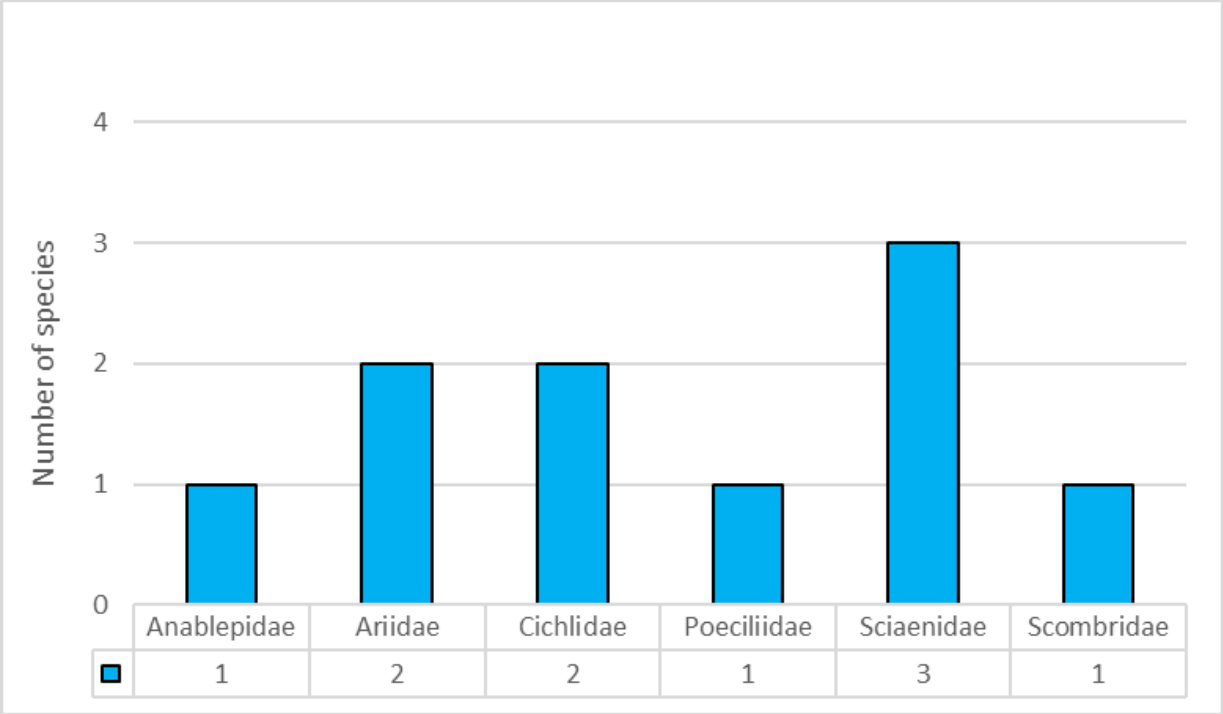


Figure 17 Number of fish species identified per family (abundance)

A short informal interview that was conducted with the fishermen in the area confirmed that the species indeed inhabit the area. They also indicated that they also have gill nets that are set close to the study area, and some of these same species are caught in the nets regularly. The fishermen also indicated that as time passes, it is getting harder to find some species such as gillbarker, seatrout, etc. and that they are concerned about it.

The conservation status of the fish species found during the survey was also considered. It was found that the majority of the species are of least concern (LC), and there is one species, *Arius (Sciades) parkeri*, the IUCN classified it as vulnerable (VU) according to a 2011 evaluation. None of the species were found on the CITES list.

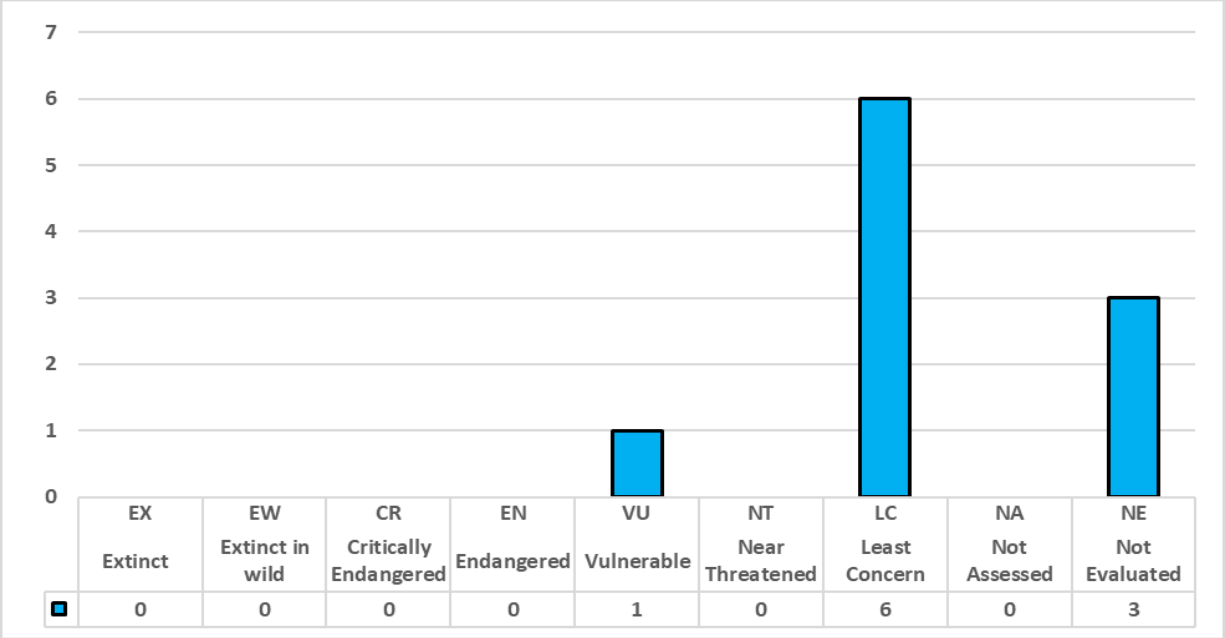


Figure 18 ICUN conservation status

In terms of invertebrates, there were a total of 7 species found and identified from 5 families (Figure 19). The Ocypodidae family was found to have the highest number of species present in the area with very high levels of abundance. The overall species diversity was computed at 1.48, which is below the normal range of 1.5 to 3.5. This means that the species diversity for the invertebrate community in the study area is low. The species evenness was computed at 0.91, which indicates that species equitability/evenness is high.

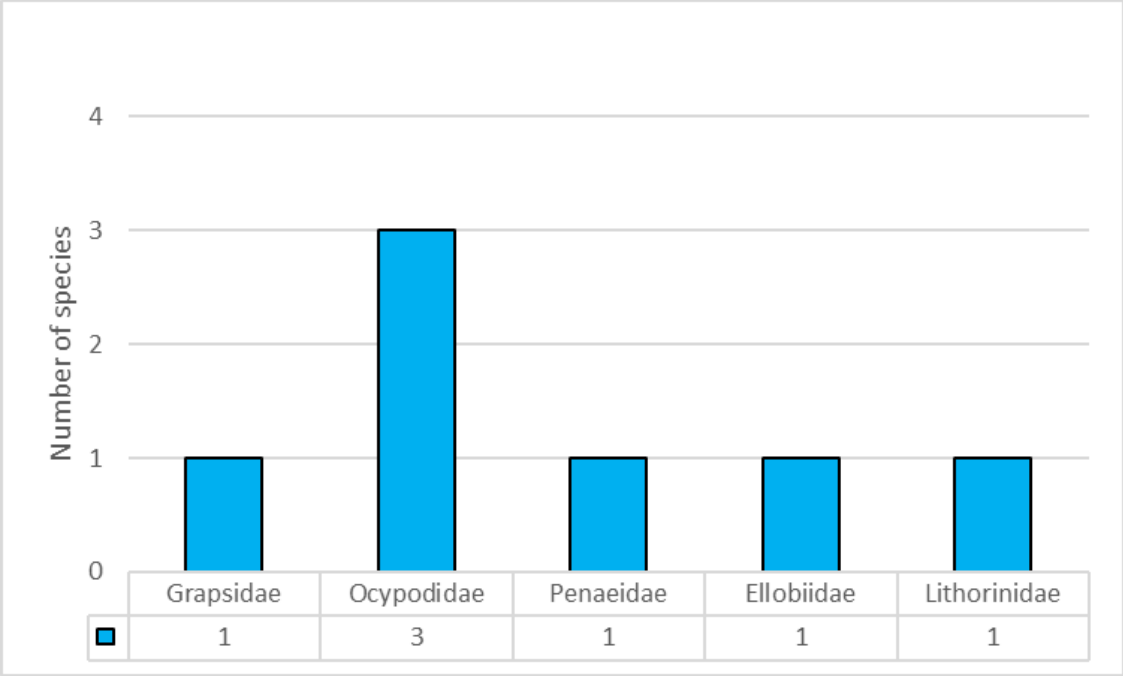


Figure 19 Number of invertebrate species identified per family (abundance)

The high rate of erosion in the study area has not only affected the mangrove stand. Fish communities in nearshore marine habitats are negatively affected when there is a loss of mangrove and other vegetation that fish species depend on for reproductive and protective cover. It has been shown by numerous studies that once the mangrove stand is negatively affected the fish community starts to decline and the fisheries area also declines. It also has been proven that the invertebrate communities within marine environments also decline due to mangrove destruction or loss due to natural processes. Invertebrate within marine habitats are one of the key sources of nourishment for many other species that inhabit that area (Blaber, 2007; Bloomfield & Gillanders, 2005; David, 2007; Ellison & Farnsworth, 1996; Osborne, Cho-Ricketts, & Salazar, 2019; Parrish, 1989; Sarathchandra et al., 2018; Shervette et al., 2006; Sitorus, Lesmana, Tarigan, & Hasan Sitorus, 2017; Wahyudewantoro, 2017).

4 Concluding Remarks

This study has shown that metal concentrations in Wellington Park Mangrove Forest were mainly dominated by Mn, Fe and La. The assessment of metal pollution showed that the mangrove closely represented urban mangroves and was most polluted by sawdust and other land-based pollutants. This study is the first comprehensive investigation of physico-chemical properties of sediments and water of this study area and therefore, the findings presented here serve as the baseline information on which further studies can be compared and evaluated. Most of the metals analysed through Handheld-XRF in the short-core sediment samples in this study did not show distinct spatial and depth variations in the system. Although the PCA indicated a variation from one side to the other of the shore (Annex 7).

The results of bio-chemical parameters study of surface water showed some of the parameters are higher than the normal range indicating the pollution status of the water. This observation, in the Wellington Park mangrove forest at the time of sampling, indicated a possible pollution as a result of human activities, high organic matter deposition or due to domestic wastewater disposal, which all eventually affect the water quality of mangrove forest. The present study gives important information about the current features of the surface water found in and around the mangrove system along with their assessment with extant literatures and in the view of the impact of human activities. It is hoped that this detailed study will be useful to develop suitable and proper management practices and protection measures of the mangroves physical environment and initiates further studies of the environment. Considering the status of E-coli found in the surface water sampled, although within the general acceptable international standard, there is, however, the need for general awareness about this microbial contaminant (E-Coli). Monitoring systems should be established for the food being harvested and sold locally to investigate if there is any transfer of this contaminant in food consumed in the community.

The normalized concentrations of microplastic materials found within the sediments were between 155 pellets of plastics and 2256 of plastic fragment /kg of dry sediment, with the highest concentrations in the stations near to the 0 – 10 cm layer of the sedimentary core. The most abundant types of microplastic were the films from the fragmentation of food bags and wrappings,

fragments of hard plastics and disposable utensils, the foams, mainly of expanded polystyrene, rope fragments and fishing nylon, etc. (which are defined as irregular plastic fragments here), followed by fragments of fibres (fabrics) and pellets of plastics of materials which could not be categorised as plastic fragments nor fabric. The reported microplastics composition in sediments from the Wellington Park Mangrove environment are examples of fragments of plastic pollution on mangrove sediments. Effective measures to control the direct disposal of the domestic waste in the mangroves and surrounding environment need to be implemented and ascertained in order to protect the system.

The overall average species diversity of the study site is for the vegetation community is computed at 0.34, which is far below the accepted normal range. This can be a result of the site being severely and primarily impacted by erosion via the longshore drift cycle. From a further examination of the vegetation assemblage, it is evident that the site is going through some rapid succession phase (a change in vegetation type), which is being rapidly advanced due to erosion. There was also evidence of littering, but it is not clear whether the litter is primarily dumped there by the residents, or it is mostly washed from the sea during high tides.

The low diversity in the case of the fish can be attributed to the severe degradation of the site. A high number of marine species are known to use the mangrove vegetation for breeding and nursery cover and the absence of this habitat may force species to seek this requirement elsewhere. With the invertebrates, the missing habitat might also be the main factor for the overall low diversity since the invertebrate also would have been depending on the mangrove stand for shelter as well. Exposure to the elements such as sun and wind may have also caused the population of invertebrates to decrease.

It should be noted that this sampling is representative of only one moment in time, that is the results of the samples taken between 14 and 17 January 2020. The dynamics of water, and some biotic components for the coast (fish, invertebrates) were not incorporated in this study. It is hereby recommended that future studies or monitoring of the mangrove system incorporate the study of these bio-physical environment and how they affect the mangrove system. In specific, tidal variation, seasonal climatic variation, possible seasonal variations in surface water quality parameters, possible variation in soil properties, vegetation dynamics for each season of the year

and the vertebrate/invertebrates' dynamics in response to each seasonal variation (wet and dry seasons for example), etc. are recommended for consideration of further studies and investigation.

The limitations of time and resources have limited this study to the one moment in time investigation reported in this study. Also, the marshy nature of some sections of the mangrove systems, which were endangering the safety of the field researchers, sampling of which would require special equipment not at the disposition of the researcher, and therefore limited the sampling of core sediments and water to the safe areas where such samples could be effectively selected. Similarly, many parameters analysed in this study were more than those covered in the SOCAR report, hence our utilisation of some of the other published sources and inferences in our discussion and understanding of those parameters not covered in SOCAR report.

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Annexes

Annex 1: Raw Results from XRF Analyses

The Raw XRF Results are attached in Microsoft Excel

Annex 2: Raw Results from Microplastic Analysis

01-10 cm

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber (Fabric)	2	1			2	
S1MP	Fragments (Irregular)	8	4	6	9	3	12
	Sphere (pellets)				1		

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber		1		6	3	2
S2MP	Fragments	18	6	70	18		16
	Sphere			6	10	4	

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber		1		4		6
S3MP	Fragments	6		12		8	
	Sphere	1			2		

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	3		1			3
S4MP	Fragments	7	3	4	6	3	2
	Sphere						

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber			3	5	1	
S5MP	Fragments	4	12	8	2	5	6
	Sphere						2

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber		2	5		4	6

S6MP	Fragments	4		3	16		13
	Sphere						2

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	1	2	1		9	6
S7MP	Fragments	60	30	10	60		20
	Sphere	1			1		

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	1		4	2		2
S8MP	Fragments	3	30	16	12	20	12
	Sphere	1		3		1	

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	1		2		2	2
S9MP	Fragments	3	10		4	3	4
	Sphere	1			2		

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	4	3	1	2		2
S10MP	Fragments	40	18		60	50	20
	C	2			4	7	1

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber		3	2		1	2
S11MP	Fragments	12	11		13		8
	Sphere		1		2		

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber		1				2

S12 MP	Fragments	4	3	3	1	4	9
	Sphere			1			

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber		1				2
S13 MP	Fragments	4	3	3	1	4	9

11-20 cm

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber		1				2
S1MP	Fragments	6		3	5	12	
	Sphere						

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	1			1		2
S2AMP	Fragments	12	5	14	60	7	16
	Sphere				4		

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber		1	4			2
S3MP	Fragments	10	8		5	8	6
	Sphere	1			2		

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	2				1	3
S4MP	Fragments		5	1		4	
	Sphere			1			

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	1					

S5MP	Fragments	2	4	2	8	4	2
	Sphere						

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	1		6	3	1	1
S6MP	Fragments	18	35	13	40	20	
	Sphere			9			

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	2		4	3	2	1
S7MP	Fragments	18	10	40	60		16
	Sphere		2		1		

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	2		3	1	4	
S8MP	Fragments	7	20	17		12	8
	Sphere			2	1		

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber					1	1
S9MP	Fragments	4		2	3	5	3
	Sphere						

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	4		2		1	
S10MP	Fragments		60	80	4		8
	Sphere	2					3

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber		4	1		3	

S11MP	Fragments	10			18		6
	Sphere					2	

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	1				2	
S12 MP	Fragments	4		5	8	4	2
	Sphere						

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	1				2	
S13 MP	Fragments	4		5	8	4	2

21-30 cm

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber		1			2	
S1MP	Fragments		8		9	5	10
	Sphere		1				2

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber		2	4			1
S2AMP	Fragments	4		18	20	40	50
	Sphere	2			4		

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber		2			2	
S3MP	Fragments	12		8	9	6	14
	Sphere						2

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	3		1			2

S4MP	Fragments		4		6	2	2
	Sphere						

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber			2	1		
S5MP	Fragments	12	2	9	4		6
	Sphere						

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber						
S1MP	Fragments						
	Sphere						

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	1		2	6	4	2
S7MP	Fragments	30	30		24		20
	Sphere			2	1	7	

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	1	1		3		2
S8MP	Fragments	16		9		8	16
	Sphere		2		1		

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber		2			1	
S9MP	Fragments	3		4	6		9
	Sphere						

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber		2	1		6	2

S10MP	Fragments	19	12	40	20	20	16
	Sphere		1		2		9

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	1		1			2
S11MP	Fragments		13		8	12	
	Sphere						

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	1		3			1
S12 MP	Fragments	6		2	4	3	2
	Sphere						

Sample	Microplastics	Field view 1	Field view 2	Field view 3	Field view 4	Field view 5	Field view 6
	Fiber	1		3			1
S13 MP	Fragments	6		2	4	3	2

Annex 3: Raw Results from Water Quality Analyses

In-Situ Analysis of the Water Parameters using Hannah Multi-parameters

Samples	Coordinates		pH	% DO	PPM DO	Conductivity	Absol.Cond.	tds (ppt)	temperature (ºC)	Salinity	Nirite (ppm)
A1	N06.18138	W057.23618	8.6	120.4	8.33	22.23	24.72	11.12	31	13.30	0
A2	N06.18138	W057.23618	7.03	99.2	6.82	22.31	25.62	11.41	31.5	13.64	0
A3	N06.18138	W057.23618	7.03	99.2	6.82	22.31	25.62	11.41	31.5	13.64	0
B1	N06.17709	W057.23738	7.02	167.3	11.09	21.66	25.33	10.33	33.91	12.83	0
B2	N06.17709	W057.23738	7.03	159.1	10.62	21.63	25.21	10.32	33.72	12.83	0
B3	N06.17709	W057.23738	7.03	159.1	10.62	21.63	25.21	10.32	33.72	12.83	0
C1	N06.17590	W057.23783	7.03	160	10.67	21.13	24.30	10.53	32.38	12.55	0
C2	N06.17590	W057.23783	7.02	172.3	11.42	21.66	25.02	10.33	33.16	12.36	0
C3	N06.17590	W057.23783	7.02	172.3	11.42	21.66	25.02	10.33	33.16	12.36	0
D1	N06.18121	W057.23611	7.03	135.1	7.59	62.73	74.00	31.45	34.26	42.07	0
D2	N06.18121	W057.23611	7.03	135.1	7.59	62.73	74.00	31.45	34.26	42.07	0
D3	N06.18121	W057.23611	7.03	135.1	7.59	62.73	74.00	31.45	34.26	42.07	0
E1	N0 6.18179	W057.23594	7.8	61.1	3.73	44.36	48.03	22.28	29.11	28.67	0
E2	N0 6.18179	W057.23594	7.8	61.1	3.73	44.36	48.03	22.28	29.11	28.67	0
E3	N0 6.18179	W057.23594	7.8	61.1	3.73	44.36	48.03	22.28	29.11	28.67	0
F1	N06.17984	W057.23656	7.41	57.3	4.31	3.93	42.66	1992	29.96	2.09	0
F2	N06.17984	W057.23656	7.41	57.3	4.31	3.93	42.60	1992	29.96	2.09	0
F3	N06.17984	W057.23656	7.41	57.3	4.31	3.93	42.65	1992	29.96	2.09	0
G1	N06.18006	W057.23644	7.11	69.1	4.41	38.82	44.14	19.41	32.41	24.50	0
G2	N06.18006	W057.23644	7.11	69.1	4.41	38.82	44.14	19.41	32.41	24.50	0
G3	N06.18006	W057.23644	7.11	69.1	4.41	38.82	44.14	19.41	32.41	24.50	0
H1	N06.17892	W057.23488	7.11	97.1	5.70	59.18	66.87	29.59	31.87	39.33	0
H2	N06.17892	W057.23488	7.12	97.1	5.70	59.18	66.87	29.59	31.87	39.33	0
H3	N06.17892	W057.23488	7.11	97.1	5.70	59.18	66.87	29.59	31.87	39.33	0
I1	N06.17888	W057.23505	7.11	155.8	10.14	26.13	28.91	13.07	30.63	15.85	0
I2	N06.17888	W057.23505	7.11	155.8	10.14	26.13	28.91	13.07	30.63	15.85	0
I3	N06.17888	W057.23505	7.11	155.8	10.14	26.13	28.91	13.07	30.63	15.85	0

GUYANA SUGAR CORPORATION INC

CENTRAL LABORATORY

Research Centre, Agriculture Department, LBI Compound, E.C.D, Guyana, S.A.

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CAEMS SOP/RF No.: 013.1	Version: 2	Revision Status: 1	Date of Issue: September 6, 1996	Expiry Date:

Analysis Report

Report Number: W 019-027/2020- B **Date**: 2020-01-29

To:
Dr. Temitope Oyedotun
Dean
Faculty of Earth and Environmental Sciences
University of Guyana
Turkeyen Campus

Tele: 222-4180 **Fax #:**
Email: temitope_oyedotun@uog.edu,gy

From:
Mr. Ganpat Jafer
Analyst

Central Laboratory
Agronomy and Analytical Services Department

Date Sample Received: 2020-01-15

Date Analysis Completed: 2020-01-28

SAMPLE TYPE: Water

SAMPLE DESCRIPTION	PARAMETER					
	TSS (mg/L)	ECw (ms/cm)	COD (mg/L)	N (mg/L)	P (mg/L)	Oil & Grease (mg/L)
A	84	21.3	360	4.09	1.25	*
B	48	20.3	560	4.93	0.07	Nd
C	14	18.9	960	9.81	0.45	Nd
D	1	59.2	1240	4.97	0.21	Nd
E	Nd	41.3	1000	10.1	0.15	*
F	Nd	4.41	440	1.58	0.47	*
G	Nd	40.7	840	4.89	0.27	Nd
H	12	58.7	2240	8.34	0.18	Nd
I	72	24.3	1080	4.50	1.33	*

Checked by:

Nd-= Not Detected
* = Not done

.....
Mr. G. Jafer

C: Mr. Gavin Ramnarain-Head-Agric. Research
Mr. Ashley Adams-Agronomy Research Manager

Results of the water analyses from GuySuco Lab.

KAIZEN
Environmental Services (Guyana) Inc.

58 High Street
Kingston
Georgetown, Guyana
Tel: (592) 231-0346/ (592) 231-0348
Email: inquiries@kaizen-guy.com

ANALYSIS DATA REPORT

Customer: Dr. Temitope D.T Oyedotun **Lab File # : 000910-1-5**
Customer's Address: Faculty of Earth & Environmental Science, University of Guyana - Turkeyen Campus
Customer Contact: Dr. Temitope D.T Oyedotun
Client Job #: 20-0013
Item(s) Analyzed: Surface Water
Date of Sampling: 15-Jan-20
Sampled By: Client
Date of Receipt: 15-Jan-20
Report Date: 22-Jan-20

ANALYSIS RESULTS

Parameter Name	Units	Results		
		000910-1 A 1	000910-2 D 1	000910-3 F
Biological Oxygen Demand	$mg.L^{-1}$	< 1.68	< 3.00	< 3.00
E.Coli	CFU/100mL	9	4.00	Not Detected

Parameter Name	Units	Results	
		000910-4 G	000910-5 H
Biological Oxygen Demand	$mg.L^{-1}$	< 3.00	< 3.00
E.Coli	CFU/100mL	Not Detected	7

** Detailed Test Methodologies and QA/QC data available upon request.*

Test Methodologies: Biological Oxygen Demand: SMEWW 5210 B
E.Coli: SMEWW 9213 D

Comments:

Report Authorized By:
Sheril Shah - Divisional Manager (Ag)

Results of some of the samples analysed at Kaizen

Annex 4: Raw Results from Vegetation Sampling

Transect 1

Common Name	**# of individuals**
Sea Purslane	526
Velvet Leaf	23
	549
Disturbance	Erosion
Magnitute	Severe
Causative Agent	Natural (Longshore Drift)

Transect 2

Common Name	**# of individuals**
Sea Purslane	200
Black mangrove	11
	211
Disturbance	Erosion
Magnitute	Severe
Causative Agent	Natural (Longshore Drift)

Transect 3

Vegetation	**# of individuals**	
Belly Ache Bush	7	
Jussia Grass	100	
Digitatus	3	
Black Sage	5	
Sea Purslane	300	
Black Mangrove	7	
	422	
Disturbance	Erosion	
Magnitute	Severe	
Causative Agent	Natural (Longshore Drift)	

Transect 4

Vegetation	**# of individuals**
Salt grass	360
Black mangrove	10
	370
Disturbance	Erosion
Magnitute	Severe
Causative Agent	Natural (Longshore Drift)

Transect 5

Vegetation	**# of individuals**
Sea Purslane	400
Red Mangrove	1
Iron Grass	10
	411
Disturbance	Erosion
Magnitute	Severe
Causative Agent	Natural (Longshore Drift)

Transect 6

Vegetation	# of individuals
Bahama Grass	20
Salt grass	100
Shame bush	50
Kihongia	300
Black mangrove	1
	471
Disturbance	Erosion
Magnitute	Severe
Causative Agent	Natural (Longshore Drift)

Transect 7

Vegetation	# of individuals
Salt grass	500
	500
Disturbance	Erosion
Magnitute	Severe
Causative Agent	Natural (Longshore Drift)

Transect 8

Vegetation	# of individuals
Bahama Grass	100
Salt grass	600
Small foxtail	120
	820
Disturbance	Erosion
Magnitute	Severe
Causative Agent	Natural (Longshore Drift)

Transect 9

Vegetation	# of individuals
Sea Purslane	1000
Small Fox	48
	1048
Disturbance	Erosion
Magnitute	Severe
Causative Agent	Natural (Longshore Drift)

Transect 10

Vegetation	# of individuals
Disturbance	Erosion
Magnitute	Severe
Causative Agent	Natural (Longshore Drift)

Annex 5: Raw Results from Vertebrates and Invertebrates

Invertebrate List

Common Name	Genus	Species	Family	IUCN Status	CITES Status
Mangrove Root Crab	*Goniopsis*	*cruentata*	Grapsidae	Not Evaluated	Not Evaluated
Orange Claw Fiddler Crab	*Uca*	*coarctata*	Ocypodidae	Not Evaluated	Not Evaluated
Orange Fiddler Crab	*Uca*	*vocans*	Ocypodidae	Not Evaluated	Not Evaluated
Rosy Fiddler Crab	*Uca*	*rosea*	Ocypodidae	Not Evaluated	Not Evaluated
Southern White Shrimp	*Penaeus (Litopenaeus)*	*schmitti*	Penaeidae	Not Evaluated	Not Evaluated
Mangrove Helmet Snail	*Cassidula*	*spp*	Ellobiidae	Least Concern	Not Evaluated
Mangrove Periwinkle	*Littorina*	*angulifera*	Lithorinidae	Least Concern	Not Evaluated

Fish List

Common Name	Genus	Species	Family	IUCN Status	CITES Status
Leatherskin	*Scomberomorus*	*brasiliensis*	Scombridae	Least Concern	Not Evaluated
Bangamary	*Macrodon*	*ancylodon*	Sciaenidae	Least Concern	Not Evaluated
Bashaw	*Micropogonias*	*furnierei*	Sciaenidae	Least Concern	Not Evaluated
Curass	*Arius (Sciades)*	*proops*	Ariidae	Not Evaluated	Not Evaluated
Gilbarker	*Arius (Sciades)*	*parkeri*	Ariidae	Vulnerable	Not Evaluated
Seatrout	*Cynoscion*	*acoupa*	Sciaenidae	Least Concern	Not Evaluated
Mud Skipper	*Anableps*	*spp*	Anablepidae	Not Evaluated	Not Evaluated
Nile Tilapia	*Oreochromis*	*niloticus*	Cichlidae	Least Concern	Not Evaluated
Blue Tilapia	*Oreochromis*	*aureus*	Cichlidae	Least Concern	Not Evaluated
Guppy	*Poecilia*	*reticulata*	Poeciliidae	Not Evaluated	Not Evaluated

Annex 6: Water Quality Parameters that was not tested

Parameter	Recommended Holding Time
Aluminium	6 Months
Manganese	6 Months
Chromium	6 Months
Iron	6 Months
Arsenic	6 Months
Lead	6 Months
Copper	6 Months
Cadmium	6 Months
Zinc	6 Months
Faecal Coliform	8 Hours
Ammonical Nitrogen	07 Days
Floating Plastic Density	N/A

Annex 7: Results of Principal Component Analysis (PCA) of the results of XRF of Sediment Samples explored (based on horizon) in Statistical Package for the Social Sciences (SPSS)

PCA of 0 – 10 cm

```
FACTOR
  /VARIABLES Ti Ni Cu Zn As Rb Sr Y Zr Nb Cd W Hg Pb Bi Th V Cr Mn Fe La
  /MISSING MEANSUB
  /ANALYSIS Ti Ni Cu Zn As Rb Sr Y Zr Nb Cd W Hg Pb Bi Th V Cr Mn Fe La /SELECT=SoilSamples(1)

  /PRINT UNIVARIATE INITIAL CORRELATION SIG EXTRACTION ROTATION FSCORE

  /FORMAT SORT

  /PLOT ROTATION

  /CRITERIA FACTORS(2) ITERATE(25)

  /EXTRACTION PC

  /CRITERIA ITERATE(25)

  /ROTATION VARIMAX

  /SAVE REG(ALL)

  /METHOD=CORRELATION.
```

Factor Analysis

Descriptive Statistics[a]

	Mean	Std. Deviation[b]	Analysis N[b]	Missing N
Ti	.20977	.078115	13	0
Ni	.00323	.001092	13	0
Cu	.00246	.001050	13	0
Zn	.00954	.002989	13	0
As	.00385	.003532	13	0
Rb	.00962	.003990	13	0
Sr	.01354	.010875	13	0
Y	.00238	.000768	13	0
Zr	.01438	.003686	13	0
Nb	.00177	.000599	13	0
Cd	.00292	.001256	13	0
W	.00077	.000832	13	0
Hg	.00054	.000519	13	0
Pb	.00338	.001850	13	0
Bi	.00038	.000768	13	0
Th	.00131	.000630	13	0
V	.0155	.00456	13	0
Cr	.0054	.00186	13	0
Mn	.1601	.17163	13	0

Descriptive Statistics[a]

	Mean	Std. Deviation[b]	Analysis N[b]	Missing N
Fe	4.1707	.63251	13	0
La	95.3682	.77824	13	0

Correlation Matrix[a,b]

		Ti	Ni	Cu	Zn	As	Rb	Sr
Correlation	Ti	1.000	.472	.408	.938	-.342	.814	.142
	Ni	.472	1.000	.626	.546	.118	.596	-.138
	Cu	.408	.626	1.000	.551	.672	.782	.232
	Zn	.938	.546	.551	1.000	-.213	.934	.313
	As	-.342	.118	.672	-.213	1.000	.120	.031
	Rb	.814	.596	.782	.934	.120	1.000	.366
	Sr	.142	-.138	.232	.313	.031	.366	1.000
	Y	.632	.680	.898	.737	.392	.868	.173
	Zr	.214	.328	.230	.048	.178	.022	-.403
	Nb	.836	.343	.448	.866	-.176	.831	.225
	Cd	-.138	.379	.408	.101	.429	.260	-.064
	W	.079	.247	-.249	-.013	-.382	-.129	-.409
	Hg	.369	.351	-.035	.442	-.451	.390	.240
	Pb	.003	.406	.888	.185	.890	.484	.134
	Bi	-.375	-.015	.588	-.170	.853	.134	.472
	Th	.736	.494	.397	.789	-.239	.747	.022
	V	.706	.842	.473	.752	-.181	.696	-.153
	Cr	.683	.719	.312	.615	-.264	.500	-.152
	Mn	-.163	-.215	.415	.040	.523	.239	.828
	Fe	.623	.531	.934	.724	.481	.893	.293
	La	-.589	-.449	-.915	-.713	-.480	-.886	-.450

Correlation Matrix[a,b]

		Y	Zr	Nb	Cd	W	Hg	Pb
Correlation	Ti	.632	.214	.836	-.138	.079	.369	.003
	Ni	.680	.328	.343	.379	.247	.351	.406
	Cu	.898	.230	.448	.408	-.249	-.035	.888
	Zn	.737	.048	.866	.101	-.013	.442	.185
	As	.392	.178	-.176	.429	-.382	-.451	.890
	Rb	.868	.022	.831	.260	-.129	.390	.484
	Sr	.173	-.403	.225	-.064	-.409	.240	.134
	Y	1.000	.120	.571	.465	-.110	.064	.708
	Zr	.120	1.000	.119	-.299	.086	-.292	.099
	Nb	.571	.119	1.000	-.026	.051	.433	.087
	Cd	.465	-.299	-.026	1.000	.061	.069	.552
	W	-.110	.086	.051	.061	1.000	.119	-.425
	Hg	.064	-.292	.433	.069	.119	1.000	-.234
	Pb	.708	.099	.087	.552	-.425	-.234	1.000
	Bi	.293	-.086	-.153	.292	-.502	-.354	.767
	Th	.596	-.234	.645	.138	-.012	.470	.176
	V	.629	.231	.647	.290	.453	.399	.132
	Cr	.500	.434	.488	.135	.481	.313	-.045
	Mn	.200	-.258	.028	.132	-.537	-.139	.476
	Fe	.876	.211	.656	.263	-.194	.089	.725
	La	-.843	-.139	-.642	-.237	.272	-.087	-.711

Correlation Matrix[a,b]

		Bi	Th	V	Cr	Mn	Fe	La
Correlation	Ti	-.375	.736	.706	.683	-.163	.623	-.589
	Ni	-.015	.494	.842	.719	-.215	.531	-.449
	Cu	.588	.397	.473	.312	.415	.934	-.915
	Zn	-.170	.789	.752	.615	.040	.724	-.713
	As	.853	-.239	-.181	-.264	.523	.481	-.480
	Rb	.134	.747	.696	.500	.239	.893	-.886
	Sr	.472	.022	-.153	-.152	.828	.293	-.450
	Y	.293	.596	.629	.500	.200	.876	-.843
	Zr	-.086	-.234	.231	.434	-.258	.211	-.139
	Nb	-.153	.645	.647	.488	.028	.656	-.642
	Cd	.292	.138	.290	.135	.132	.263	-.237
	W	-.502	-.012	.453	.481	-.537	-.194	.272
	Hg	-.354	.470	.399	.313	-.139	.089	-.087
	Pb	.767	.176	.132	-.045	.476	.725	-.711
	Bi	1.000	-.265	-.286	-.406	.832	.403	-.484
	Th	-.265	1.000	.648	.351	-.246	.512	-.449
	V	-.286	.648	1.000	.828	-.317	.531	-.450
	Cr	-.406	.351	.828	1.000	-.355	.402	-.332
	Mn	.832	-.246	-.317	-.355	1.000	.380	-.526
	Fe	.403	.512	.531	.402	.380	1.000	-.984
	La	-.484	-.449	-.450	-.332	-.526	-.984	1.000

a. Only cases for which Soil Samples = 1 are used in the analysis phase.

b. This matrix is not positive definite.

Communalities[a]

	Initial	Extraction
Ti	1.000	.836
Ni	1.000	.566
Cu	1.000	.941
Zn	1.000	.883
As	1.000	.787
Rb	1.000	.951
Sr	1.000	.224
Y	1.000	.884
Zr	1.000	.038
Nb	1.000	.681
Cd	1.000	.181
W	1.000	.384
Hg	1.000	.308
Pb	1.000	.848
Bi	1.000	.929
Th	1.000	.619
V	1.000	.834
Cr	1.000	.676
Mn	1.000	.679
Fe	1.000	.932
La	1.000	.932

Extraction Method: Principal

Component Analysis.

a. Only cases for which Soil Samples = 1 are used in the analysis phase.

Total Variance Explained[a]

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.841	42.098	42.098	8.841	42.098	42.098
2	5.271	25.102	67.200	5.271	25.102	67.200
3	2.566	12.218	79.417			
4	1.589	7.567	86.984			
5	.966	4.599	91.583			
6	.637	3.031	94.614			
7	.409	1.949	96.563			
8	.355	1.691	98.255			
9	.182	.868	99.122			
10	.087	.413	99.535			
11	.069	.328	99.864			
12	.029	.136	100.000			
13	5.119E-016	2.438E-015	100.000			
14	3.431E-016	1.634E-015	100.000			
15	3.022E-016	1.439E-015	100.000			
16	2.215E-016	1.055E-015	100.000			
17	3.868E-018	1.842E-017	100.000			
18	-1.052E-016	-5.008E-016	100.000			
19	-1.526E-016	-7.267E-016	100.000			
20	-3.021E-016	-1.438E-015	100.000			
21	-3.292E-016	-1.568E-015	100.000			

Total Variance Explained[a]

Component	Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	8.023	38.204	38.204
2	6.089	28.996	67.200
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			

Extraction Method: Principal Component Analysis.

a. Only cases for which Soil Samples = 1 are used in the analysis phase.

Component Matrix[a,b]

	Component	
	1	2
Rb	.975	-.036
Fe	.929	.263
Y	.928	.151
La	-.901	-.346
Zn	.882	-.325
Cu	.866	.437
Ti	.769	-.494
Nb	.761	-.320
V	.753	-.517
Ni	.714	-.236
Th	.690	-.379
Cr	.588	-.575
Cd	.329	.269
Zr	.152	-.121
Bi	.187	.945
As	.234	.856
Mn	.196	.801
Pb	.582	.714
W	-.072	-.615
Hg	.297	-.468
Sr	.257	.397

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

b. Only cases for which Soil Samples = 1 are used in the analysis phase.

Rotated Component Matrix[a,b]

	Component	
	1	2
Zn	.930	.137
Ti	.912	-.066
V	.908	-.094
Rb	.873	.435
Nb	.821	.084
Cr	.791	-.223
Th	.787	-.002
Y	.742	.577
Ni	.740	.134
Fe	.690	.676
Hg	.485	-.269
Zr	.191	-.034
Bi	-.288	.920
Pb	.170	.905
As	-.204	.864
Cu	.551	.798
Mn	-.211	.797
La	-.626	-.735
W	.231	-.574
Sr	.036	.472
Cd	.160	.394

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

b. Only cases for which Soil Samples = 1 are used in the analysis phase.

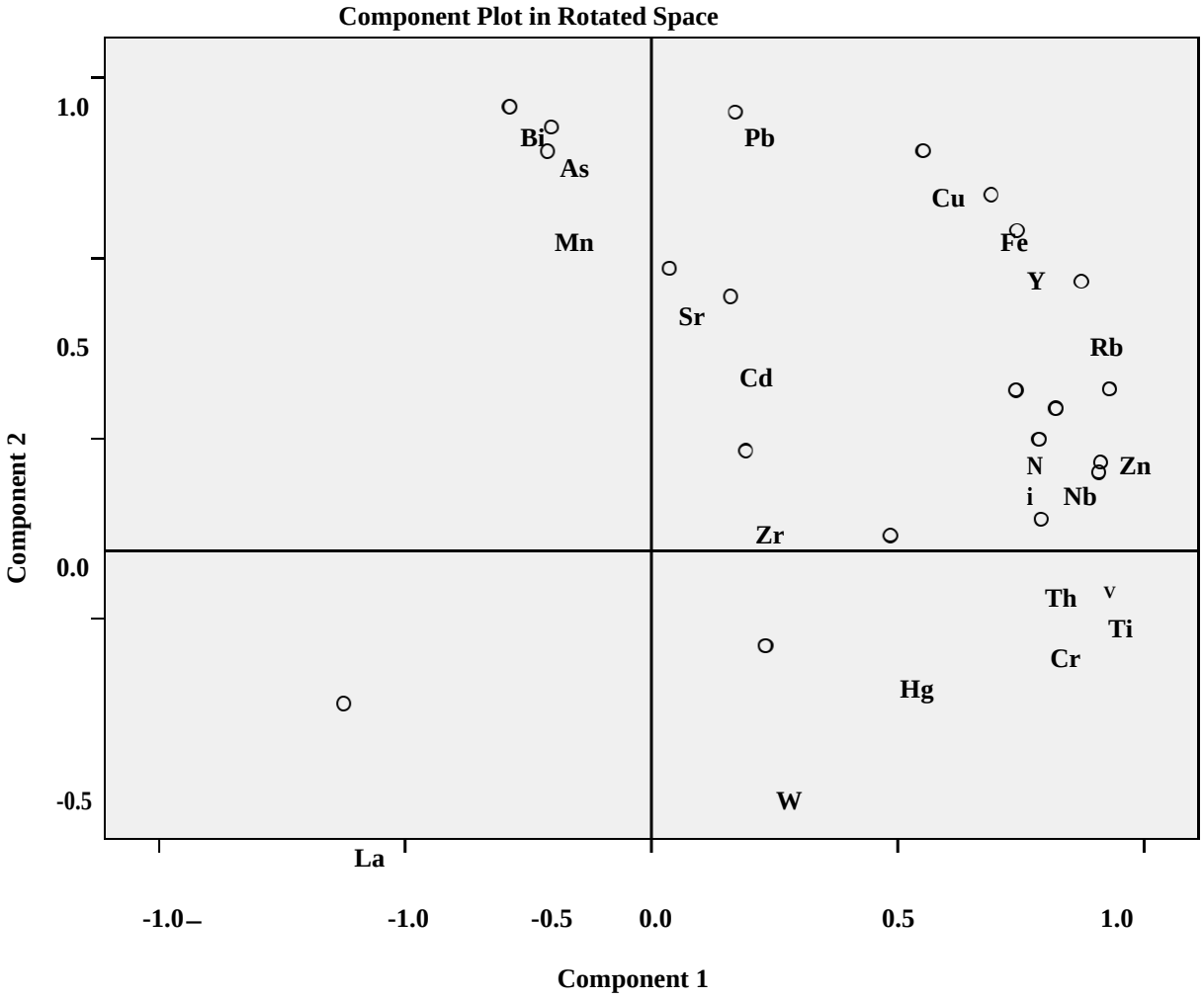
Component Transformation Matrix[a]

Component	1	2
1	.878	.479
2	-.479	.878

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Only cases for which Soil Samples = 1 are used in the analysis phase.



Component Score Coefficient Matrix[a]

	Component	
	1	2
Ti	.121	-.041
Ni	.092	-.001
Cu	.046	.120
Zn	.117	-.006
As	-.054	.155
Rb	.100	.047
Sr	-.010	.080
Y	.078	.075
Zr	.026	-.012
Nb	.105	-.012
Cd	.008	.063
W	.049	-.106
Hg	.072	-.062
Pb	-.007	.150
Bi	-.067	.168
Th	.103	-.026
V	.122	-.045
Cr	.111	-.064
Mn	-.053	.144
Fe	.068	.094
La	-.058	-.106

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

Component Scores.

a. Only cases for which Soil Samples = 1 are used in the analysis phase.

Component Score Covariance Matrix[a]

Component	1	2
1	1.000	.000
2	.000	1.000

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

Component Scores.

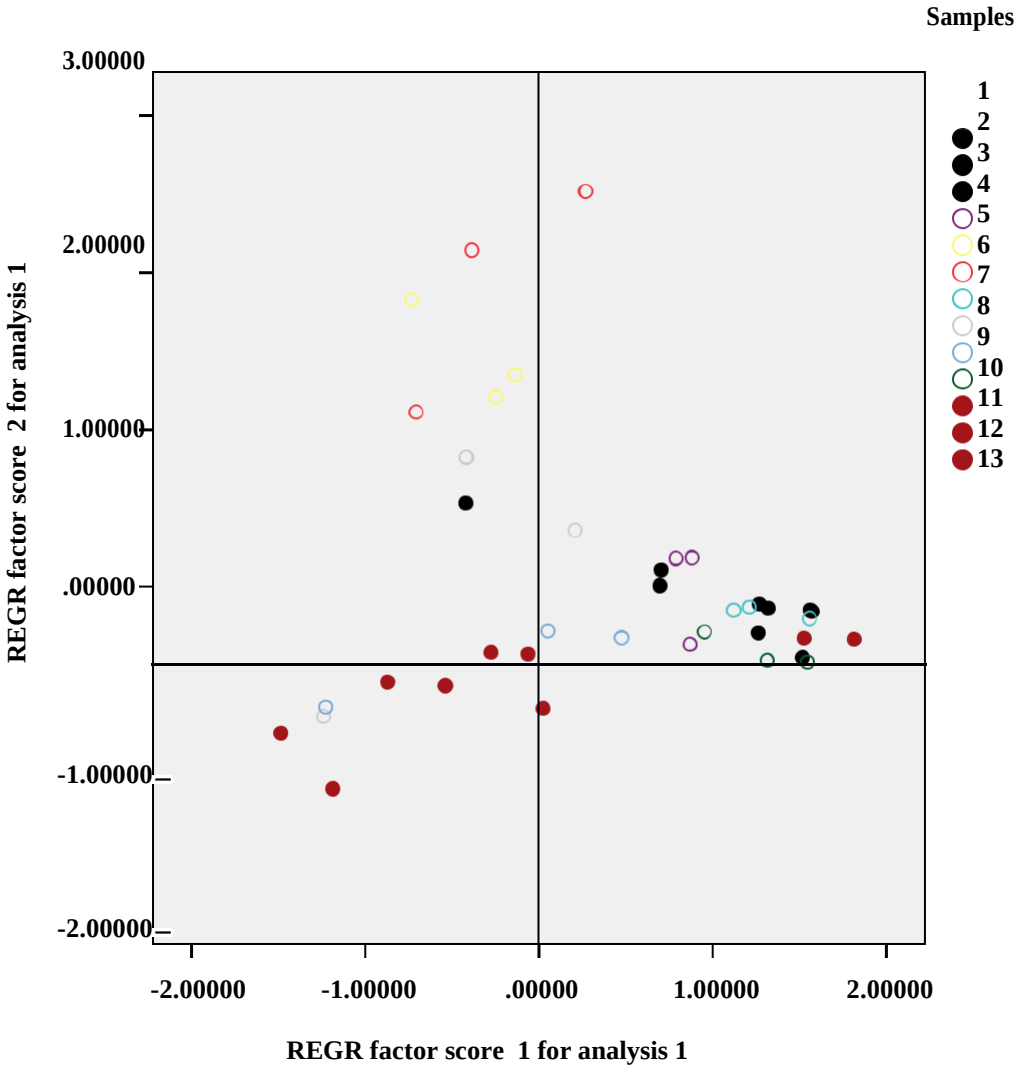
a. Only cases for which Soil Samples = 1 are used in the analysis phase.

GRAPH

/SCATTERPLOT(BIVAR)=FAC1_4 WITH FAC2_4 BY transect

/MISSING=LISTWISE

Graph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2
3
4
5
6
7
8
9
10
11
12
13
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2.00000
1.00000
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-1.00000
-2.00000
REGR factor score 2 for analysis 1
-2.00000
-1.00000
.00000
1.00000
2.00000
REGR factor score 1 for analysis 1

PCA of 11 – 20 cm

```
FACTOR
    /VARIABLES Ti Ni Cu Zn As Rb Sr Y Zr Nb Cd W Hg Pb Bi Th V Cr Mn Fe La
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    /ANALYSIS Ti Ni Cu Zn As Rb Sr Y Zr Nb Cd W Hg Pb Bi Th V Cr Mn Fe La /SELECT=SoilSamples(2)
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    /FORMAT SORT
    /PLOT ROTATION
    /CRITERIA FACTORS(2) ITERATE(25)
    /EXTRACTION PC
    /CRITERIA ITERATE(25)
    /ROTATION VARIMAX
    /SAVE REG(ALL)
    /METHOD=CORRELATION.
```

Factor Analysis

Descriptive Statistics[a]

	Mean	Std. Deviation[b]	Analysis N[b]	Missing N
Ti	.23462	.072241	13	0
Ni	.00400	.001000	13	0
Cu	.00292	.001115	13	0
Zn	.01115	.003211	13	0
As	.00415	.003848	13	0
Rb	.01146	.003597	13	0
Sr	.01177	.003270	13	0
Y	.00254	.000660	13	0
Zr	.01377	.003166	13	0
Nb	.00192	.000494	13	0
Cd	.00285	.000689	13	0
W	.00062	.000768	13	0
Hg	.00062	.000506	13	0
Pb	.00362	.001609	13	0
Bi	.00046	.000877	13	0
Th	.00146	.000660	13	0
V	.0173	.00409	13	0
Cr	.0056	.00142	13	0
Mn	.1004	.07214	13	0

Descriptive Statistics[a]

	Mean	Std. Deviation[b]	Analysis N[b]	Missing N
Fe	4.6074	.89953	13	0
La	94.9610	.97336	13	0

Correlation Matrix[a,b]

		Ti	Ni	Cu	Zn	As	Rb	Sr
Correlation	Ti	1.000	.346	-.070	.925	-.584	.634	.357
	Ni	.346	1.000	.598	.415	.108	.463	.382
	Cu	-.070	.598	1.000	.143	.702	.591	.772
	Zn	.925	.415	.143	1.000	-.326	.816	.567
	As	-.584	.108	.702	-.326	1.000	.115	.420
	Rb	.634	.463	.591	.816	.115	1.000	.903
	Sr	.357	.382	.772	.567	.420	.903	1.000
	Y	.831	.379	.287	.862	-.232	.799	.680
	Zr	.592	.579	.254	.397	-.318	.332	.196
	Nb	.593	.507	.443	.744	.007	.820	.659
	Cd	-.191	.484	.200	-.101	.293	-.070	.020
	W	.035	.217	-.232	-.177	-.373	-.443	-.437
	Hg	.451	.494	.386	.450	-.181	.563	.546
	Pb	-.163	.259	.864	.093	.724	.624	.837
	Bi	-.591	.000	.721	-.382	.866	.191	.505
	Th	.829	.379	.052	.829	-.424	.640	.401
	V	.841	.671	.111	.776	-.467	.505	.238
	Cr	.532	.740	.341	.623	-.073	.463	.356
	Mn	-.337	.053	.710	-.134	.885	.266	.571
	Fe	.188	.448	.647	.440	.638	.588	.653
	La	-.235	-.458	-.659	-.479	-.615	-.627	-.688

Correlation Matrix[a,b]

		Y	Zr	Nb	Cd	W	Hg	Pb
Correlation	Ti	.831	.592	.593	-.191	.035	.451	-.163
	Ni	.379	.579	.507	.484	.217	.494	.259
	Cu	.287	.254	.443	.200	-.232	.386	.864
	Zn	.862	.397	.744	-.101	-.177	.450	.093
	As	-.232	-.318	.007	.293	-.373	-.181	.724
	Rb	.799	.332	.820	-.070	-.443	.563	.624
	Sr	.680	.196	.659	.020	-.437	.546	.837
	Y	1.000	.543	.649	-.169	-.051	.671	.290
	Zr	.543	1.000	.308	-.132	.337	.460	-.035
	Nb	.649	.308	1.000	-.038	-.524	.539	.379
	Cd	-.169	-.132	-.038	1.000	.351	.055	.093
	W	-.051	.337	-.524	.351	1.000	.016	-.467
	Hg	.671	.460	.539	.055	.016	1.000	.417
	Pb	.290	-.035	.379	.093	-.467	.417	1.000
	Bi	-.177	-.259	.089	.127	-.457	.058	.845
	Th	.721	.454	.630	-.014	.051	.326	-.054
	V	.760	.755	.578	.008	.271	.520	-.149
	Cr	.575	.373	.461	.465	.312	.543	.123
	Mn	.062	-.102	.173	.011	-.440	-.002	.741
	Fe	.326	.054	.440	.290	-.331	-.032	.529
	La	-.383	-.097	-.478	-.258	.339	-.016	-.543

Correlation Matrix[a,b]

		Bi	Th	V	Cr	Mn	Fe	La
Correlation	Ti	-.591	.829	.841	.532	-.337	.188	-.235
	Ni	.000	.379	.671	.740	.053	.448	-.458
	Cu	.721	.052	.111	.341	.710	.647	-.659
	Zn	-.382	.829	.776	.623	-.134	.440	-.479
	As	.866	-.424	-.467	-.073	.885	.638	-.615
	Rb	.191	.640	.505	.463	.266	.588	-.627
	Sr	.505	.401	.238	.356	.571	.653	-.688
	Y	-.177	.721	.760	.575	.062	.326	-.383
	Zr	-.259	.454	.755	.373	-.102	.054	-.097
	Nb	.089	.630	.578	.461	.173	.440	-.478
	Cd	.127	-.014	.008	.465	.011	.290	-.258
	W	-.457	.051	.271	.312	-.440	-.331	.339
	Hg	.058	.326	.520	.543	-.002	-.032	-.016
	Pb	.845	-.054	-.149	.123	.741	.529	-.543
	Bi	1.000	-.399	-.532	-.258	.805	.337	-.331
	Th	-.399	1.000	.722	.501	-.219	.235	-.274
	V	-.532	.722	1.000	.727	-.290	.189	-.228
	Cr	-.258	.501	.727	1.000	-.045	.451	-.466
	Mn	.805	-.219	-.290	-.045	1.000	.637	-.644
	Fe	.337	.235	.189	.451	.637	1.000	-.998
	La	-.331	-.274	-.228	-.466	-.644	-.998	1.000

a. Only cases for which Soil Samples = 2 are used in the analysis phase.

b. This matrix is not positive definite.

Communalities[a]

	Initial	Extraction
Ti	1.000	.906
Ni	1.000	.470
Cu	1.000	.815
Zn	1.000	.863
As	1.000	.937
Rb	1.000	.866
Sr	1.000	.872
Y	1.000	.811
Zr	1.000	.442
Nb	1.000	.684
Cd	1.000	.034
W	1.000	.294
Hg	1.000	.421
Pb	1.000	.845
Bi	1.000	.881
Th	1.000	.717
V	1.000	.889
Cr	1.000	.556
Mn	1.000	.810
Fe	1.000	.671
La	1.000	.706

Extraction Method: Principal

Component Analysis.

a. Only cases for which Soil Samples = 2 are used in the analysis phase.

Total Variance Explained[a]

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.453	40.251	40.251	8.453	40.251	40.251
2	6.038	28.751	69.002	6.038	28.751	69.002
3	2.323	11.062	80.063			
4	1.552	7.392	87.456			
5	.944	4.494	91.950			
6	.629	2.995	94.945			
7	.415	1.976	96.921			
8	.258	1.226	98.147			
9	.199	.950	99.097			
10	.087	.413	99.509			
11	.058	.275	99.785			
12	.045	.215	100.000			
13	5.743E-016	2.735E-015	100.000			
14	2.814E-016	1.340E-015	100.000			
15	2.351E-016	1.120E-015	100.000			
16	8.101E-017	3.858E-016	100.000			
17	-1.227E-017	-5.841E-017	100.000			
18	-9.998E-017	-4.761E-016	100.000			
19	-1.847E-016	-8.794E-016	100.000			
20	-2.023E-016	-9.635E-016	100.000			
21	-2.887E-016	-1.375E-015	100.000			

Total Variance Explained[a]

Component	Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	7.906	37.647	37.647
2	6.584	31.354	69.002
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			

Extraction Method: Principal Component Analysis.

a. Only cases for which Soil Samples = 2 are used in the analysis phase.

Component Matrix[a,b]

	Component	
	1	2
Rb	.927	.083
Y	.845	-.313
Sr	.842	.404
Zn	.831	-.415
Nb	.826	-.032
La	-.703	-.460
V	.697	-.635
Cr	.697	-.266
Ti	.683	-.663
Ni	.681	-.075
Th	.677	-.508
Fe	.663	.482
Cu	.642	.634
Hg	.624	-.177
Zr	.505	-.433
As	.118	.961
Bi	.095	.934
Mn	.293	.851
Pb	.530	.751
W	-.221	-.495
Cd	.094	.160

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

b. Only cases for which Soil Samples = 2 are used in the analysis phase.

Rotated Component Matrix[a],[b]

	Component	
	1	2
Zn	.929	.030
Ti	.916	-.258
V	.915	-.227
Y	.892	.127
Th	.837	-.125
Rb	.776	.514
Nb	.742	.365
Cr	.740	.097
Zr	.650	-.141
Ni	.635	.258
Hg	.633	.141
Pb	.109	.913
As	-.353	.901
Mn	-.147	.888
Bi	-.361	.866
Cu	.263	.863
Sr	.548	.756
La	-.400	-.739
Fe	.354	.739
W	.041	-.540
Cd	.007	.185

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

b. Only cases for which Soil Samples = 2 are used in the analysis phase.

Component Transformation Matrix[a]

Component	1	2
1	.880	.476
2	-.476	.880

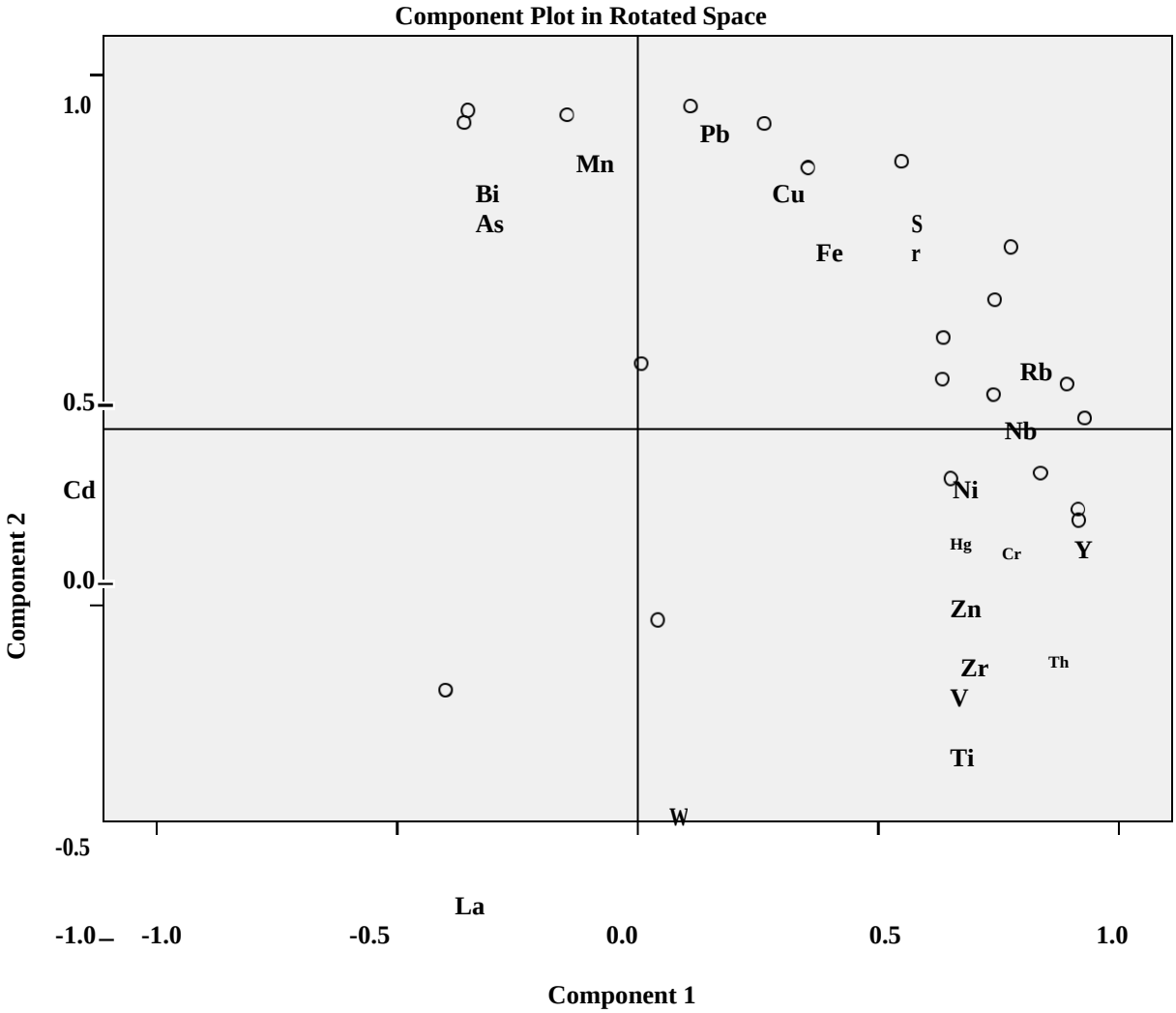
Extraction Method: Principal

Component Analysis.

Rotation Method: Varimax with

Kaiser Normalization.

a. Only cases for which Soil Samples = 2 are used in the analysis phase.



Component Score Coefficient Matrix[a]

	Component	
	1	2
Ti	.123	-.058
Ni	.077	.027
Cu	.017	.129
Zn	.119	-.014
As	-.063	.147
Rb	.090	.064
Sr	.056	.106
Y	.113	.002
Zr	.087	-.035
Nb	.088	.042
Cd	-.003	.029
W	.016	-.085
Hg	.079	.009
Pb	-.004	.139
Bi	-.064	.141
Th	.111	-.036
V	.123	-.053
Cr	.093	.000
Mn	-.037	.140
Fe	.031	.107
La	-.037	-.107

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

Component Scores.

a. Only cases for which Soil Samples = 2 are used in the analysis phase.

Component Score Covariance Matrix[a]

Component	1	2
1	1.000	.000
2	.000	1.000

Extraction Method: Principal

Component Analysis.

Rotation Method: Varimax with

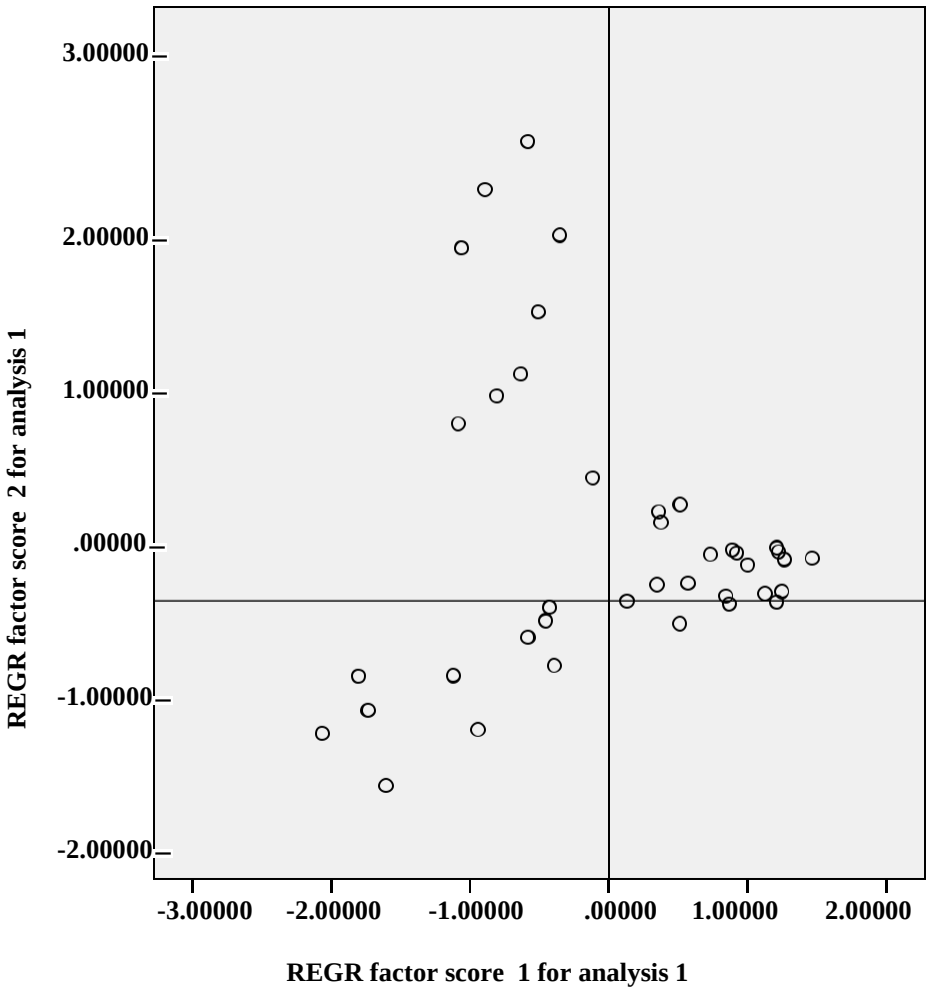
Kaiser Normalization.

Component Scores.

a. Only cases for which Soil Samples = 2 are used in the analysis phase.

```
GRAPH
  /SCATTERPLOT(BIVAR)=FAC1_2 WITH FAC2_2
  /MISSING=LISTWISE
```

Graph

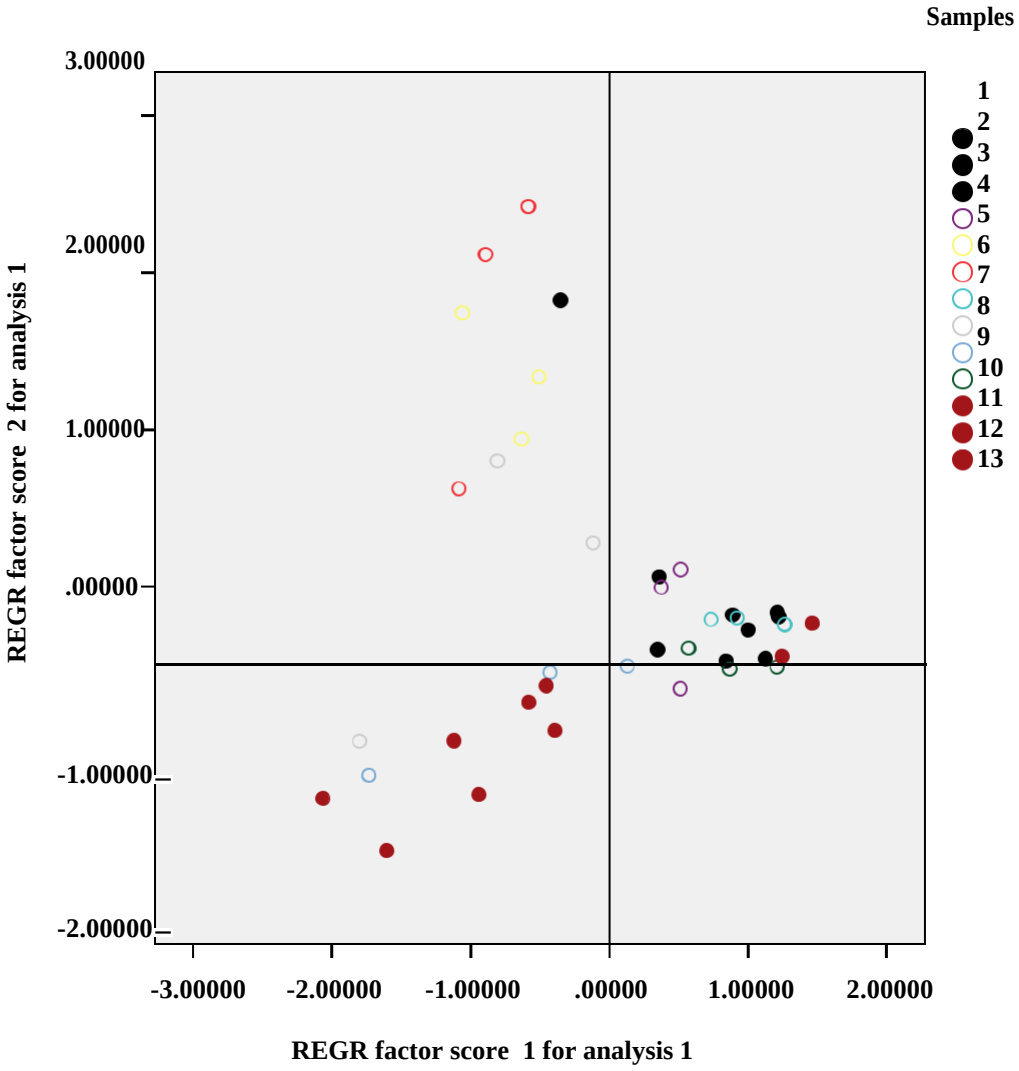


GRAPH

/SCATTERPLOT(BIVAR)=FAC1_2 WITH FAC2_2 BY transect

/MISSING=LISTWISE

Graph


Samples
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2
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4
5
6
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10
11
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13
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2.00000
1.00000
.00000
-1.00000
-2.00000
REGR factor score 2 for analysis 1
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-2.00000
-1.00000
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1.00000
2.00000
REGR factor score 1 for analysis 1

PCA of 21 – 30 cm

```
FACTOR
    /VARIABLES Ti Ni Cu Zn As Rb Sr Y Zr Nb Cd W Hg Pb Bi Th V Cr Mn Fe La
    /MISSING MEANSUB
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    /PRINT UNIVARIATE INITIAL CORRELATION SIG EXTRACTION ROTATION FSCORE
    /FORMAT SORT
    /PLOT ROTATION
    /CRITERIA FACTORS(2) ITERATE(25)
    /EXTRACTION PC
    /CRITERIA ITERATE(25)
    /ROTATION VARIMAX
    /SAVE REG(ALL)
    /METHOD=CORRELATION.
```

Factor Analysis

Descriptive Statistics[a]

	Mean	Std. Deviation[b]	Analysis N[b]	Missing N
Ti	.24885	.069468	13	0
Ni	.00392	.001256	13	0
Cu	.00262	.000961	13	0
Zn	.01154	.002847	13	0
As	.00308	.002139	13	0
Rb	.01154	.003526	13	0
Sr	.01185	.002193	13	0
Y	.00277	.000439	13	0
Zr	.01600	.004983	13	0
Nb	.00223	.000725	13	0
Cd	.00346	.001050	13	0
W	.00069	.000855	13	0
Hg	.00062	.000506	13	0
Pb	.00354	.001450	13	0
Bi	.00031	.000751	13	0
Th	.00185	.000555	13	0
V	.0207	.00477	13	0
Cr	.0052	.00207	13	0
Mn	.0807	.03621	13	0

Descriptive Statistics[a]

	Mean	Std. Deviation[b]	Analysis N[b]	Missing N
Fe	4.3261	.36716	13	0
La	95.2417	.42863	13	0

Correlation Matrix[a,b]

		Ti	Ni	Cu	Zn	As	Rb	Sr
Correlation	Ti	1.000	.705	-.100	.966	-.678	.823	.624
	Ni	.705	1.000	.181	.759	-.308	.725	.419
	Cu	-.100	.181	1.000	.021	.583	.386	.405
	Zn	.966	.759	.021	1.000	-.555	.882	.669
	As	-.678	-.308	.583	-.555	1.000	-.183	-.033
	Rb	.823	.725	.386	.882	-.183	1.000	.831
	Sr	.624	.419	.405	.669	-.033	.831	1.000
	Y	.428	.570	.563	.575	.198	.788	.480
	Zr	-.476	-.426	-.522	-.446	-.141	-.730	-.702
	Nb	.856	.662	.018	.864	-.603	.697	.391
	Cd	.081	.345	.025	.217	.094	.130	-.148
	W	.510	.054	-.258	.450	-.487	.253	.195
	Hg	.221	.474	.356	.156	-.047	.312	.092
	Pb	-.122	.208	.879	.025	.738	.444	.526
	Bi	-.523	-.150	.640	-.396	.918	-.068	.031
	Th	.737	.580	-.277	.637	-.621	.557	.459
	V	.756	.622	-.463	.711	-.612	.475	.194
	Cr	.737	.766	-.271	.752	-.687	.500	.258
	Mn	-.339	-.161	.710	-.209	.616	.111	.297
	Fe	.848	.523	-.231	.864	-.537	.727	.575
	La	-.884	-.574	.152	-.906	.528	-.790	-.636

Correlation Matrix[a,b]

		Y	Zr	Nb	Cd	W	Hg	Pb
Correlation	Ti	.428	-.476	.856	.081	.510	.221	-.122
	Ni	.570	-.426	.662	.345	.054	.474	.208
	Cu	.563	-.522	.018	.025	-.258	.356	.879
	Zn	.575	-.446	.864	.217	.450	.156	.025
	As	.198	-.141	-.603	.094	-.487	-.047	.738
	Rb	.788	-.730	.697	.130	.253	.312	.444
	Sr	.480	-.702	.391	-.148	.195	.092	.526
	Y	1.000	-.496	.444	.432	.017	.318	.605
	Zr	-.496	1.000	-.369	.159	-.137	-.396	-.588
	Nb	.444	-.369	1.000	.177	.393	.262	-.128
	Cd	.432	.159	.177	1.000	-.200	-.109	.042
	W	.017	-.137	.393	-.200	1.000	-.296	-.326
	Hg	.318	-.396	.262	-.109	-.296	1.000	.192
	Pb	.605	-.588	-.128	.042	-.326	.192	1.000
	Bi	.234	-.267	-.447	.228	-.359	-.101	.753
	Th	.184	-.362	.510	-.154	.243	.365	-.199
	V	.253	-.090	.601	.294	.285	.280	-.401
	Cr	.258	-.110	.700	.368	.239	.083	-.255
	Mn	.279	-.295	-.187	-.131	-.247	-.145	.748
	Fe	.414	-.265	.756	.133	.267	.026	-.130
	La	-.469	.338	-.792	-.129	-.297	-.052	.064

Correlation Matrix[a,b]

		Bi	Th	V	Cr	Mn	Fe	La
Correlation	Ti	-.523	.737	.756	.737	-.339	.848	-.884
	Ni	-.150	.580	.622	.766	-.161	.523	-.574
	Cu	.640	-.277	-.463	-.271	.710	-.231	.152
	Zn	-.396	.637	.711	.752	-.209	.864	-.906
	As	.918	-.621	-.612	-.687	.616	-.537	.528
	Rb	-.068	.557	.475	.500	.111	.727	-.790
	Sr	.031	.459	.194	.258	.297	.575	-.636
	Y	.234	.184	.253	.258	.279	.414	-.469
	Zr	-.267	-.362	-.090	-.110	-.295	-.265	.338
	Nb	-.447	.510	.601	.700	-.187	.756	-.792
	Cd	.228	-.154	.294	.368	-.131	.133	-.129
	W	-.359	.243	.285	.239	-.247	.267	-.297
	Hg	-.101	.365	.280	.083	-.145	.026	-.052
	Pb	.753	-.199	-.401	-.255	.748	-.130	.064
	Bi	1.000	-.677	-.533	-.551	.543	-.493	.468
	Th	-.677	1.000	.604	.685	-.263	.620	-.644
	V	-.533	.604	1.000	.634	-.771	.728	-.703
	Cr	-.551	.685	.634	1.000	-.280	.604	-.635
	Mn	.543	-.263	-.771	-.280	1.000	-.279	.216
	Fe	-.493	.620	.728	.604	-.279	1.000	-.993
	La	.468	-.644	-.703	-.635	.216	-.993	1.000

a. Only cases for which Soil Samples = 3 are used in the analysis phase.

b. This matrix is not positive definite.

Communalities[a]

	Initial	Extraction
Ti	1.000	.964
Ni	1.000	.661
Cu	1.000	.850
Zn	1.000	.957
As	1.000	.871
Rb	1.000	.978
Sr	1.000	.668
Y	1.000	.702
Zr	1.000	.638
Nb	1.000	.747
Cd	1.000	.031
W	1.000	.234
Hg	1.000	.138
Pb	1.000	.970
Bi	1.000	.792
Th	1.000	.624
V	1.000	.747
Cr	1.000	.670
Mn	1.000	.637
Fe	1.000	.781
La	1.000	.835

Extraction Method: Principal

Component Analysis.

a. Only cases for which Soil Samples = 3 are used in the analysis phase.

Total Variance Explained[a]

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.286	44.220	44.220	9.286	44.220	44.220
2	5.209	24.803	69.023	5.209	24.803	69.023
3	1.838	8.753	77.776			
4	1.510	7.192	84.968			
5	.843	4.016	88.985			
6	.801	3.813	92.797			
7	.568	2.705	95.503			
8	.364	1.735	97.237			
9	.269	1.279	98.516			
10	.199	.947	99.464			
11	.077	.366	99.830			
12	.036	.170	100.000			
13	5.136E-016	2.446E-015	100.000			
14	2.187E-016	1.042E-015	100.000			
15	1.416E-016	6.742E-016	100.000			
16	8.381E-017	3.991E-016	100.000			
17	-1.267E-016	-6.035E-016	100.000			
18	-1.448E-016	-6.895E-016	100.000			
19	-3.817E-016	-1.818E-015	100.000			
20	-5.247E-016	-2.499E-015	100.000			
21	-7.032E-016	-3.349E-015	100.000			

Total Variance Explained[a]

Component	Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	7.732	36.818	36.818
2	6.763	32.205	69.023
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			

Extraction Method: Principal Component Analysis.

a. Only cases for which Soil Samples = 3 are used in the analysis phase.

Component Matrix[a,b]

	Component	
	1	2
Ti	.982	.017
Zn	.966	.154
La	-.912	-.049
Fe	.883	-.025
Nb	.863	.046
Rb	.815	.560
V	.804	-.318
Cr	.800	-.176
Th	.780	-.127
Ni	.761	.285
As	-.670	.650
W	.410	-.256
Cd	.150	.094
Pb	-.131	.976
Cu	-.140	.911
Mn	-.346	.719
Bi	-.556	.695
Y	.471	.693
Zr	-.410	-.686
Sr	.576	.580
Hg	.259	.266

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

b. Only cases for which Soil Samples = 3 are used in the analysis phase.

Rotated Component Matrix[a,b]

	Component	
	1	2
Rb	.987	-.063
Zn	.855	-.475
Sr	.811	.100
Y	.798	.255
Ti	.783	-.593
Ni	.775	-.246
La	-.748	.525
Zr	-.746	-.286
Nb	.707	-.496
Fe	.679	-.565
Hg	.368	.049
Cd	.176	-.019
As	-.126	.925
Bi	-.008	.890
Pb	.500	.849
Cu	.452	.803
Mn	.172	.780
V	.436	-.746
Cr	.520	-.632
Th	.535	-.581
W	.165	-.455

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

b. Only cases for which Soil Samples = 3 are used in the analysis phase.

Component Transformation Matrix[a]

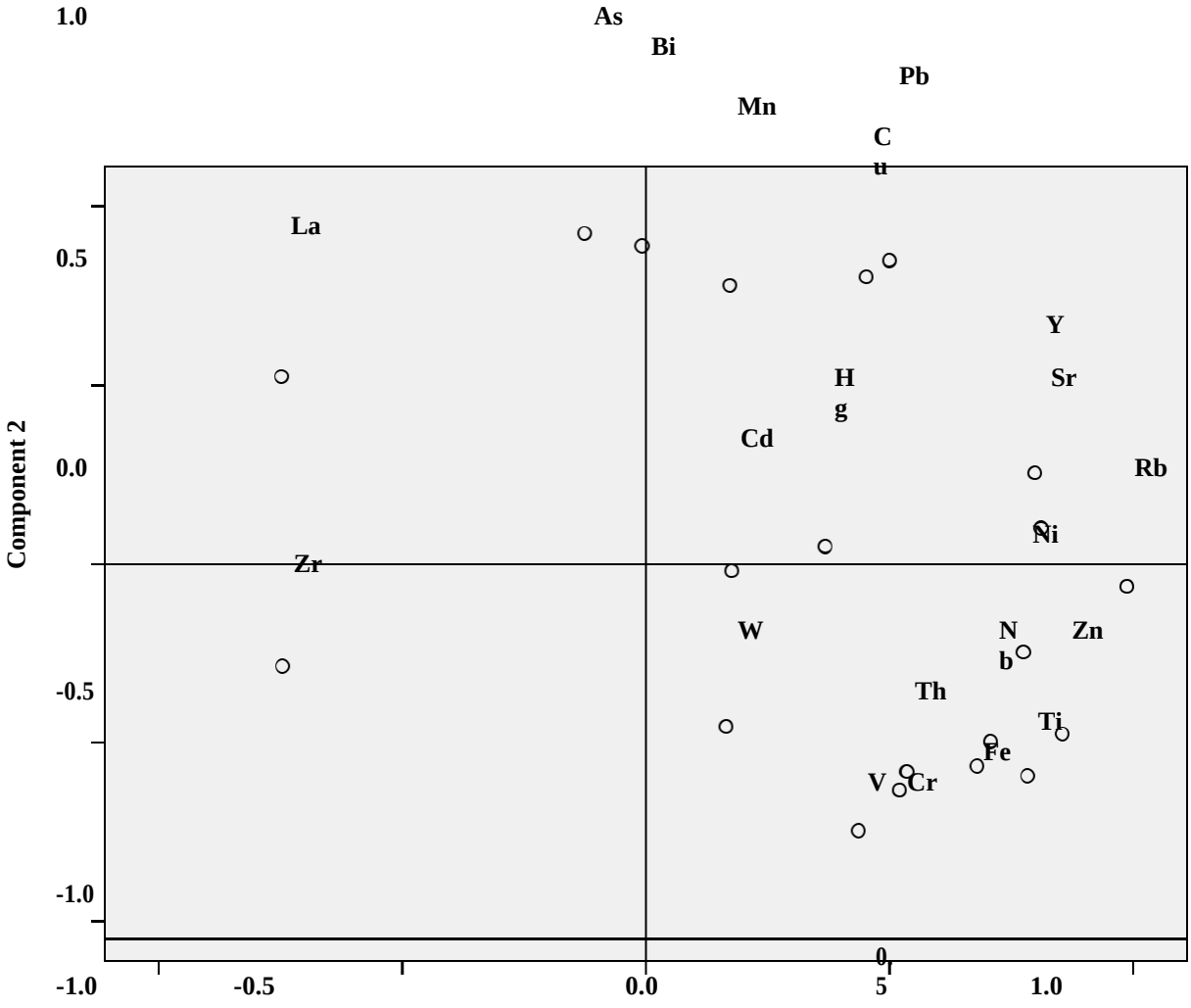
Component	1	2
1	.787	-.617
2	.617	.787

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Only cases for which Soil Samples = 3 are used in the analysis phase.

Component Plot in Rotated Space



Component Score Coefficient Matrix[a]

	Component	
	1	2
Ti	.085	-.063
Ni	.098	-.008
Cu	.096	.147
Zn	.100	-.041
As	.020	.143
Rb	.135	.030
Sr	.117	.049
Y	.122	.073
Zr	-.116	-.076
Nb	.079	-.050
Cd	.024	.004
W	.004	-.066
Hg	.053	.023
Pb	.105	.156
Bi	.035	.142
Th	.051	-.071
V	.030	-.101
Cr	.047	-.080
Mn	.056	.132
Fe	.072	-.063
La	-.083	.053

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

Component Scores.

a. Only cases for which Soil Samples = 3 are used in the analysis phase.

Component Score Covariance Matrix[a]

Component	1	2
1	1.000	.000
2	.000	1.000

Extraction Method: Principal

Component Analysis.

Rotation Method: Varimax with

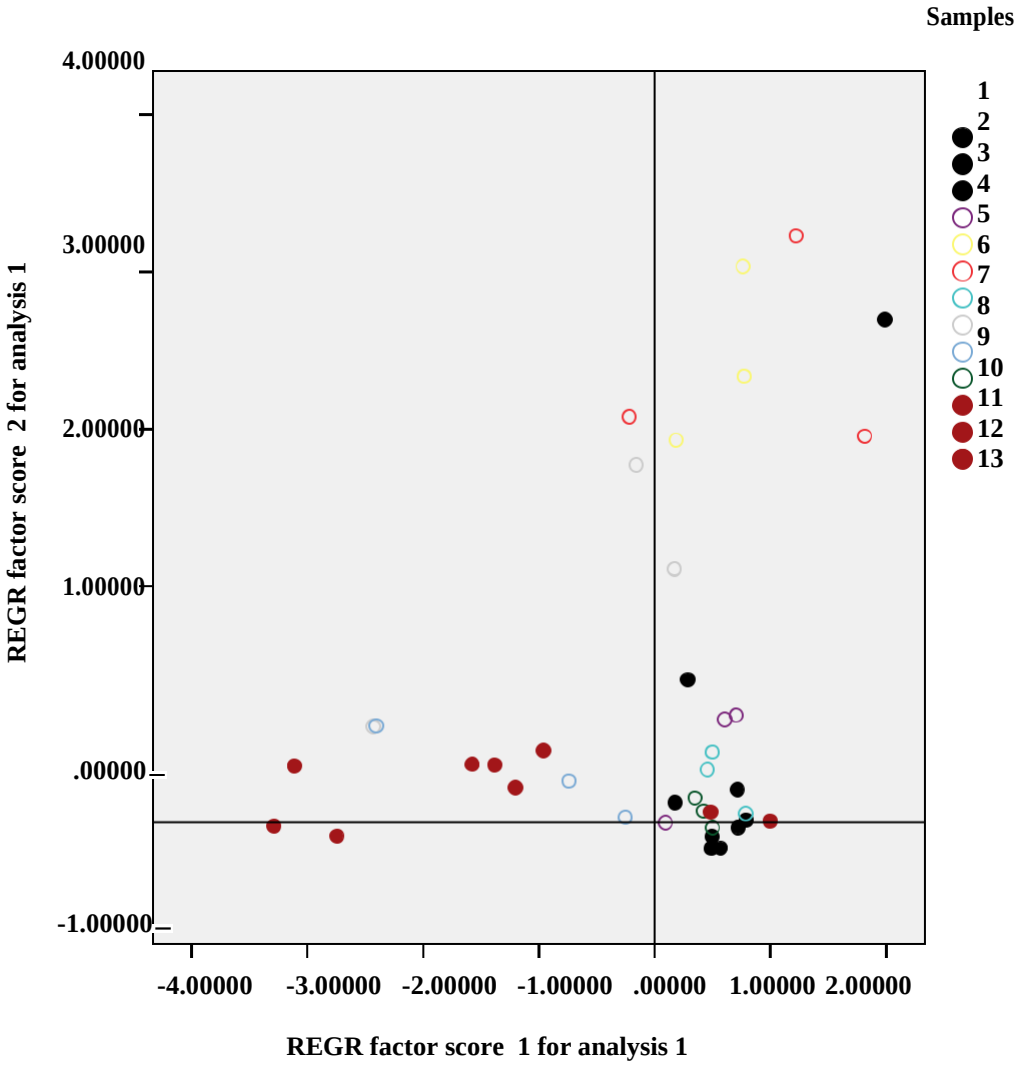
Kaiser Normalization.

Component Scores.

a. Only cases for which Soil Samples = 3 are used in the analysis phase.

```
GRAPH
  /SCATTERPLOT(BIVAR)=FAC1_3 WITH FAC2_3 BY transect
  /MISSING=LISTWISE
```

Graph


Samples
1
2
3
4
5
6
7
8
9
10
11
12
13
4.00000
3.00000
2.00000
1.00000
.00000
-1.00000
REGR factor score 2 for analysis 1
-4.00000
-3.00000
-2.00000
-1.00000
.00000
1.00000
2.00000
REGR factor score 1 for analysis 1