MANGROVE WETLAND SURVEYS

Nelson's Dockyard National Park | 2020 Report

This study was conducted by the National Parks Authority through partnership with the Antigua & Barbuda Department of Environment.

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Cover photo: Crab Hole Mangrove, Nelson's Dockyard National Park, Antigua & Barbuda. © Britney Hay/EAG
Report designed by Ms. Shanna Challenger and Britney Hay of the Environmental Awareness Group.

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Executive Summary

Background

In-situ ecological surveys of 79.3% of the known mangrove wetlands found within the boundaries of the Nelson's Dockyard National Park (NDNP) were carried out in the third quarter of 2020. These surveys allowed for an in-situ assessment of the health of these ecosystems in terms of their diversity and ecological characterization, while generating baseline data from which further monitoring and management of these wetland areas can occur. These surveys were also paired with aerial mapping and spatial analysis to determine the distribution and historical change in the size of these wetland systems. Five of the six major mangrove wetlands systems were assessed, namely: Indian Creek, English Harbour, Marsh Village, Crab Hole and Doig. These surveys collected information on the biodiversity of the mangrove wetlands while documenting the unique attributes of each ecosystem. These surveys were paired with aerial mapping (using drones) and historical images of the NDNP to provide information on the change in spatial distribution of mangrove wetland ecosystems.

Floral Diversity and Distribution

This study found that red mangrove plants were tallest at the Indian Creek mangrove wetland, and that black mangrove plants were tallest at the English Harbour mangrove wetland. No red mangrove flora was recorded at the Doig site, and no buttonwood mangroves were recorded at any of the sites surveyed in this report (although buttonwood plants were visually observed in low density at some of the wetland sites). The Marsh Village mangrove wetland had the densest accumulation of mangrove flora overall recorded, which was likely driven by anthropogenic disturbances limiting the area available for mangrove floral growth.

Seedling Abundance

High numbers of red and black mangrove seedlings were recorded throughout the surveys, with a lower number of white mangrove seedlings and no buttonwood seedlings. Trash was noted at all mangrove wetland sites, with the Marsh Village wetland raising the most concern. Faunal diversity was noted at all mangrove wetland sites, and consisted primarily of birds, crustaceans and reptiles.

Threats

Illegal Dumping and poor waste management is a problem among mangrove wetland areas, particularly those with a relative ease-of-access by human activity. Some evidence of backfilling observed and needs to be addressed. Termites appear to be a major threat to Red mangrove flora at several sites.

Historical Analysis

A historical analysis of the mangrove wetland areas within the NDNP indicated that ~27% of mangrove wetlands had been lost within the last ~70yrs, further emphasizing the need to protect these valuable ecosystems.

Next Steps

The mangrove wetlands assessed were considered relatively healthy with a high ecological variation observed among the wetland ecosystems. These surveys are the first documented in-situ surveys to be carried out within NDNP and have provided data from which management interventions can be developed while providing a baseline from which future monitoring of these diverse and highly important ecosystems can be carried out.

Picture 1: Red Mangrove Root System. © Chaso Media/EAG

List of Abbreviations

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DBH	Diameter at Breast Height
DoE	Antigua & Barbuda Department of Environment
EPMA	Environmental Protection and Management Act
IUCN	International Union for Conservation of Nature
NBSAP	National Biodiversity Strategic Action Plan
NDNP	Nelson's Dockyard National Park
NPA	National Parks Authority
UAV	Unmanned Aerial Vehicle
UNEP	United Nations Environment Programme

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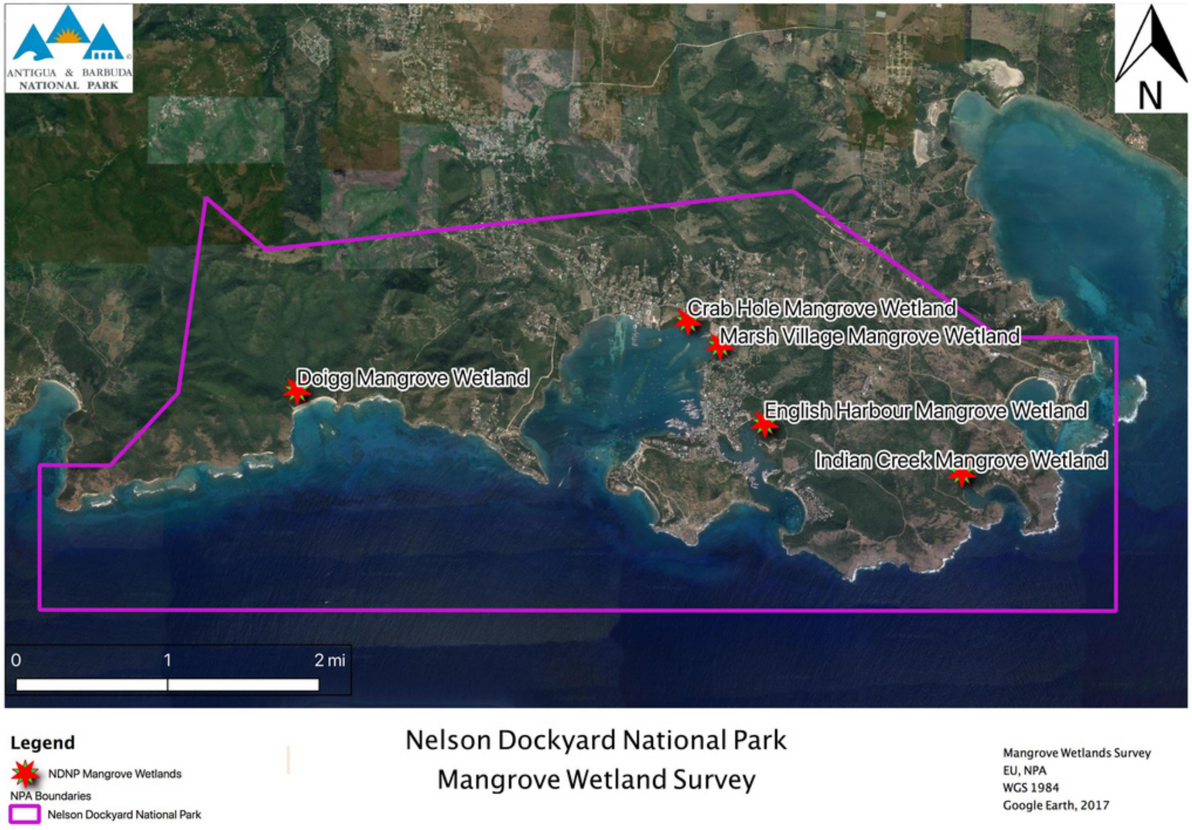
Introduction

Nelson Dockyard National Park Mangrove Wetlands

The National Parks Authority (NPA) is a non-profit statutory organization of the government of Antigua and Barbuda, which was established in 1984 under the National Parks Act (1984). Its purpose is to preserve, protect, manage and develop the natural, physical and ecological resources and the historical and cultural heritage of Antigua and Barbuda.

The NPA has been mandated to manage several terrestrial and marine areas around Antigua and Barbuda: Nelson's Dockyard, Fort Barrington, Green Castle Hill. The largest of these is the Nelson's Dockyard National Park (NDNP) [Map 1], which has a total area of 40.7 km^2 hectares (marine: 18.62km^2 terrestrial: 22.08km^2). Mangrove wetlands are distributed throughout the coastline of the NDNP, covering an area of 260,855m^2, and provide a variety of ecosystem services which are essential to the maintenance of the rich biodiversity and cultural values of NDNP.



Map 1: Displaying the boundaries of the Nelson Dockyard National Park and the mangrove wetlands assessed in these surveys.

There is limited information on the mangrove wetlands found within the NDNP. Several vegetative inventories for Antigua & Barbuda have mentioned these wetland ecosystems, but no in-depth studies have been carried out to determine their ecological characterization or distribution. Mangrove Species are protected under the Environmental Protection and Management Act (2019) and are highly valued with the NPA due to the ecosystem services they provide at an ecological, economic and societal level.

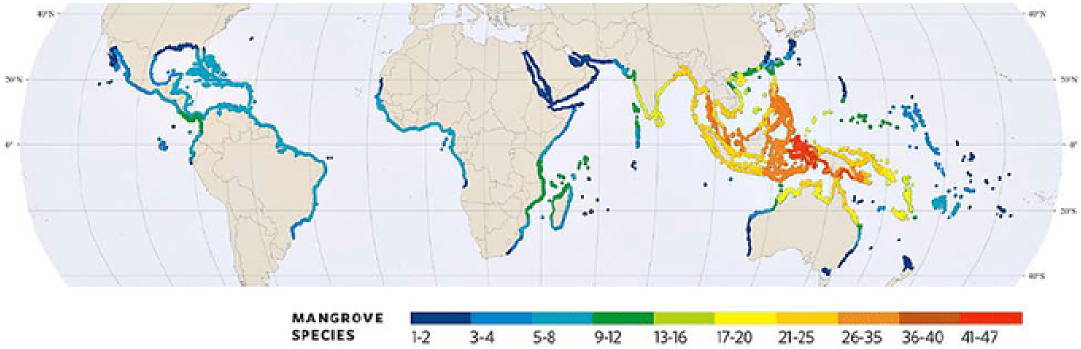
With the intention of improving monitoring capacity of these vital ecosystems in the future, the NPA conducted mangrove ecosystem surveys within the boundaries of NDNP. Five major mangrove wetland sites within NDNP were identified and assessed during the NDNP Mangrove Wetland Surveys. While this is not an exhaustive list, it is representative of the mangrove wetland diversity found within NDNP. These surveys allowed for an in-situ assessment of the health of these ecosystems in terms of their ecological characterization and diversity, spatial distribution and historical changes, while generating baseline data from which further monitoring and management of these wetland areas may occur.

Picture 2: Black-Crowned Night Heron in Mangrove Wetland. © Nick Hollands/EAG

Picture 3: Aerial image of the English Harbour Mangrove Wetland. © Ruleo Camacho/NPA

Mangrove Wetlands

Wetland ecosystems are defined by their permanently or seasonally flooded soils. Mangrove wetland ecosystems are unique to all other wetland types (for example estuaries, salt marshes, etc.) because of the presence of mangrove plants, which are defined as tropical or subtropical trees or shrubs that primarily grow in coastal wetland areas or intertidal zones. Mangrove wetland ecosystems (Picture 1) are the most dominant wetland ecosystems found in the Caribbean and are commonly referred to as 'swamps' in Antigua and Barbuda.



Map 2: World map of mangrove distribution zones and the number of mangrove species in each region. Deltares 2014.

Mangrove wetlands are crucial ecosystems that can be found all over the world (Map 2) and carry out a host of ecosystem services which directly benefit anthropogenic activities while simultaneously providing biodiversity and ecosystem support to coastal, marine and terrestrial ecosystems all over the world. They are one component of the "Holy Trinity" of marine ecosystems, which also includes seagrass beds and coral reef ecosystems.

Diversity

Mangrove flora in the Caribbean consists of four (4) main species that exhibit a zonation pattern from most salt tolerant (and typically found closest to the ocean) to least salt tolerant (which are found most landward).

Red Mangroves *(Rhizophora mangle)*

Picture 4: Red mangrove plants along the water's edge. © Ruleo Camacho/NPA

Picture 5: Red Mangrove prop roots (top), leaves (lower left) and propagule (lower right). © Ruleo Camacho/NPA

These are typically located within saltwater and along the water's edge (Picture 4) due to their affinity for high saline environments (halophilic plants). These mangrove plants are easily identified by their red 'prop roots' (Picture 5: top), also commonly referred to as 'stilt roots,' which are elliptical in shape and act as stilts for the plants, holding or propping it above the water. Red mangrove flora can also be identified by their leaves, which are thick, leathery and elongated (Picture 5: lower left). These leaves store excess salt and eventually turn yellow and fall off, causing them to be referred to as "sacrificial" leaves.

Red mangrove plants are viviparous, meaning that they bear live young. Their seeds can germinate while still attached to the parent plant (these are called propagules [Picture 5: lower right]). Propagules continue to float in the sea until they locate a substrate suitable enough for growth.

Black Mangroves (*Avicennia germinans*)

Picture 6: Black Mangrove flora displaying dark black bark and pneumatophores. © Ruleo Camacho/NPA

The name 'black' mangrove (Picture 6) originates from the trunks of these trees which are blackish in colour, and have a lower salt tolerance than that of red mangroves. They are typically in the 'swampier' area, which is muddy and frequently inundated by tidal fluctuations.

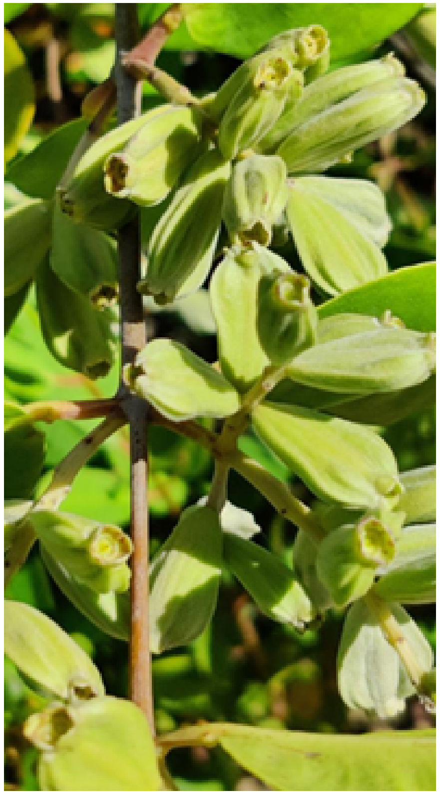
Black mangrove plants can be identified by their leaves which have an elongated, oval shape and often have salt grains on their surface (Picture 7: lower left). This unique adaptation allows the plants to get rid of excess salt. Another unique identifier of black mangrove flora is their roots which protrude from the floor of the wetland called 'pneumatophores' or 'snorkel roots' (Picture 7: top). These roots allow the plant to access oxygen which is otherwise difficult to secure from the heavily saturated and compacted soil.

Black mangrove plants produce oval shaped seeds, which fall off the plant before germination occurs (Picture 7: lower right).

Picture 7: Black mangrove pneumatophores (top), leaves with salt crystals (lower left) and seeds (lower right). © Ruleo Camacho/NPA

White Mangroves (*Laguncularia racemosa*)

White mangrove plants are less tolerant to saline environments and as a result are typically found closer to the landward edge of the mangrove ecosystem where they tend to encounter lower saline conditions. They are considered the third least salt tolerant of the mangrove flora in the Caribbean region.



Picture 9: White Mangrove plant seeds (left) and leaves showing nectaries (right). © Ruleo Camacho/NPA

Picture 8: Flowering White Mangrove flora. © Ruleo Camacho/NPA

These plants have a reddish/gray-brown bark and produce a white flower (Picture 8), from which they get their name. While they are typically located closer to land, they still encounter some saline conditions. As a result, these plants have developed a unique adaptation whereby small glands called nectarines at the base of each leaf excrete excess salt taken up through the plants root system (Picture 9: right). The presence of these nectarines is the simplest way to identify these plants.

White mangroves may also produce prop roots or pneumatophores and their leaves are oval-shaped and leathery. The seeds of white mangrove plants fall off prior to germination (Picture 7: left).

Buttonwood Mangroves (*Conocarpus erectus*)

Picture 10: Buttonwood Mangrove plants. © Ruleo Camacho/NPA

Picture 11: Buttonwood Mangrove leaf highlighting pores (left) and the buttonwood seeds (right). © Ruleo Camacho/NPA

Buttonwood mangrove plants (Picture 10) are like white mangroves in terms of their reduced tolerance for saline environments and are considered the least salt tolerant of the four mangrove flora found within the Caribbean region. They tend to thrive in areas of the wetland where the water is freshest, making them most commonly found furthest inland.

The leaves have an elongated shape with a pore on either side just prior to the base (Picture 11: left). This aids the plant in getting rid of any salt it may intake due to its proximity to saline environments. These plants get their name from the unique buttonwood seeds which they produce (Picture 11: right).

Function

Mangrove ecosystems work in conjunction with seagrass beds and coral reef ecosystems to create a thriving, functional marine ecosystem. Due to ecological connectivity, when these three ecosystems are healthy and able to support one another, marine life flourishes. They provide habitats and nurseries for a variety of coastal marine species. They protect coastlines from storm surges and help to stabilize coastal sediment thereby guarding against erosion. They also serve to maintain good water quality by filtering polluted water from the land before it reaches the sea (Figure 1).

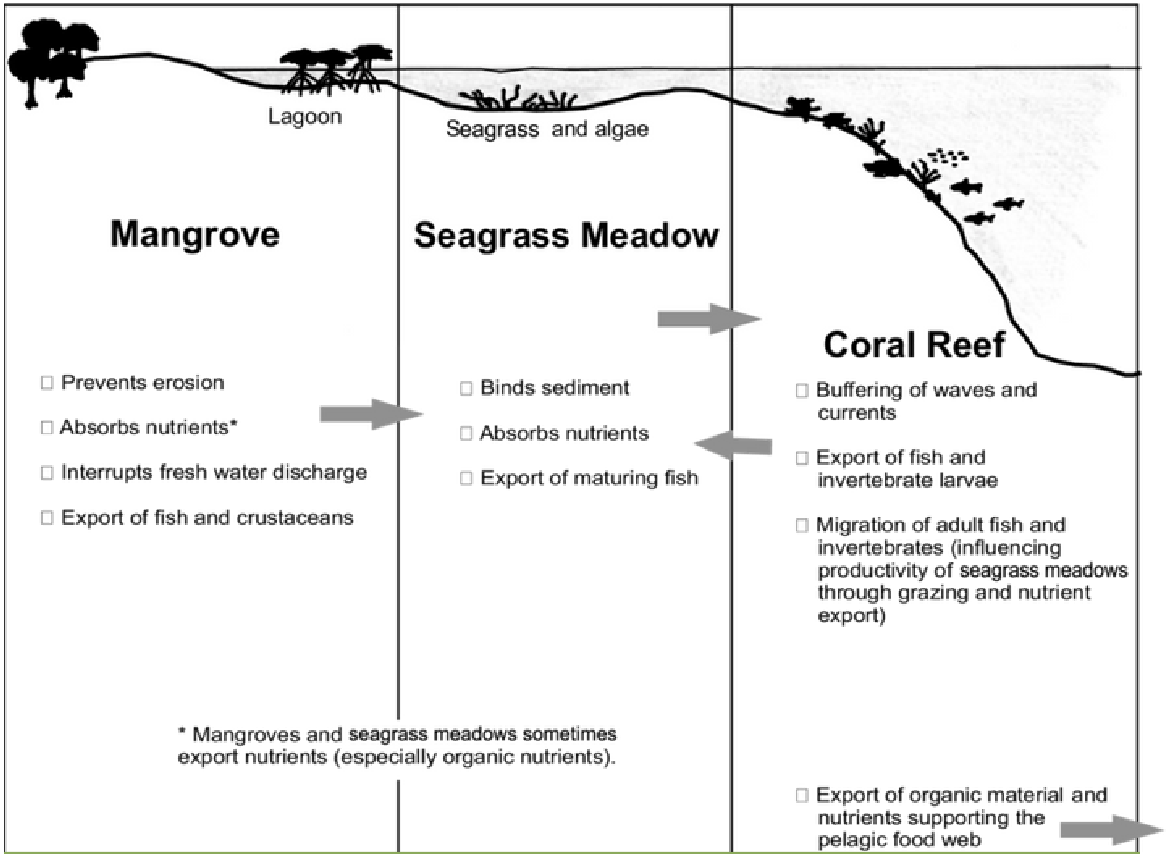


Figure 1: Connectivity of coastal ecosystems (Kallesoe et al., 2008).

Mangrove ecosystems play an important role in the maintenance of anthropogenic activities, through enhancement and provision of eco-tourism and livelihood opportunities. They also act as an essential carbon sink in the fight against Climate Change, being valued US$33,000 to US$55,000 per hectare per year by The United Nations Environment Program (UNEP) due to the ecosystem services they provide. More details on these essential mangrove ecosystem services can be found below:

Coastal Protection

Mangrove plants act as natural breakers of waves and wind, protecting the coastline from erosion that may be caused by water and/or wind action (Figure 2). These plants are up to 5x more cost effective than any known man-made barrier (Narayan, et al. 2016). This is especially important in countries like Antigua and Barbuda and the wider Caribbean, who are increasingly vulnerable to storms and hurricanes as a result of climate change. By protecting the coastline, mangroves also protect the livelihoods that benefit from it, the homes and property that exists along the coast, and the organisms who make it their home. Culturally, the coastal protective services of mangrove wetlands have been long recognized, with local fishing community members securing their boats in mangrove areas during the approach of a hurricane.

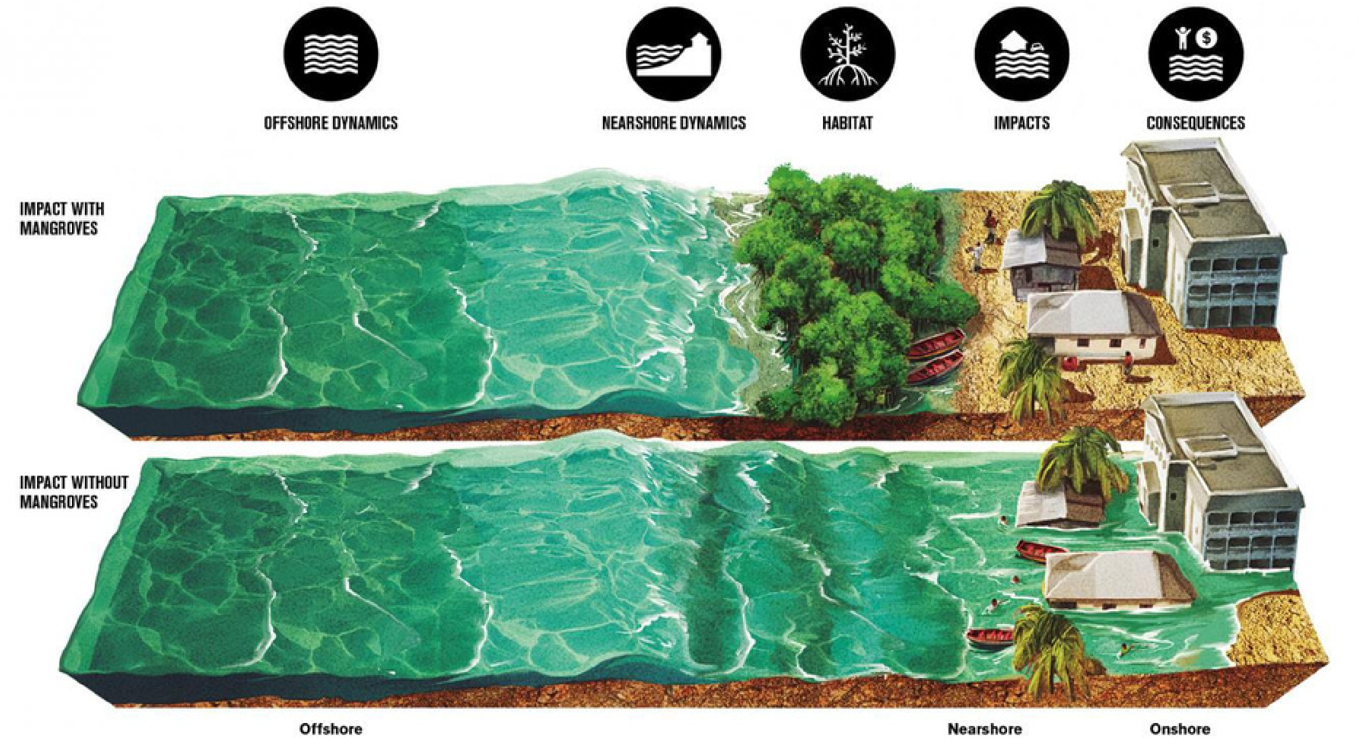


Figure 2: Impact on coastline with vs without mangroves (Menendez et al. 2020 via Oceanographic Magazine)

Carbon Sequestration

Mangrove wetland ecosystems act as massive carbon sinks, sequestering three to five times more carbon than even tropical rainforests (Donato et al. 2011). These ecosystems therefore have a big impact on the amount of carbon available within our atmosphere and are an essential tool in the fight to mitigate climate change (Figure 3).

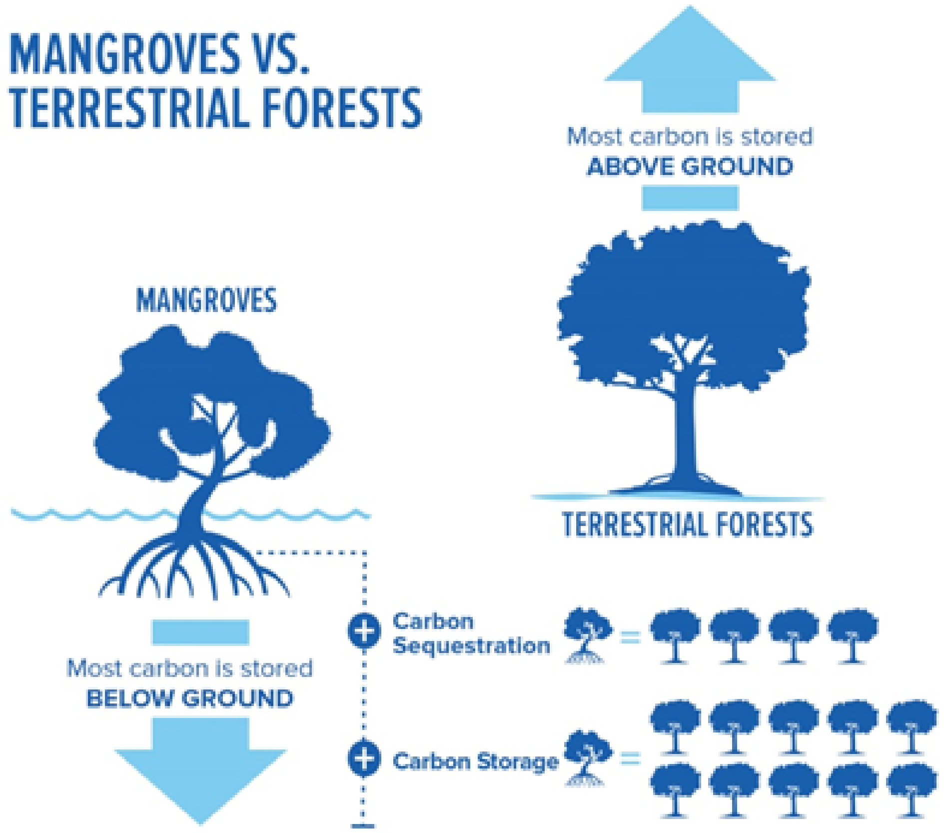


Figure 3: Carbon absorption in mangroves vs terrestrial plants (Mulhern, 2020)

Nutrient Absorption

The abundance of life in a wetland ecosystem makes it an incredibly nutrient-rich area. Animal waste, organism death and minerals carried by surface runoff all provide a source of nutrients for these ecosystems. Nutrient absorption also helps contribute to water filtration as the nutrients absorbed may include harmful substances such as pesticides and fertilizers.

Water Filtration

The roots of mangrove plants provide a physical barrier for garbage moving through the ecosystem, filtering out large objects as water flows from the land to the sea. Additionally, microorganisms that exist on the floor and root systems of mangrove plants further purify incoming water by breaking down organic compounds present (Neil Crenshaw, 2018). Therefore, as run-off from the land makes its way through the wetland, impurities are removed so that clean water is released into the sea.

Habitat and Biodiversity Support

Mangrove wetlands provide habitat and food for many species, marine and terrestrial. They are home to a wide variety of birds, fish, crustaceans and reptiles. The prop roots of red mangroves act as nurseries and breeding grounds for marine organisms, while the leaf litter generated from these plants provide food for organisms (Cassie et al. 1998). The tree canopy of mangrove wetlands also provides nesting areas for a variety of coastal birds. Mangroves filter terrestrial runoff so it doesn't directly affect seagrass beds and coral reef ecosystems, thus ensuring that these important marine habitats can support a variety of marine species.

Livelihood and Economic Support

Mangrove wetland ecosystems support anthropogenic livelihoods in a variety of ways. They support fisheries by providing nursery areas and habitats for commercially important species (e.g. Snappers (*Lutjanidae*) and Groupers (*Serranidae*). They filter terrestrial runoff, preventing it from directly impacting seagrass beds and coral reefs ecosystems (which are significant ecotourism areas). Mangrove wetlands themselves can also be important contributors to the tourism product through protection of coastal structures, provision of ecotourism attractions, and maintenance of a pristine marine environment (Figure 4).

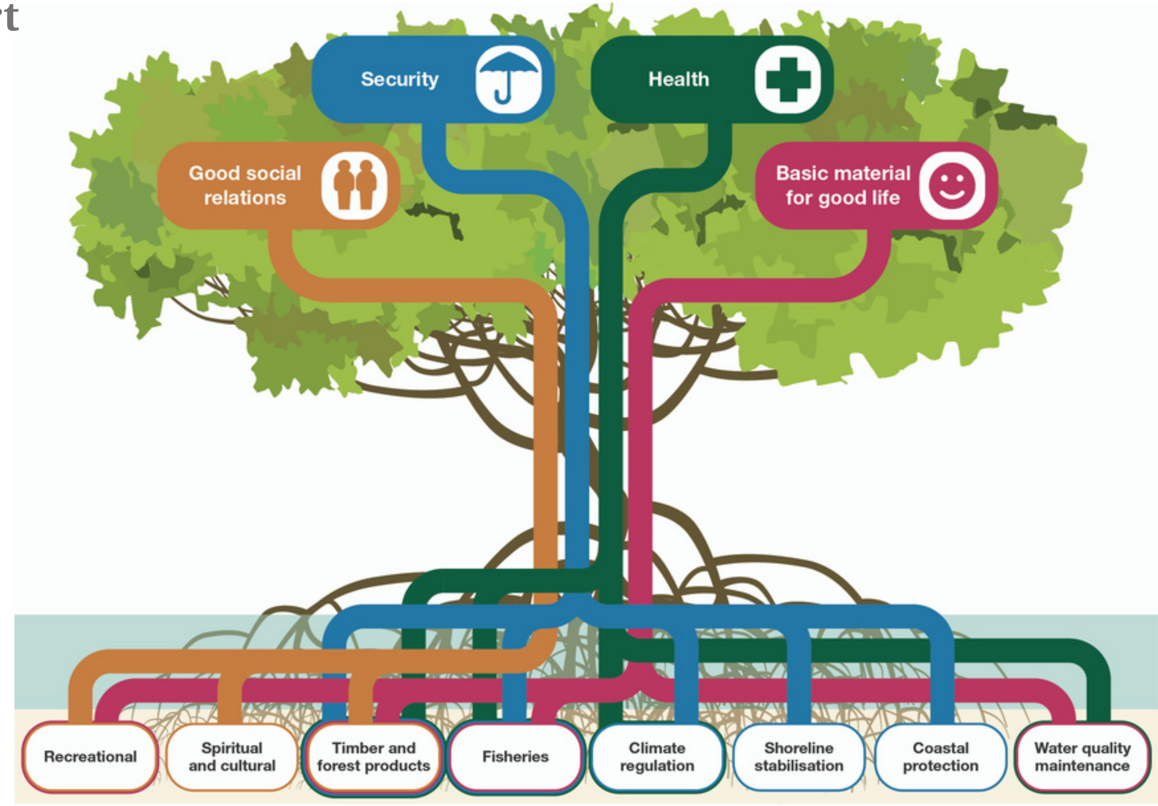


Figure 4: Highlighting the various ecosystem services provided by Mangrove Wetlands (UNEP, 2014)

Threats

The International Union for the Conservation of Nature (IUCN) has raised concerns regarding the rate of mangrove wetland destruction on a global level. Thirty-five percent of mangrove forest around the world has been lost between 1980 and 2000, a rate 3-5 times higher than that of terrestrial forests (Duraiappah et al., 2005). Threats to these ecosystems have increased due to weak institutional arrangements, policies and management systems. Figure 5 shown below highlights some of the global threats to mangrove wetlands.

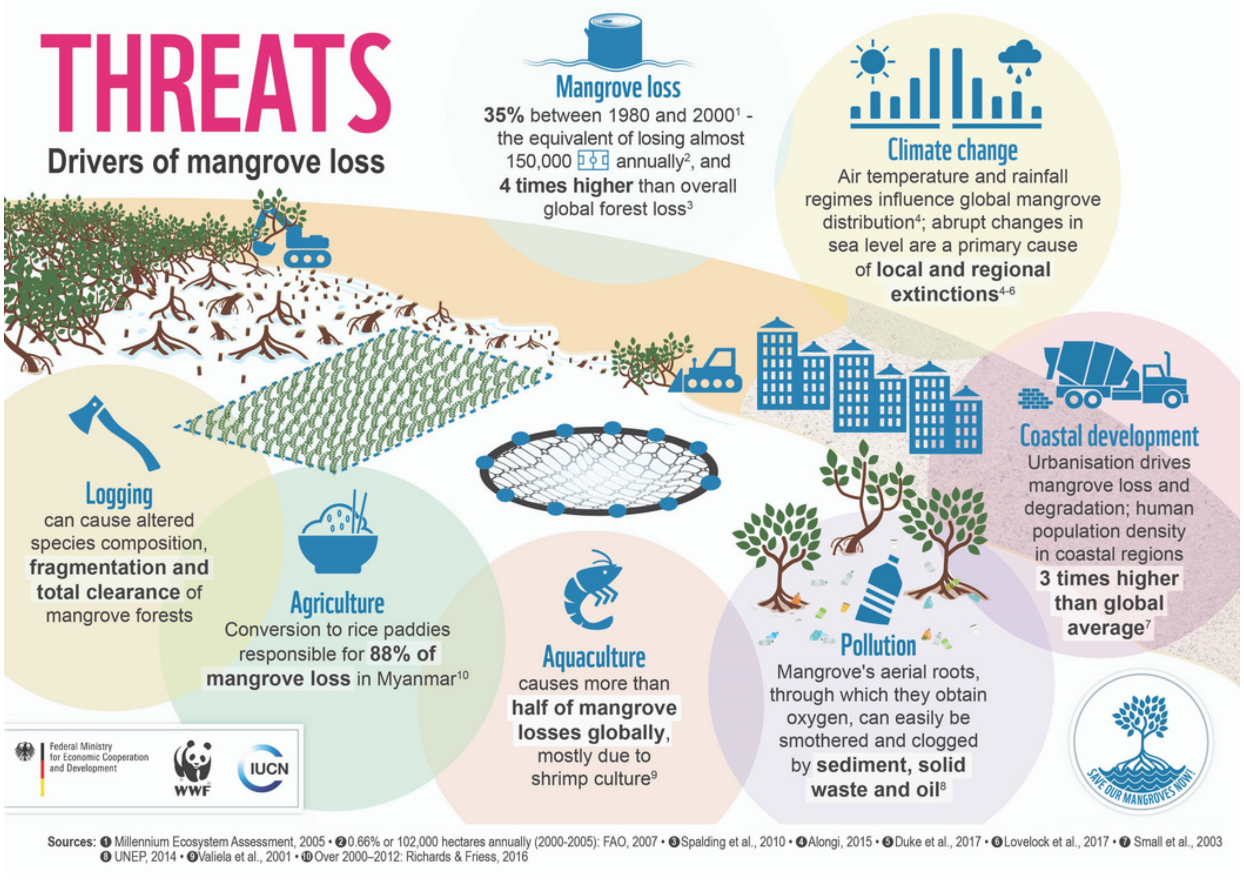


Figure 5: IUCN figure depicting the threats faced by Mangrove Wetland Ecosystems on a global level ("Mangroves and Coastal Ecosystems," n.d.).

Local Threats

From a local perspective, the mangrove wetlands in Antigua and Barbuda face many of the threats highlighted in the graphic above. While industries such as logging, agriculture and aquaculture are not a major issue locally, others such as pollution, coastal development and climate change are significant problems our mangrove wetlands face today. Further details on local threats to mangrove wetland ecosystems can be found below.

Pollution

Mangrove Wetlands are often referred to as "swamps" and regarded as dumping grounds for physical and chemical waste. Physical waste can stifle the ability of the roots to gain nutrients and oxygen, while physically disrupting the ecosystem (Picture 12). Chemical waste alters the dynamics of the ecosystem, changing the chemical environment and resulting in loss of function of the flora, leading to death of mangrove associated fauna.

Picture 12: Discarded anthropogenic and biological waste in a mangrove wetland site. © Ruleo Camacho/NPA

Backfilling and Coastal Development

Mangrove wetland ecosystems are often undervalued, leading to them being backfilled and removed to make space for developments (Picture 13). However, the ecosystem services lost when these ecosystems are destroyed can have far reaching effects on the wider environment (biodiversity, seagrass and coral reefs), as well as increased cost as it relates to coastal protection from extreme weather systems.

Picture 13: Mangrove Wetland being backfilled. © Ruleta Camacho-Thomas/NPA

Climate Change

The function of wetland ecosystems are affected by increasing temperatures and increased drought conditions, two direct outputs of climate change. These can lead to desiccation of the wetland (Picture 15), which encourages the proliferation of diseases, and reduction in the size of the wetland, impacting its ability to expand.

Picture 15: Red and white mangrove flora displaying symptoms of desiccation. © Britney Hay/EAG

Picture 14: Termite nest on red mangrove trunk. © Britney Hay/EAG

Termites and Diseases

Mangroves are susceptible to the effects of termites (Picture 14) and diseases, and the impacts of these are often exacerbated by anthropogenic activities. Pollution of the wetland encourages these negative effects and therefore impacts the function and survivability of the mangrove flora.

Compacting of the wetland through Vehicle-Related Activity

The terrestrial side of wetlands is often subject to off-road vehicles who are utilizing them for recreation (Picture 16). This compacts the wetland, by affecting the hydrology of the area, a process which is often extremely difficult to re-engineer. This results in a reduction of the function of the mangrove wetland ecosystem.

Picture 16: Wetland showing tire tracks. © Ruleo Camacho/NPA

Management

The National Parks Authority (NPA) is currently developing a programme aimed at improving the management of the sensitive and vital ecosystems within its boundaries, inclusive of mangrove wetlands. The programme hopes to accomplish this by establishing baselines to monitor and manage threats and designing management interventions to facilitate healthier ecosystems.

Mangrove Wetlands are protected in Antigua & Barbuda under the Environmental Management and Protection Act (2019). The National Biodiversity Strategic Action Plan (NBSAP 2014-2025) has set a goal in Target 5: By 2020, an effective monitoring protocol for critical habitats, including forest, mangroves and coral reefs has been implemented to assist in reducing degradation and fragmentation and measures developed and undertaken to reduce the rate of loss by 10%.

To date, the only mangrove wetland site in Antigua and Barbuda designated as Internationally Important by the Ramsar Convention is the Codrington Lagoon, home to the largest gathering of Magnificent Frigatebirds in the Western Hemisphere. Being a part of this convention recognized this wetland as critically important ecosystem, not only for the nesting frigate birds, but also the surrounding ecosystems and communities in Barbuda, Antigua and the wider Caribbean Region.

Picture 17: Crab Hole Mangrove Wetland. © Britney Hay/EAG

Data Collection

Methodology

Mangrove Surveys

This methodology allows the surveyor to determine the biodiversity, species richness and distribution of mangrove flora within each wetland ecosystem. The recovery potential of the wetland is also assessed using this methodology through the documentation of seedlings present within the survey area. Where necessary, multiple transects were run on a site to ensure a comprehensive assessment was conducted. A summary of the methodology can be seen below.

Each mangrove ecosystem was surveyed along a 100meter (m) maximum transect that extended from the water's edge of the wetland to the landward side. 25m^2 quadrants were then taken on alternating sides along the transect. Each quadrant was measured using a tape measure and marked using flagging tape before data collection began.

Data collection was done using Kobo Toolbox. The following information was recorded in each transect:

Biotic Measurements

- Floral Diversity
- Canopy Height (m)
- Diameter at Breast Height (DBH) [cm] (measured circumference at 1.3m height) (only for plants with a circumference equal or greater than 10cm at 1.3m)
- Number of seedlings along with species
- Ground percentage (%) cover (leaves, pneumatophores, prop roots)
- Faunal presence

Picture 18: Surveyors navigating through red mangrove prop roots to start a survey. © Ruleo Camacho/NPA

Abiotic Measurements

- Trash

The results of this survey were paired with Unmanned Aerial Vehicle (UAV) surveys conducted in 2019 in collaboration with the Department of Environment (Camacho, 2019), to produce maps for each area and estimate the size of the wetland.

Historical Analysis

Historical aerial images from 1941 and 1954, taken by the US Army Air Corps (1941) and US Navy (1954), and obtained from the Heritage Department of the NPA were used to a conduct a historical analysis of the change in mangrove coverage within the NDNP. Images were scanned and georeferenced into QGIS Software. An analysis was then conducted to determine the size of the mangrove wetlands that existed then.

Sites

Five major mangrove wetland sites within NDNP were identified and assessed during the NDNP Mangrove Wetland Surveys (Map 1). These sites represented the mangrove wetland ecosystems within the NDNP which exhibited ecosystem level mangrove wetland characteristics, and not just the presence of mangrove flora. An additionally mangrove wetland system, the Windward Bay Mangrove Wetland, was not assessed in this study from an ecological level, but included in spatial analysis.

Crab Hole Mangrove Wetland

This mangrove wetland is located south of the main road which runs between Falmouth and Cobbs Cross Village and is at the Northern end of Falmouth Harbour (Map 3). The defined mangrove wetland area is 68463m^2.

Marsh Village Mangrove Wetland

This wetland is located west of the road that between Cobbs Cross and English Harbour Village (Map 4). It is bordered by a man-made drain which has essentially fragmented the wetland. The defined mangrove wetland area is 11723m^2.

English Harbour Mangrove Wetland

This wetland is located at the northern end of English Harbour, south of the road that leads to Shirley Heights (Map 5). The defined mangrove wetland area is 59024m^2.

Doig Mangrove Wetland

This mangrove wetland is in the Rendezvous area, at the landward side of the Doig beach (Map 6). The defined mangrove wetland area is 8138m^2.

Indian Creek Mangrove Wetland

The Indian Creek mangrove wetland is located at the base of a watershed, to the eastern end of the NDNP boundary (Map 7). The defined mangrove wetland area is 59430m^2 .

Results

© Britney Hay/EAG

Data Analysis by Site

A total of ten (10) transects were recorded in the Nelson Dockyard National Park Mangrove Wetland assessment. These transects covered a total of 3150 m^2 of Mangrove wetlands.

- Crab Hole Mangrove Wetlands – two (2) transects
- Marsh Village Mangrove Wetlands – one (1) transect
- English Harbour Mangrove Wetlands – two (2) transects
- Doig Mangrove Wetland – two (2) transects
- Indian Creek Mangrove Wetlands – three (3) transects.

Crab Hole Mangrove Wetlands

Map 3: Crab Hole Mangrove Wetland Site illustrating survey areas.

Crab Hole A

A total of eighteen (18) quadrants were made from the coastline inward, covering 450m^2 (90m long transect) of mangrove wetland.

Mangrove Diversity

The first 45m (9 quadrants) of the transect were dominated by red mangrove plants, with quadrant height averages ranging between 6.0m and 7.6m, while DBH was from 5.3cm to 7.8cm. In quadrant ten (#10), black mangroves were observed along with the reds, and the black mangroves dominated the remainder of the quadrants. The average quadrant height of the black mangrove plants ranged from 1.8m to 7.6m with DBH ranging between 3.1cm and 12.7cm. In several quadrants (#13, 17 & 18), neither black nor red mangrove plants were observed, and the quadrants were dominated by open "swamp-like" conditions (Figure 6: A and B). Tree density varied throughout the transect, with the number of plants in the initial quadrants being less than the following quadrants. Black mangrove plants had a lower number of plants per quadrant than the red mangrove plants. In areas where taller plants dominated the quadrant, the density of plants was lower than in quadrants dominated by smaller plants (Figure 6: C).

Seedlings

There were no seedlings in the first quadrant from the coastline, followed by only red mangrove seedlings for the next 40m inwards (Quadrant #2-9). Quadrant ten (#10) (45m inland) had red, black and white seedlings, with reds being the most numerous (30 seedlings) and white the least (10 seedlings). Quadrant #11 contained black and red seedlings only, with a higher number of black mangrove seedlings. The remaining 35m (Quadrants #12-18) of the transect had no red seedlings. Quadrant #12 contained black seedlings only, before there was an absence of seedlings entirely for the next 10 meters. The last 20m of the transect primarily had black seedlings, with five (5) white seedlings present only in the very last quadrant [#18] (Figure 6: D).

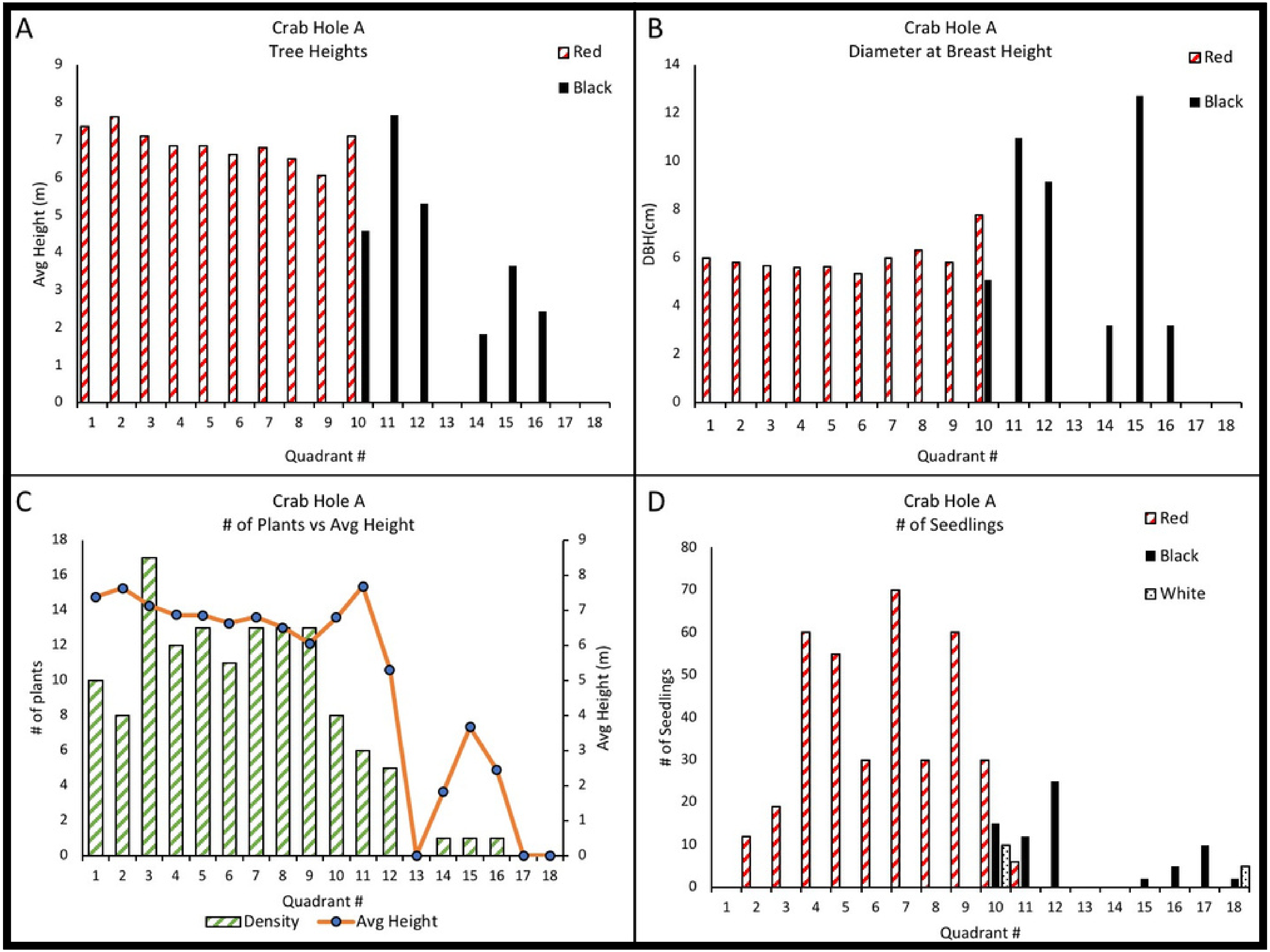


Figure 6: Crab Hole Mangrove Transect A graph displaying: A-Average height and species distribution across transects, B- DBH of trees across transects, C-Density of plants vs average height of plants, D- Density of seedlings across transects.

Leaf litter, Prop Root coverage and Pneumatophores

Leaf litter was minimal throughout the transect, with no observations recorded. Prop root coverage remained at 76-100% for the first 45m (Quadrants #1-9), before dropping off for the remaining 40m, where no prop roots were observed. Pneumatophores were not observed until the 50m mark (Quadrant #10), with the remainder of the transect displaying varying amounts which peaked in quadrants #11 and #12 (55-60m from the coastline) at 76-100% coverage.

Animals

Crab holes were observed within most of the quadrants along the transect. Different bird species were heard throughout the survey but were not directly observed.

Garbage

Minimal garbage was observed along the transect, namely: plastic deposits, glass bottles and fiberglass pieces.

Crab Hole B

At this site, 11 quadrants were assessed from the landward side of the mangrove, covering a total of 275m^2 (55m long transect) of mangrove wetland.

Mangrove Diversity

White mangrove plants were found within the first 10m of the transect (quadrants #1 and #2) only, with an average quadrant height of 6.7m and 6.0m, and DBH of 12.5cm and 5.4 cm respectively. Black mangroves were observed in quadrant one (#1) and not again until quadrant five (#5) (25m along the transect). Quadrants #5-9 exclusively contained black mangroves. No black mangrove plants were observed in quadrant ten (#10) (50m along the transect) but made a reappearance in quadrant #11. The average height per quadrant of these black mangrove plants ranged between 2.3m and 6.7m, whereas the DBH ranged between 6.9cm and 10cm. Red mangrove plants were not seen until the final quadrant (#11), with an average quadrant height and DBH of 4.6m and 5.5cm respectively (Figure 7: A and B). Tree density varied along the transect with the number of plants in the first and last quadrant being higher than those quadrants in between. Tree density seemed to be directly proportional to average tree height in each quadrant (except for quadrant #2), where the denser the trees in the quadrant, the higher the average height of the plants (Figure 7: C).

Seedlings

Black seedlings were found in all quadrants along the transect, except for quadrant four (#4) in which no seedlings were counted. The highest number of black seedlings were counted in quadrant #2 at 60 seedlings. White seedlings were counted in the first two quadrants and the last with a maximum number of 40 in the first quadrant of the transect. Red mangrove seedlings were found near the end of the transect in quadrants #8, 10 and 11, the highest count being in the last quadrant, with a total of 75 seedlings (Figure 7: D).

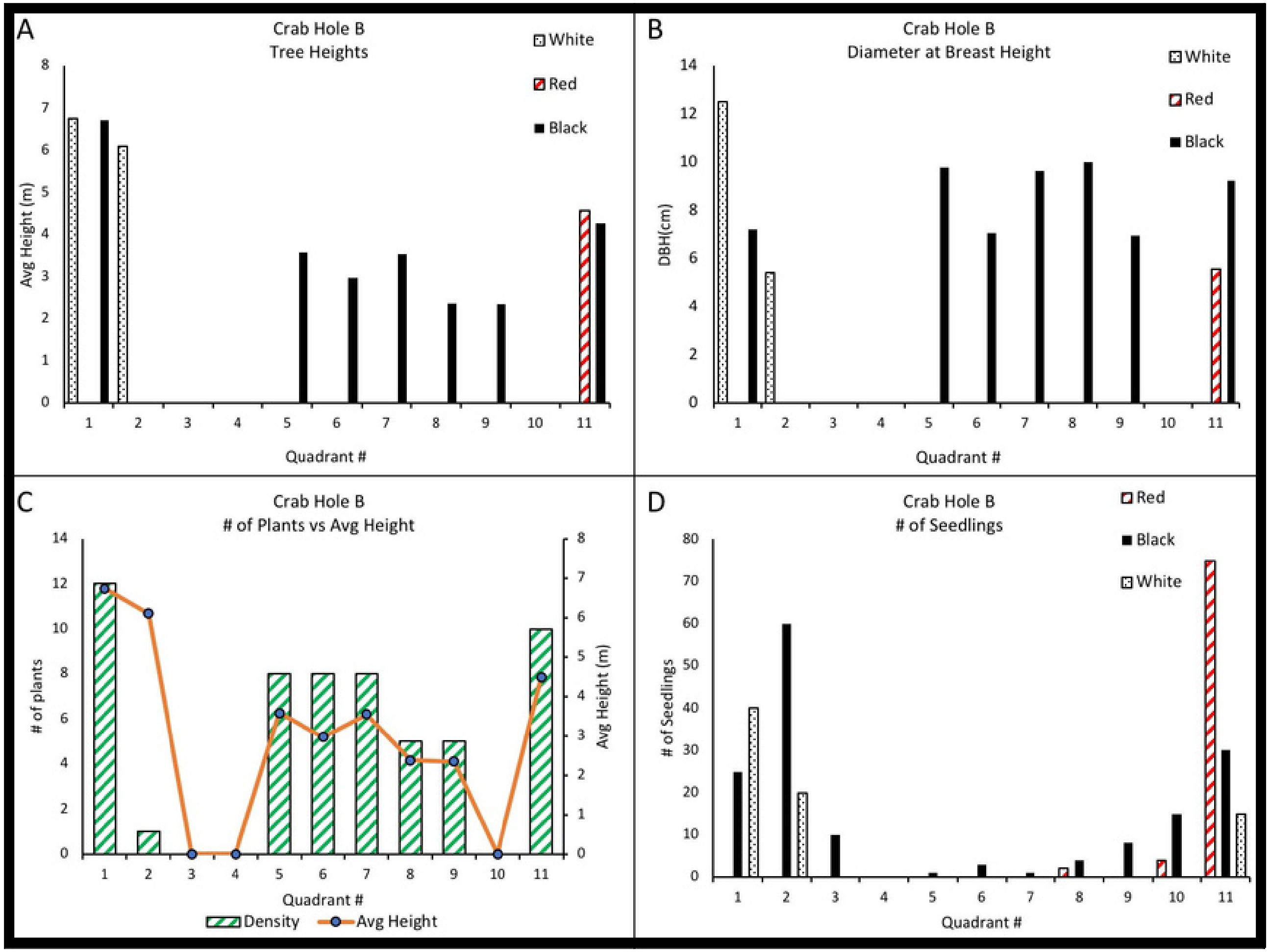


Figure 7: Crab Hole Mangrove Transect B graph displaying: A-Average height and species distribution across transects, B- DBH of trees across transects, C-Density of plants vs average height of plants, D- Density of seedlings across transects.

Leaf Litter, Prop Root coverage and Pneumatophores

Leaf litter was relatively low overall along the transect, the highest percent coverage being 25-50% in the first two quadrants. Quadrants #4-9 and #11 had 1-25% coverage, and there was no observable leaf litter in quadrants #3 and #10. No prop roots were observed in quadrants #1-9, however quadrant #10 showed relatively low coverage (25-50%). Pneumatophore coverage varied along the transect, showing an increase in the first 4 quadrants before remaining steady at 76-100% coverage until quadrant #10, where coverage drops to 26-50% and remains the same in quadrant #11.

Animals

The animals seen along the transect were fiddler crabs and snails (Picture 19).

Garbage

Along the transect an assortment of cans and glass and plastic bottles and/or pieces of plastic were observed.

Picture 19: Snails seen among the mangrove flora
© Ruleo Camacho/NPA

Marsh Village Mangrove Wetlands

Fourteen (14) quadrants were completed along a 70m transect, covering 350m^2 of mangrove wetland. Beyond those 70m, there was a man-made drain which has essentially fragmented the wetland.

Map 4: Marsh Village Mangrove Wetland Site highlighting survey area

Mangrove Diversity

The first 55m (quadrants #1-11) of the transect were dominated by red mangroves, whose average quadrant height ranged between 6.7m and 8.6m and average DBH between 5.8cm and 9.1cm. The remaining 15m of the transect (quadrants #12-14) were dominated by black mangroves whose average quadrant height ranged between 0.3m and 1.6m and DBH between 4.4cm and 9.8cm (Figure 8: A and B). The density of the plants varied along the transect, significantly increasing between quadrants 1 and 2 before steadily falling between quadrants #3-5. An overall decrease in density was evident for the remaining quadrants #6-14. The average height of these trees fluctuates along the transect but undergoes an overall decreasing trend between quadrants #1-14 (Figure 8: C)

Seedlings

After the first quadrant of the transect, in which no mangrove seedlings were counted, quadrants #2-10 were dominated by red mangrove seedlings. The number of red seedlings remained relatively steady between quadrants #2-7 and gradually increased between quadrants #8-10. The highest red seedling count was in quadrant #11 (50 seedlings) which also contained the first white seedlings seen along the transect. In Quadrants #12 and #13, black and white mangrove seedlings were observed, the number of black seedlings significantly increasing between the two quadrants from 25 to 100. The final quadrant (#14) had black, white and red seedlings with the count for black being the highest (100 seedlings) and red being the lowest (5 seedlings) [Figure 8: D].

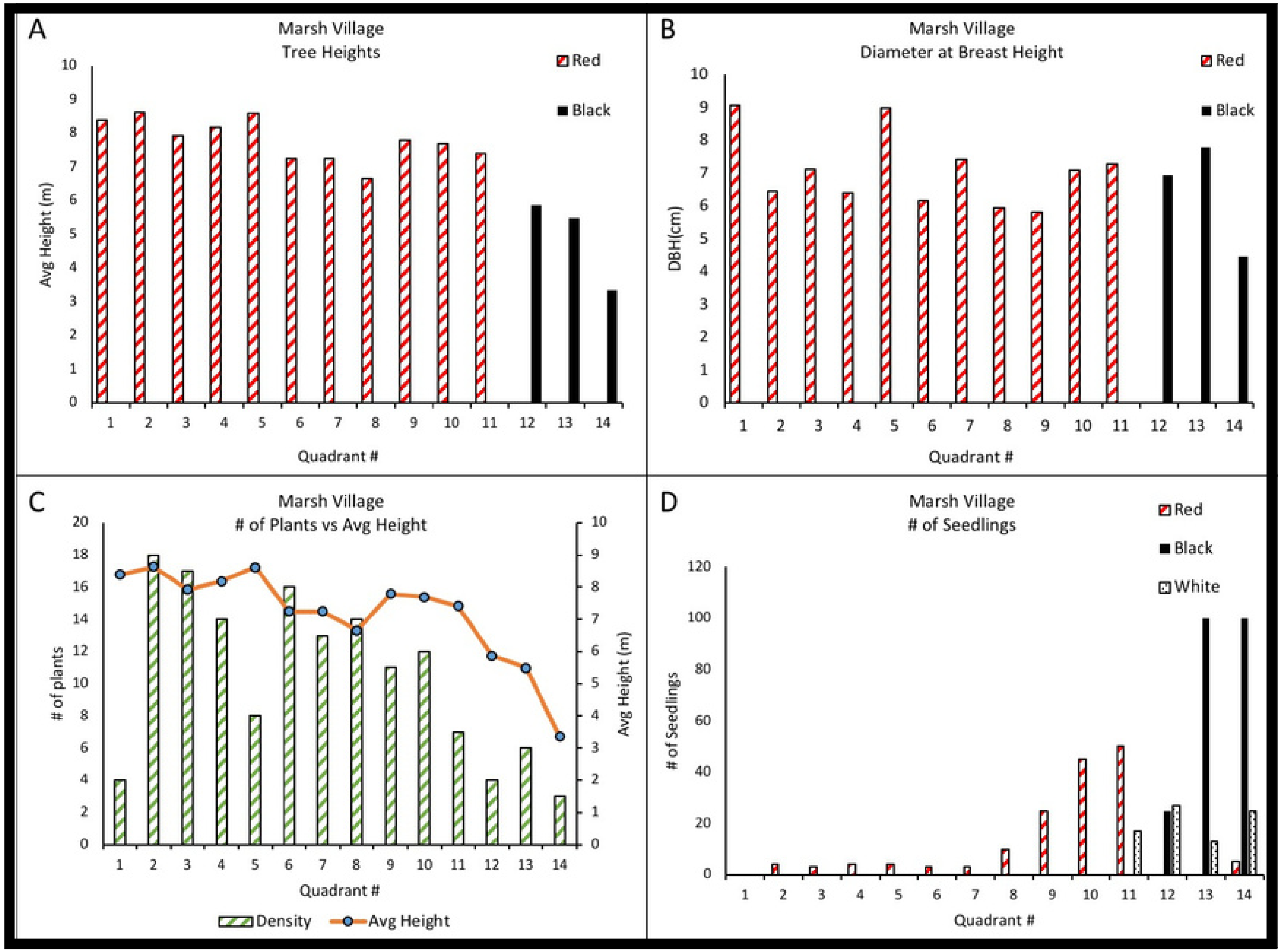


Figure 8: Marsh Village graph displaying: A-Average height and species distribution across transects, B- DBH of trees across transects, C-Density of plants vs average height of plants, D- Density of seedlings across transects.

Leaf Litter, Prop Root coverage and Pneumatophores

Leaf litter remained at 0-25% coverage for the length of transect. For the first 55m, there was 0-25% pneumatophore coverage. Prop root coverage remained high at 76-100% for the first 45m of the transect (quadrants #1-9) before dropping slightly in quadrants #10 and #11 to 51-75% and dropping further in quadrants #12-14 to 0-25%. No pneumatophores were counted for the first 50m of the transect (quadrants #1-10). Quadrants #11-13 showed a slight increase in coverage (1-25%) before dropping off again in the last quadrant (#14).

Animals

In each quadrant along the transect, fiddler crabs were observed along with spiders and even hummingbirds. Among the prop roots, fish were observed.

Garbage

Trash was observed included glass and plastic bottles, Styrofoam, animal carcasses fuel (residue seen among pneumatophores but not measured), buckets and footballs were seen.

Picture 20: Surveyor traversing through Red Mangrove prop roots. © Britney Hay/EAG

English Harbour Mangrove Wetlands

Map 5: English Harbour Mangrove Wetland Site highlighting survey areas

English Harbour A

The transect along which data was collected for English Harbour A was a total of 85m (425m^2 of mangrove wetland), made up of 17 quadrants.

Mangrove Diversity

Red mangroves were found along the first 55m of the transect (quadrants #1-11), their average quadrant height ranging between 5.3m and 10.0m and DBH between 7.1cm and 11.0cm. While red mangroves primarily dominated quadrants #1-10, quadrant #11 contained both black and red mangroves. The following 15m of the transect (quadrants #12-14) were primarily dominated by black mangroves, their average quadrants heights ranging between 1.8m and 4.2m (DBH between 3.1cm and 9.8cm). In quadrants #15, #16 and #17, no mangrove plants were observed. Instead, black mangrove shrubs were observed in an area with water spaces (Figure 9: A and B). The tree density along the transect varied with the number of plants dropping significantly between quadrants #1 and #2 before rising between quadrants #2 and #3 and remaining steady for the following 3 quadrants (#4-6). The maximum number of plants is reached in quadrant #7 at 19 plants before a decreasing trend in plant number is seen between quadrants #8-15. No plants were counted in quadrants #15-17. The average height of these plants showed an irregular decrease along the course of the transect (Figure 9: C).

Seedlings

The first 6 quadrants along the transect had no observable seedlings, apart from quadrant #2 which contained only red seedlings. Quadrants #7-10 were primarily dominated by red seedlings, whose number increased along the transect until reaching a peak in quadrant #10 at 60 seedlings. Quadrant #10 also contained black seedlings. The remaining 35m of the transect (quadrants #11-17) were dominated by black mangrove seedlings, except for quadrant #15 which had no seedlings. Quadrants #10-13 showed an increase in the number of seedlings (the peak count of quadrant #13 being 110 seedlings) before dropping to 8 seedlings in quadrant #14 and rising between quadrants #16 and #17 (Figure 9: D)

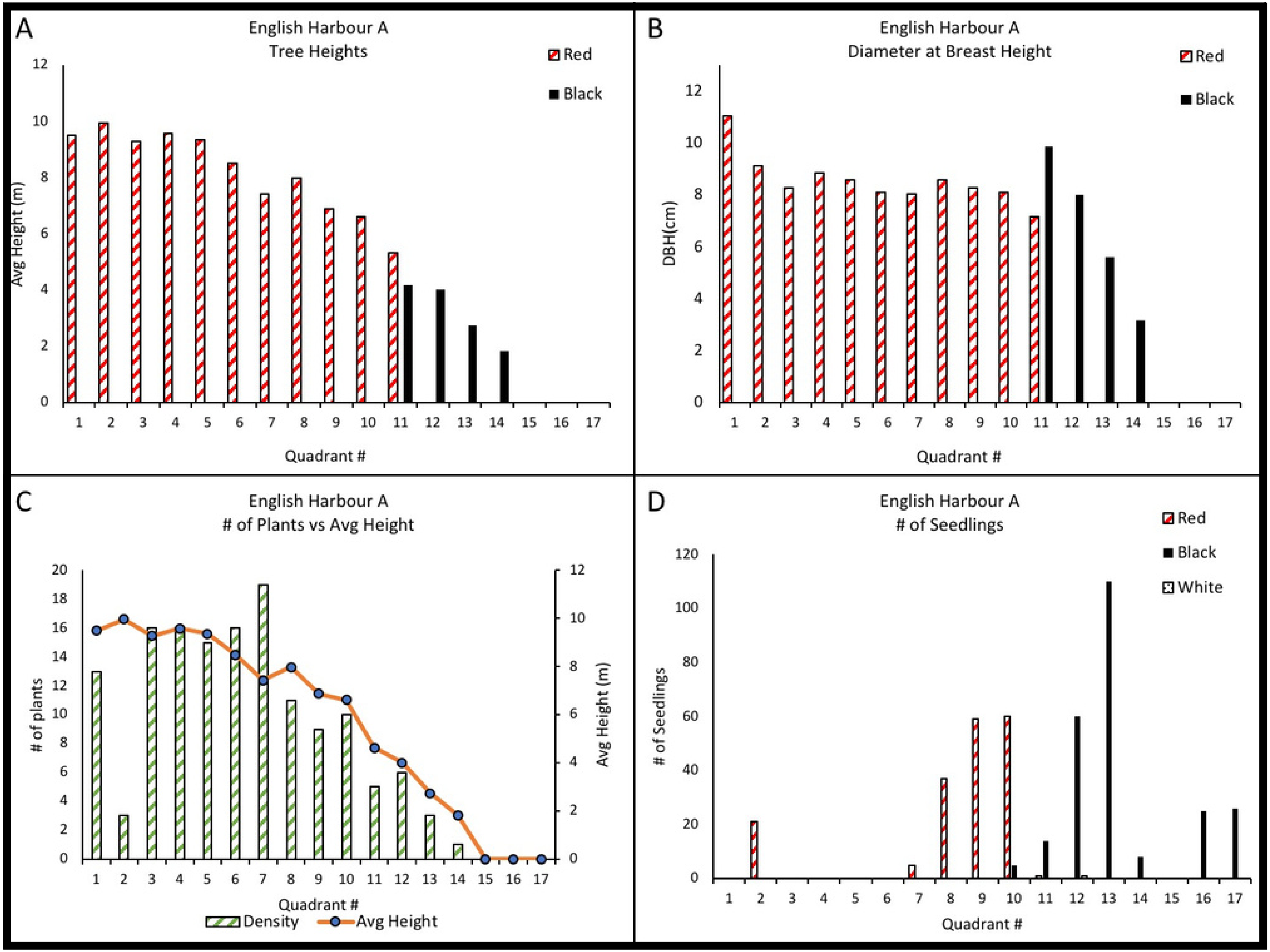


Figure 9: English Harbour A graph displaying: A-Average height and species distribution across transects, B- DBH of trees across transects, C-Density of plants vs average height of plants, D- Density of seedlings across transects.

Leaf Litter, Prop Root coverage and Pneumatophores

Leaf litter coverage remained consistent at 1-25% coverage for the first 65m of the transect (quadrants #1-13) before dropping for the next four (4) quadrants. The remaining inland quadrants had no leaf litter recorded. The first quadrant (#1) along the transect had no observable prop roots, however coverage increased to 76-100% in the second quadrant (#2) and stayed at this level for the next 30m (Quadrants #3-8). Prop root coverage dropped in quadrants #9 and #10 to 51-75%, and again in quadrant #11 to 1-25%. The remaining 30m of the transect (quadrants #12-17) had no observable prop roots. No pneumatophores were observed for the first 45m along the transect (Quadrants #1-9). Coverage increased slightly in Quadrant #10 to 1-25% before significantly increasing for the next three (3) quadrants to 76-100% coverage. The remaining 20m of the transect (quadrants #14-17) showed a decrease in pneumatophore coverage to 51-75%, except for quadrant #14 which had 26-50% coverage.

Animals

All quadrants along this transect contained crabs and sand-flies, with the occasional observation of snails.

Garbage

The few pieces of garbage identified along the transect were mainly glass and plastic bottles and cans. A buoy and fridge were also seen along the transect.

English Harbour B

English Harbour B was a transect of length 100m (500m^2 of mangrove wetland), made up of 20 quadrants total.

Mangrove Diversity

Black mangroves were the only plant species observed along this transect. The black mangrove plants had an average quadrant height ranging between 1.7m and 10.0m (average quadrant DBH ranged between 9.0cm to 22.9cm). Quadrants #1, #5, #9 and #14-20 contained no mangrove plants (Figure 10: A and B). The density of plants varied by quadrant, as did the average height of these plants (Figure 10: C).

Seedlings

Black seedlings were found in all the quadrants formed along this transect apart from quadrant #20. Quadrants #1 and #4 contained the highest number of black seedlings with a count of 100, whereas quadrant #19 had the lowest count at one (1) seedling. White mangrove seedlings were counted in quadrants #9 (one seedling) and quadrants #13-16, where the maximum number (in quadrant #13) was 13 white seedlings (Figure 10: D).Black seedlings were found in all the quadrants formed along this transect apart from quadrant #20. Quadrants #1 and #4 contained the highest number of black seedlings with a count of 100, whereas quadrant #19 had the lowest count at one (1) seedling. White mangrove seedlings were counted in quadrants #9 (one seedling) and quadrants #13-16, where the maximum number (in quadrant #13) was 13 white seedlings (Figure 10: D).

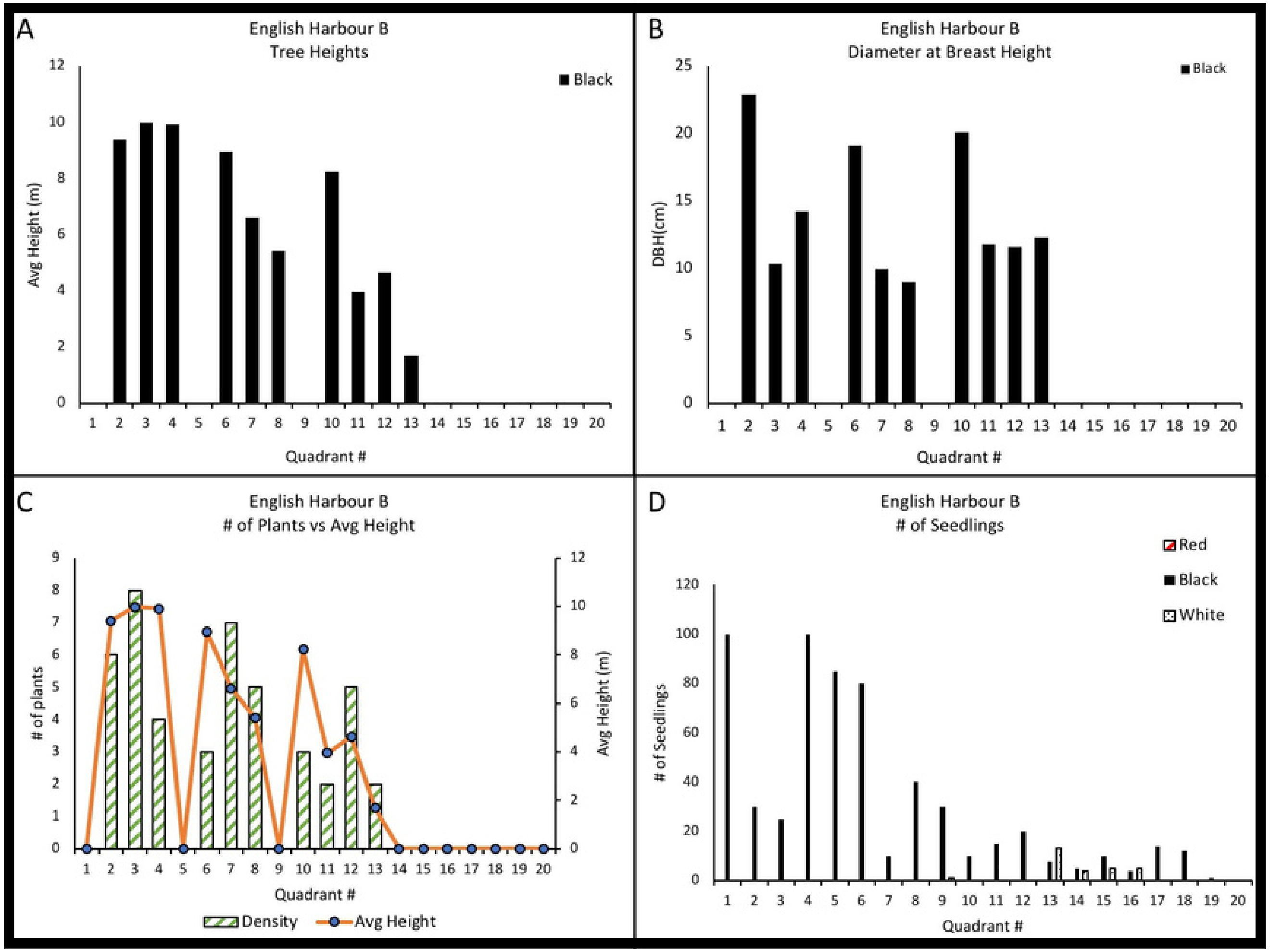


Figure 10: English Harbour B graph displaying: A-Average height and species distribution across transects, B-DBH of trees across transects, C-Density of plants vs average height of plants, D- Density of seedlings across transects.

Picture 21: Surveyors pausing to collect data as they move through mangrove wetland ecosystem © Britney Hay/EAG

Leaf Litter, Prop Root coverage and Pneumatophores

Leaf litter coverage fluctuated between quadrants #1-12, peaking in quadrants #3, #4 and #6 at 76-100% coverage. The remaining quadrants (#13-20) had very minimal leaf litter coverage. No prop roots were observed along this transect. Pneumatophore coverage fluctuated over the first 11 quadrants between 51-75% and 26-50% coverage (except for quadrants #2 and #9, which were 76-100% and 1-25% covered respectively). The remainder of the transect (quadrants 12-20) showed very minimal pneumatophore coverage, fluctuating between 1-25% and no observable coverage.

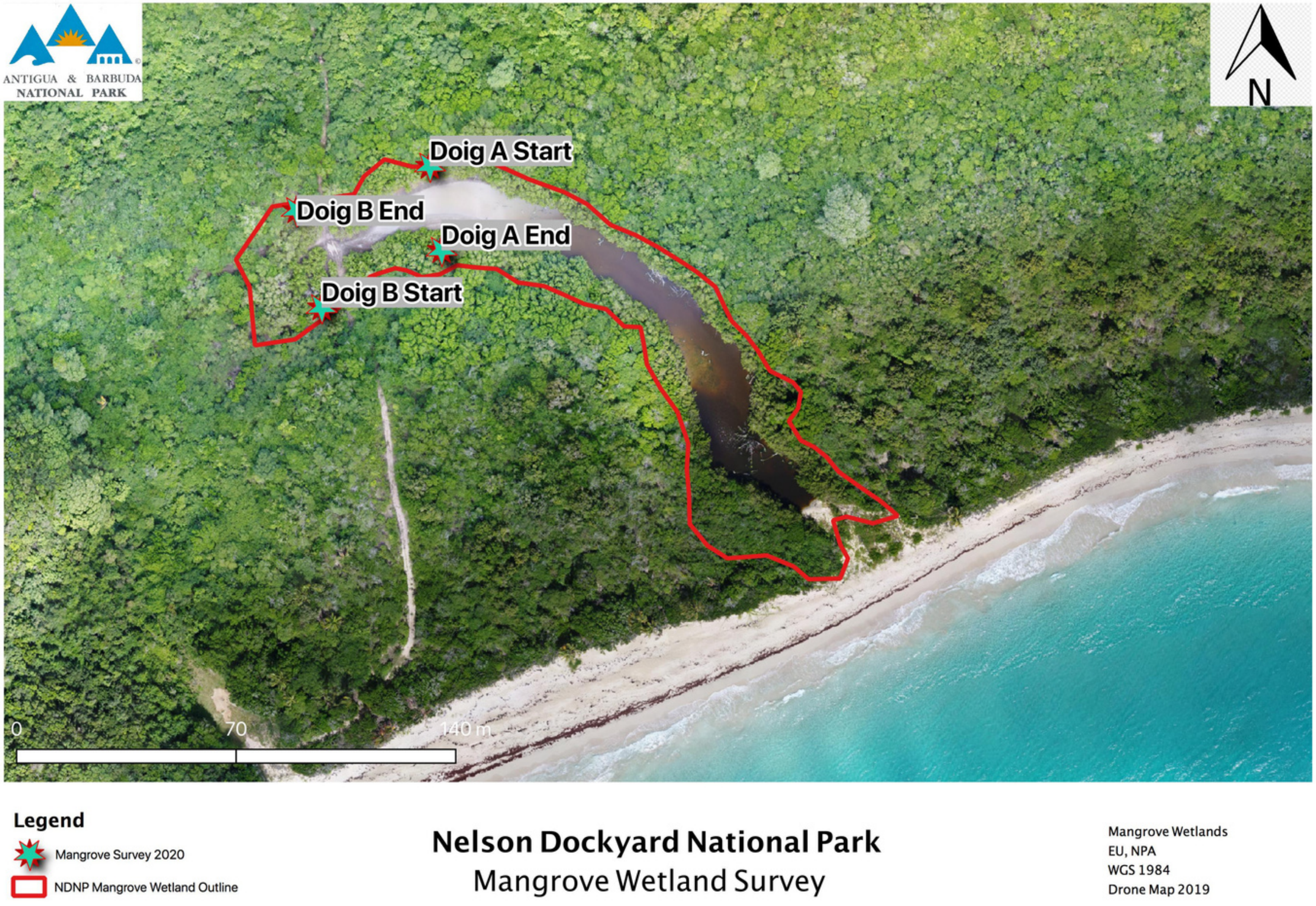
Animals

Crab Holes were observed in most of the quadrants. On some of the larger black mangrove plants, occasional termites and green lizards were observed.

Garbage

Plastic and glass bottles, aluminium cans and styrofoam were the most commonly observed pieces of garbage along the transect.

Doig Mangrove Wetlands



Map 6: Doig Mangrove Wetland Site highlighting survey areas.

Doig A

This transect covered 150m^2 of mangrove wetland (transect length 30m) consisting of 6 quadrants. The quadrant began on the land side of the wetland basin (Map 6).

Mangrove Diversity

No red mangrove plants were seen along the transect at this site. Black mangrove plants were observed in quadrants #1, #5 and #6 with an average quadrant height ranging between 3.9m and 4.5m and a DBH between 6.5cm and 7.0cm. White mangrove plants were seen in quadrants #1 and #6 with an average quadrant height ranging from 2.1m to 6.6m (DBH ranged between 3.8cm and 5.6cm). Quadrants #2-4 contained no mangrove plants as they were part of the wetland basin (Figure 11: A and B, Picture 20). The density of plants between quadrants #1, #5 and #6 varied, with quadrant #5 having the lowest number of plants and quadrant #1 the highest. Quadrant #1 plants had the shortest average height, whereas quadrant #6 had the tallest trees on average along the transect (Figure 11: C).

Seedlings

Black mangrove seedlings were found in quadrants #1, #4 and #5 with quadrants #1 and #5 having the same count of 100 seedlings. White seedlings were only found in quadrant #2 with a count of two (2) seedlings (Figure 11: D).

Picture 22: Doig open basin illustrating surveyor transiting across. © Britney Hay/EAG

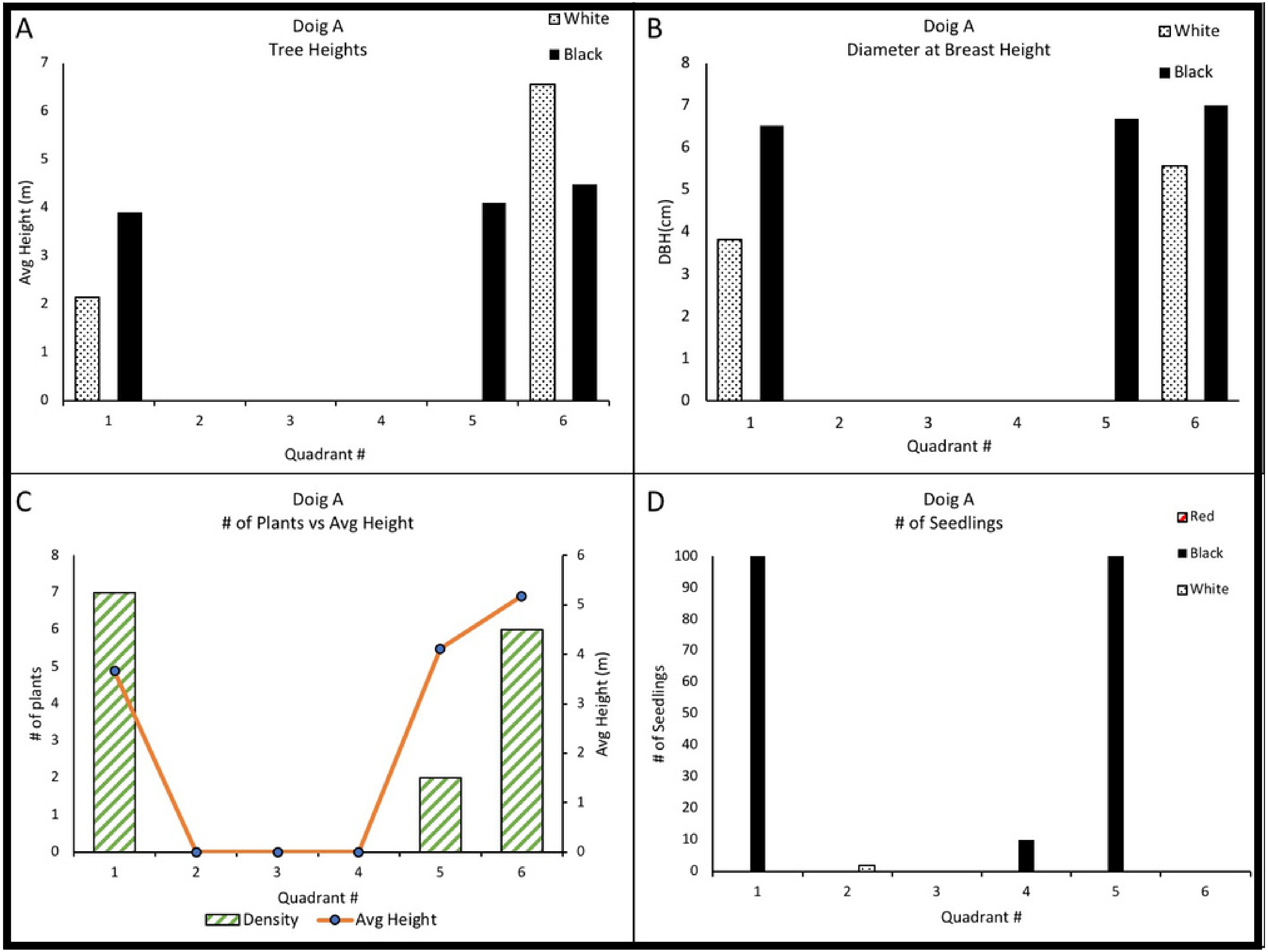


Figure 11: Doig A graph displaying: A-Average height and species distribution across transects, B- DBH of trees across transects, C-Density of plants vs average height of plants, D- Density of seedlings across transects.

Leaf Litter, Prop Root coverage and Pneumatophores

Leaf litter coverage in the first quadrant along the transect was high at 76-100% coverage, before dropping over the next three quadrants (#2-4) to a minimal level. The remaining two quadrants (#5 and #6) had high leaf litter coverage once again, at 76-100%. There were no prop roots observed along this transect. Pneumatophore coverage began at a moderate level (51-75% coverage) before dropping for the next 3 quadrants (#2-4) to a minimal level. The last 2 quadrants of the transects had high (76-100%) pneumatophore coverage.

Animals

Animals observed along the transect were mainly crabs, mosquitos, sand-flies and red ants.

Garbage

No garbage was observed along this transect.

Doig B

The second transect was taken to get a representation of an aspect of the mangrove wetland without a basin. 150m^2 of mangrove wetland were surveyed (30m long transect).

Mangrove Diversity

Red mangrove plants were absent along the transect at this wetland site. Black mangroves were observed in the first four (4) quadrants, with an average quadrant height ranging between 4.2m and 8.0m and a DBH ranging between 4.6cm and 13.0cm. There were no black mangroves observed for the remainder of the transect (quadrants #5 and #6). White mangrove plants were observed in quadrants #4-6, with an average quadrant height ranging between 3.7m and 5.0m (DBH ranging between 3.1cm and 4.6cm) [Figure 12: A and B]. The number of plants in quadrants #1 and #2 remained the same (although the average height of the plants dropped by four meters between the quadrants). Quadrant #3 showed a drop in the number plants but a slight increase in their average height. The remaining quadrants of the transect (quadrants #4-6) showed a fluctuation in plant density as quadrant #4 increased in plant number, followed by a decrease in quadrant #5 and another spike in quadrant #6. Between quadrants #3 and #4 the average height of the plants dropped, followed by a gradual increase from quadrants #4 to #5 and quadrants #5 to #6 (Figure 12: C). The first four (4) quadrants held notable amounts of dead mangrove plant debris, and quadrants #5 and #6 contained very few mangrove plants but a lot of other terrestrial plant species were present (i.e. there was mixed vegetation in these quadrants).

Seedlings

The first quadrant along the transect had both black and white mangrove seedlings, black being the most numerous with a count of 10 (and white a count of one [1]). In the next three (3) quadrants (quadrants #2, #3 and #4), only black mangrove seedlings were observed with an increasing count of 5, 15 and 60 respectfully. The last quadrants taken along the transect (quadrants #5 and #6) contained white mangrove seedlings, with a count of 8 and 6 seedlings respectively (Figure 12: D).

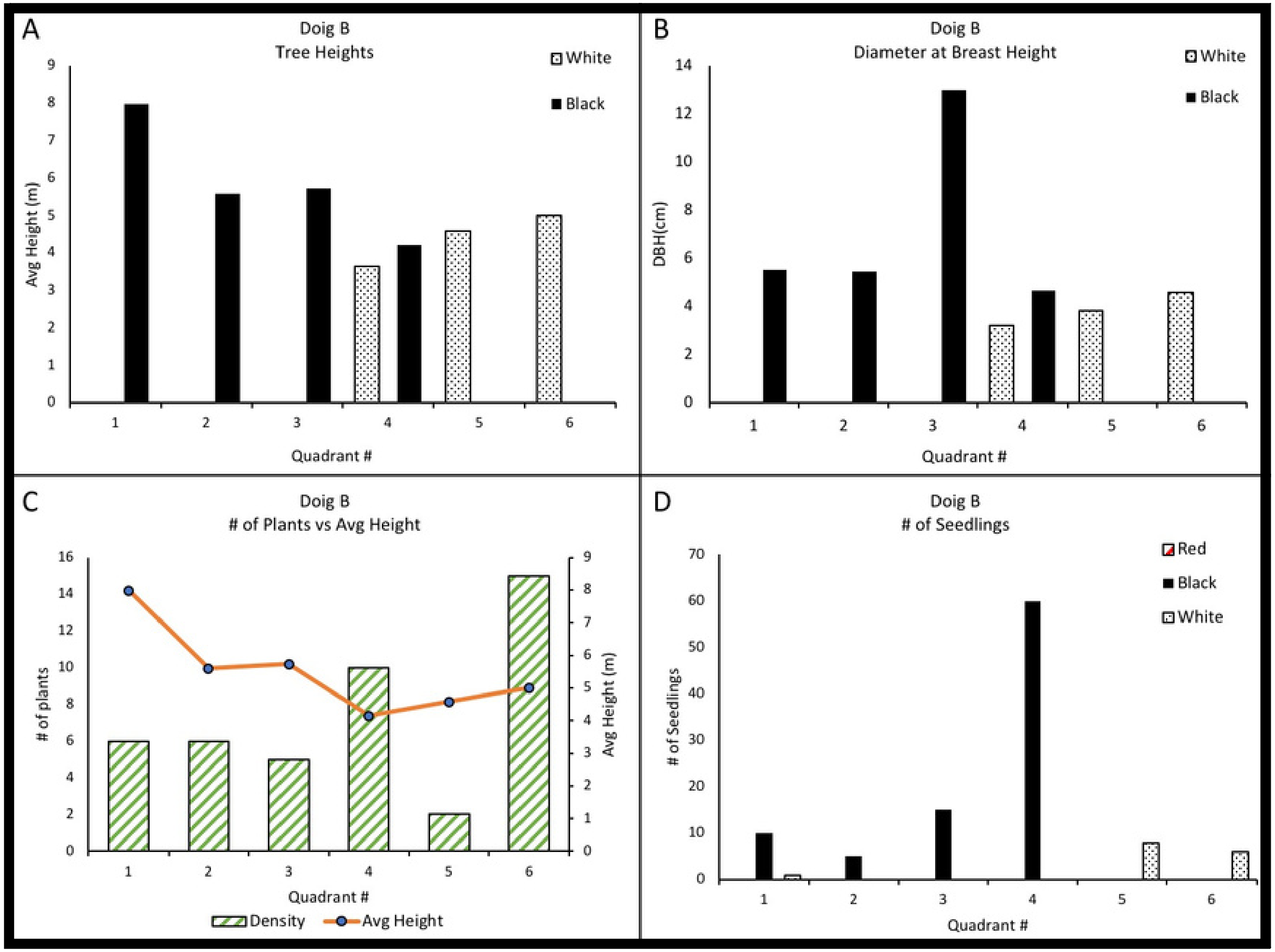


Figure 12: Doig B graph displaying: A-Average height and species distribution across transects, B- DBH of trees across transects, C-Density of plants vs average height of plants, D- Density of seedlings across transects.

Leaf Litter, Prop Root coverage and Pneumatophores

Leaf litter coverage remained high throughout the length of the transect at 76-100% coverage, and no prop roots were observed along the transect. Pneumatophore coverage increased along the first three quadrants from 26-50% coverage to 76-100% coverage. Coverage remained high in quadrant #4 until dropping for the remainder of the transect (quadrants #5 and #6) to a minimal level.

Animals

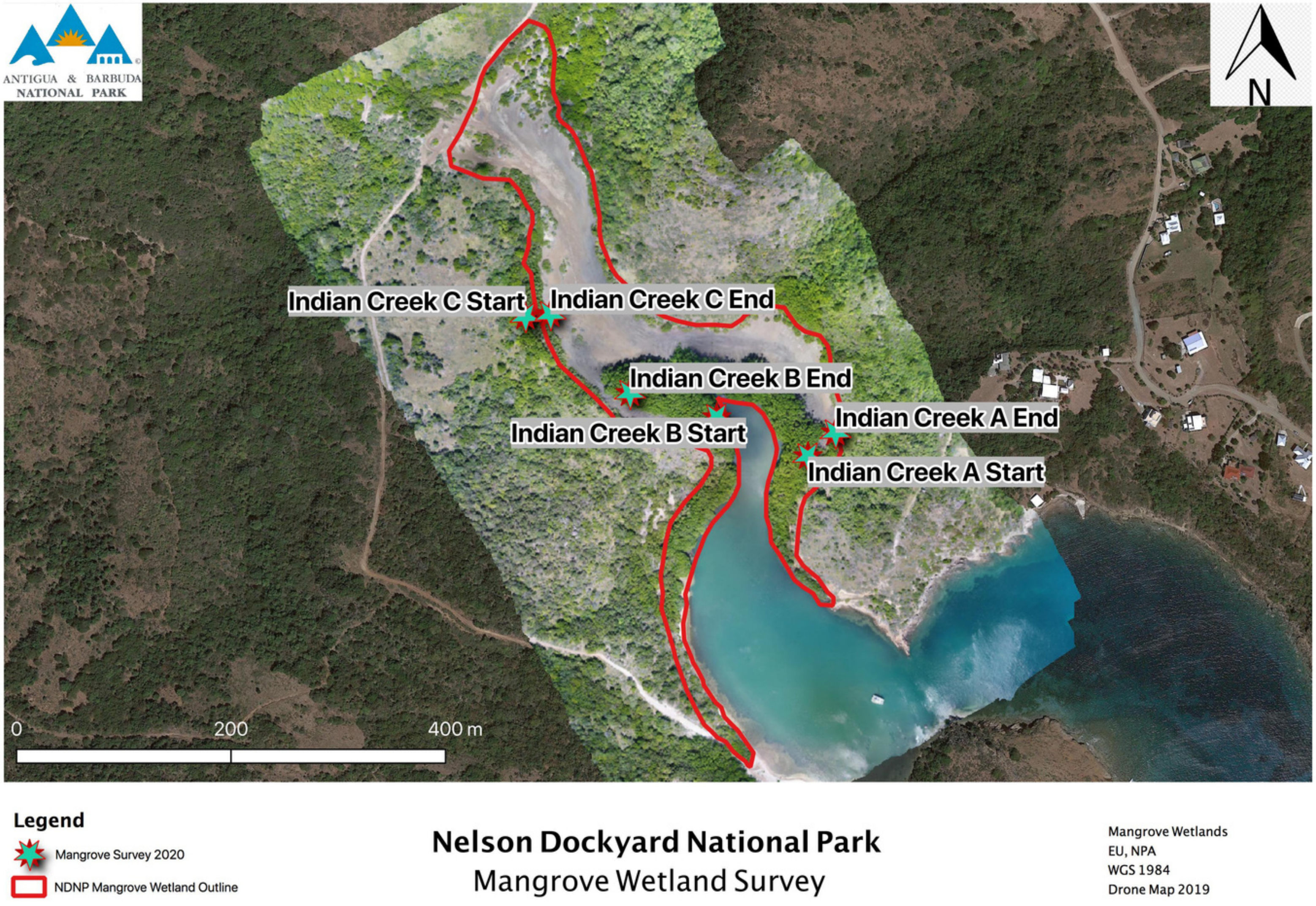
Animals observed along the transect were mainly crabs and mosquitos.

Garbage

No garbage was observed along this transect.

Picture 23: View of Doig beach. © Britney Hay/EAG

Indian Creek Mangrove Wetlands



Map 7: Indian Creek Mangrove Wetland Site highlighting survey areas.

Indian Creek A

This transect covered a total of 200m^2 (40m long transect) of mangrove wetland and consisted of 8 quadrants total. It began on the water-facing side of the wetland, where the trees were all angling out towards the sea (Map 7).

Mangrove Diversity

No black or white mangroves were observed along this transect. Red mangroves were recorded within the first 6 quadrants, with an average quadrant height ranging between 6.7m and 12.1m, and DBH values ranging between 7.1cm and 12.1cm. No mangrove plants were observed in quadrants 7 and 8 (Figure 13: A and B). The first three (3) quadrants showed a change in the number of plants consistent with the average height of these plants. The plant density increased between quadrants #1 and #2 along with the average height, and as the density dropped between quadrants #2 and #3, so did the average height. Quadrants #3 and #4, however, had the same number of plants but a slight drop in the average height of these plants. Quadrant #5 showed a drop in the number of plants (and a drop in the average height of plants) before an increase in plant density was observed in quadrant #6, with only a very slight increase in average plant height (Figure 13: C). There were a lot of dead mangrove plants in quadrants #2 and #3, which increased in quadrant #4 and remained at the same level in quadrants #5 and #6. Quadrant #7 showed a drop in the number of dead mangrove trees as the transect moved into an open mud area.

Seedlings

In the first three quadrants, no seedlings were observed. Red seedlings were counted in all the remaining quadrants (#4-8), with the highest count being 25 in quadrant #7. White seedlings were counted in quadrants #7 and #8, each quadrant having a count of 8 and 16 seedlings respectively (Figure 13: D).

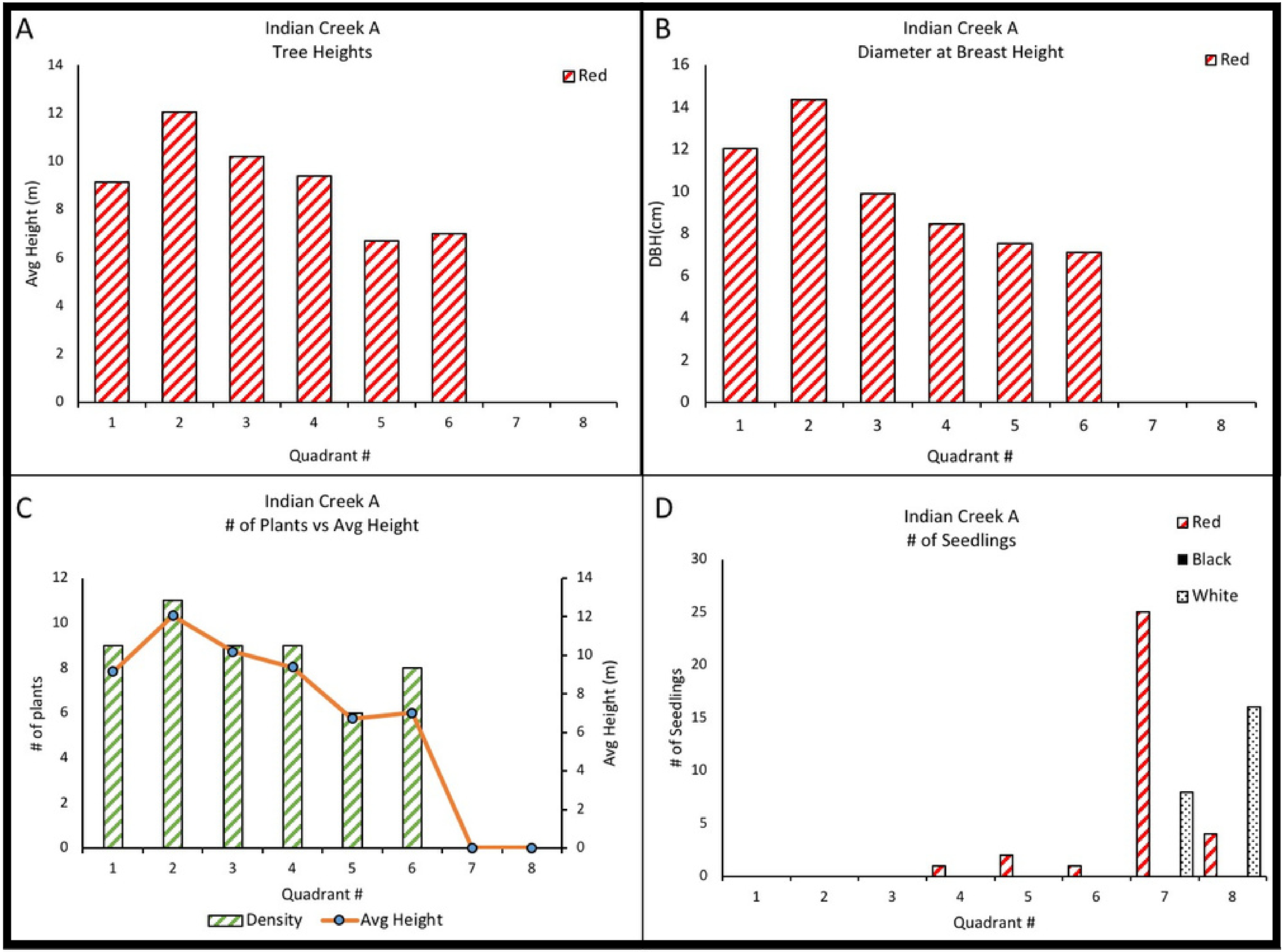


Figure 13: Indian Creek A graph displaying: A-Average height and species distribution across transects, B- DBH of trees across transects, C-Density of plants vs average height of plants, D- Density of seedlings across transects.

Leaf Litter, Prop Root coverage and Pneumatophores

There was no notable leaf litter coverage in the first quadrant along the transect, however the remaining quadrants maintained a consistently low level of coverage at 1-25%. Prop root coverage remained high at 76-100% for the first six (6) quadrants, before dramatically dropping in quadrant #7 to 1-25% coverage and remaining very low in quadrants #8 and #9. No pneumatophores were observed along the length of this transect.

Animals

Some animals observed along the transect include fiddler crabs, snails, mosquitoes, lizards and the occasional hummingbird.

Garbage

No garbage was observed along this transect.

Indian Creek B

This transect covered a total of 95m (475m^2 of mangrove wetland), consisting of 19 quadrants. The quadrant began closest to the water's edge, where the mangrove trees were leaning towards the water. At the end point of the transect, red mangroves continued for the next 35m.

Mangrove Diversity

No white or black mangroves were recorded along the length of the transect. Red mangrove plants were observed in all 19 quadrants, with an average height ranging between 9.1m and 14.1m (DBH ranged between 6.4cm and 28.6cm) [Figure 14: A and B]. What appeared to be an inverse relationship between the number of plants and the average height of plants in each quadrant (where an increase in the number of plants resulted in a decrease in average plant height) was observed, with the exception of quadrants #12, #13 and #19. Instead, in these quadrants, a direct relationship was observed, where an increase in plant number resulted in a higher average height, and a decrease in plant number resulted in a lower average height (Figure 14: C). Quadrants #2-5 were unique in the presence of inundated water and extremely complex root systems, which resulted in there not being many independent, separate trees.

Additionally, dead debris became notable in quadrant #11. Quadrant #12 showed an increase in the amount of dead debris, which remained at the same level in quadrant #13. Quadrants #14-17, however, showed increasing amounts of dead debris before leveling off in coverage again in quadrant #17 and continuing to rise for the remainder of the transect (quadrants #18 and #19).

Seedlings

Only one red mangrove seedling was counted in quadrant one (#1), with no further seedlings counted in quadrants #2-6. The remaining quadrants (#7-19) all contained red mangrove seedlings, the highest count being 40 in quadrant #18, and the lowest count being 1 in quadrant #9 (Figure 14: D).

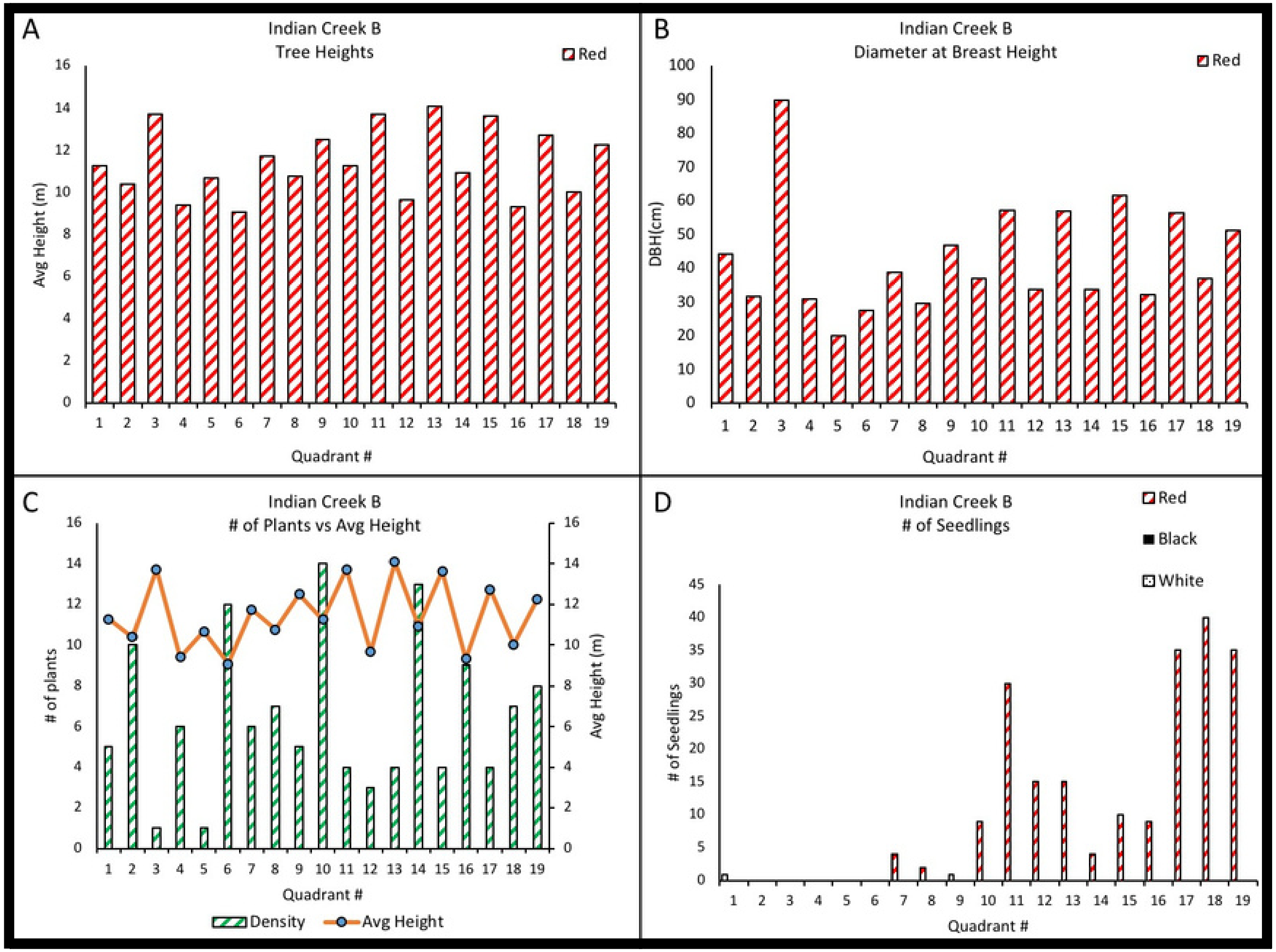


Figure 14: Indian Creek B graph displaying: A-Average height and species distribution across transects, B- DBH of trees across transects, C-Density of plants vs average height of plants, D- Density of seedlings across transects.

Leaf Litter, Prop Root coverage and Pneumatophores

Leaf litter was below a notable level for the first three quadrants of the transect but increased slightly in quadrant #4 (to 1-25% coverage) and remained consistent throughout the remaining length of the transect. Prop root coverage remained high throughout the length of the transect at 76-100% coverage. No pneumatophores were observed along the transect.

Animals

Animals observed along the transect included fish, crabs and snails.

Garbage

Garbage was observed only in the last quadrant (#19) along the transect, where a plastic container was recorded.

Indian Creek C

This transect covered 175m^2 of mangrove wetland (35m long transect), consisting of 7 quadrants.

Mangrove Diversity

No red or black mangrove plants were observed along this transect. White mangrove plants were recorded in quadrants #1-6, with an average height ranging between 2.7m and 8.0m (DBH ranging between 4.9cm and 15.8cm). No mangrove plants were observed in quadrant #7 (Figure 15: A and B). The density of mangrove plants within quadrants #1-5 was inversely related to the average height of the plants in each quadrant, where an increase in the number plants resulted in a decrease in the average height and vice versa. An opposite pattern was observed between quadrants #5 and #6, however, where the number of plants decreased between quadrants and the average height of the plants also decreased (Figure 15: C).

Seedlings

No mangrove seedlings were observed along the length of this transect, apart from quadrant #6 which contained five (5) white mangrove seedlings (Figure 15: D).

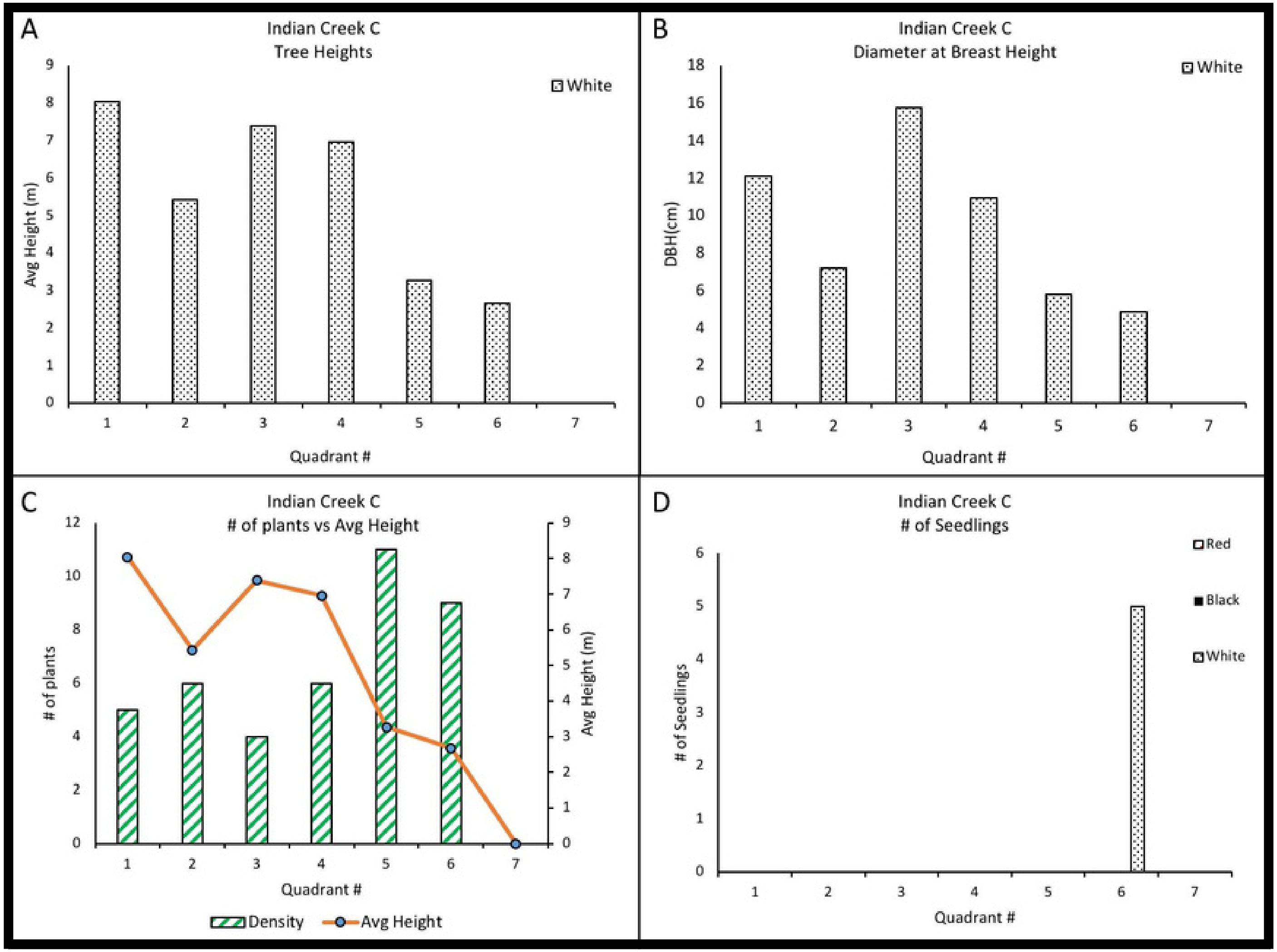


Figure 15: Indian Creek C graph displaying: A-Average height and species distribution across transects, B- DBH of trees across transects, C-Density of plants vs average height of plants, D- Density of seedlings across transects.

Picture 24: Surveyor creating a quadrant within the mangrove wetland
© Ruleo Camacho/NPA

Leaf Litter, Prop Root coverage and Pneumatophores

Leaf litter coverage starts off high in quadrant #1 at 76-100% coverage before dropping slightly in quadrant #2 to 51-75%. Coverage rises and remains high for the next 4 quadrants (#3-6) before dropping off to a very minimal level in quadrant #6. No prop roots or pneumatophores were observed along the transect.

Animals

Crabs, termites, ants, lizards and mosquitos were the main fauna observed along the transect.

Garbage

Glass and plastic bottles and cans were the main sources of garbage observed along the transect.

Overall NDNP Wetlands

During the study period, 3150 m^2 of Mangrove wetlands were surveyed representing 79.3% of the known mangrove wetlands found within the boundaries of the Nelson's Dockyard National Park (NDNP). The dominant mangrove flora was Red Mangrove, with the tallest trees on average were observed at Indian Creek, achieving a maximum average of approximately 11m, while the shortest were seen at Crab Hole B [~4.5m] (Figure 16: Red Mangrove). No red mangroves were recorded at Doig mangrove wetland. Black Mangrove plants were the second most common mangrove flora, with the highest observed at English Harbour B (~7.5m) while English Harbour A had the lowest black mangrove average height (~3.5m). No black mangroves were recorded at Indian Creek (Figure 16: Black Mangrove). White mangrove plants were the least common mangrove flora and were recorded at 3 of the 5 sites surveyed. The highest specimens were recorded at Crab Hole B (~6.6m) and lowest recorded at Doig B (~4.8m) [Figure 16: White Mangrove]. No buttonwood mangrove flora was recorded throughout the surveys.

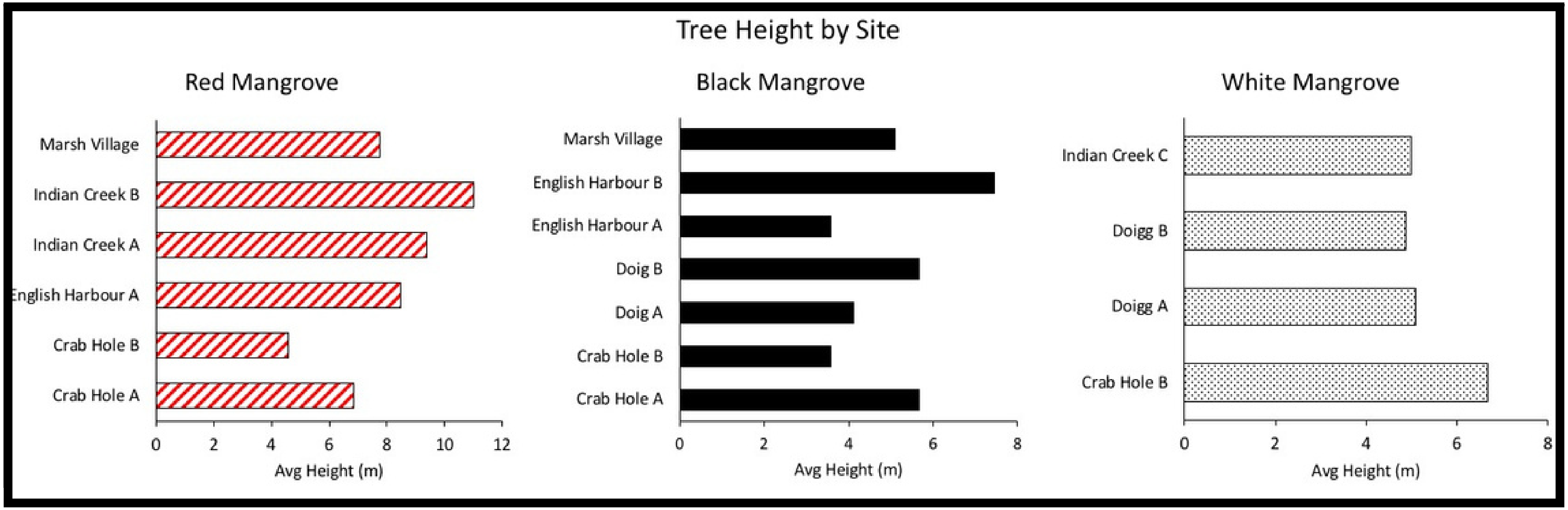


Figure 16: Mangrove species canopy height (m) according to site.

DBH varied by site and species but followed a similar pattern to what was observed for average height. The largest average DBH among red mangrove plants was recorded at Indian Creek B (12.4cm), with the smallest average DBH among these plants being seen at Crab Hole B [5.5cm] (Figure 17: Red Mangrove). The greatest DBH was seen among Black Mangrove flora, with the largest average DBH recorded at English Harbour B (13.7cm), with the smallest recorded at Doig B (6.6cm) [Figure 17: Black Mangrove]. White mangrove flora had the smallest DBH, with the largest average DBH seen at Crab Hole B (~11.6cm) and the smallest at Doig B (~4.4cm) [Figure 17: White Mangrove].

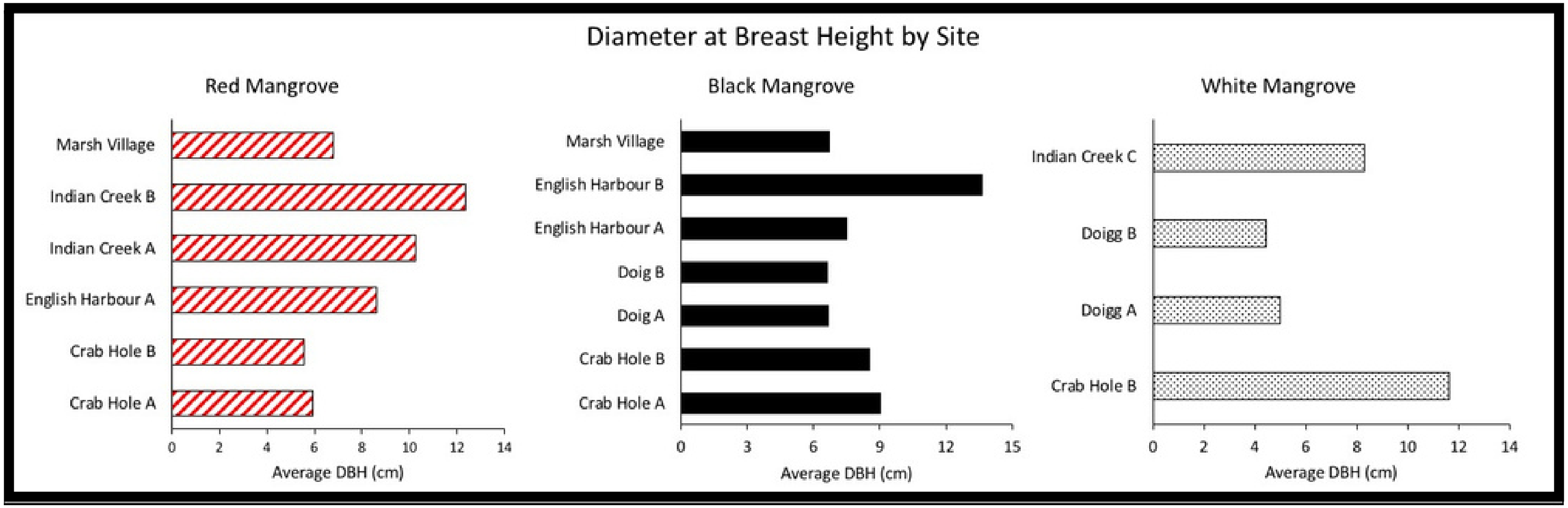


Figure 17: Mangrove species average Diameter at Breast Height (DBH) (cm) according to site.

Mangrove floral density varied across all survey transects, with the highest density of mangrove plants (i.e. average number of plants per quadrant) recorded at the Marsh Village mangrove wetland (Figure18:A), which was dominated by red mangrove plants. The lowest density of plants was seen along the English Harbour B transect. No assessed transect had more than two (2) mangrove species recorded (Figure 18:B).

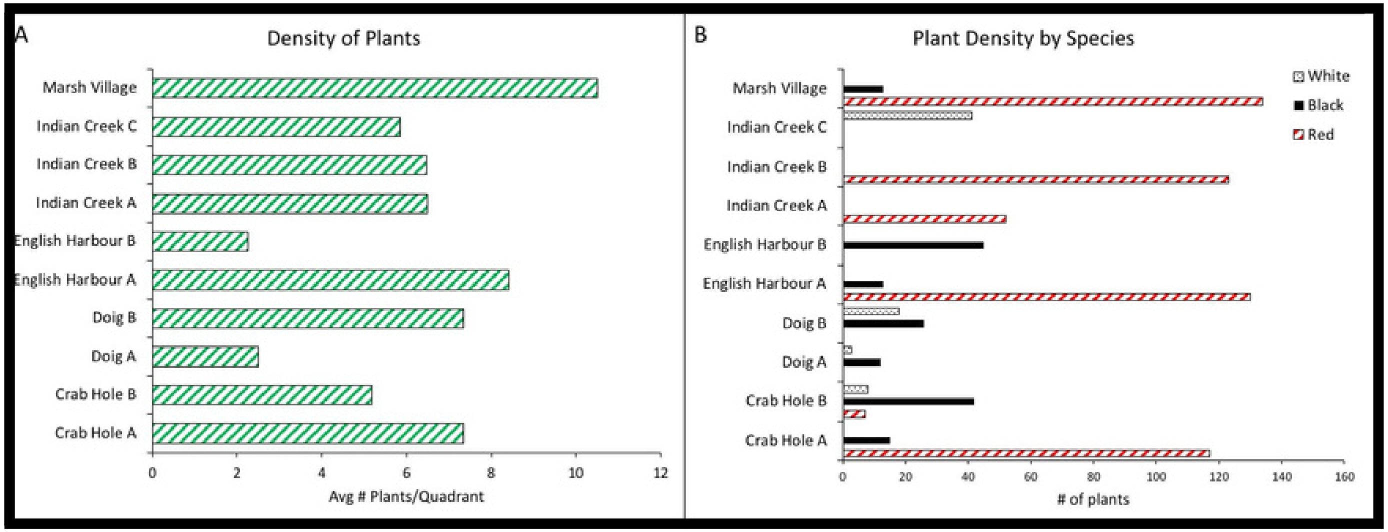


Figure 18: Density of mangrove plants by site (A) and by species (B).

Seedling number varied across the mangrove wetland sites assessed. Red, black and white mangrove seedlings were observed throughout the assessment. The largest number of seedlings overall were counted along the English Harbour B transect, with black mangrove seedlings significantly dominating over the other mangrove seedling species. On the other hand, the lowest number of seedlings were counted at Indian Creek, with only Indian Creek B showing a sizeable number of red mangrove seedlings (Figure 19).

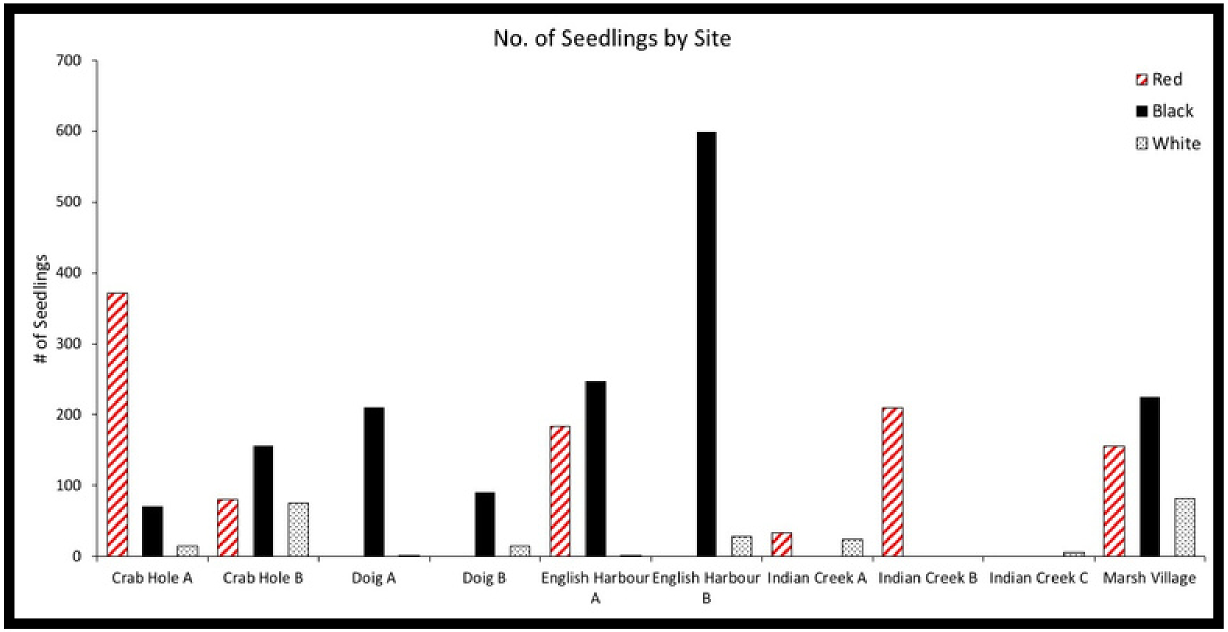
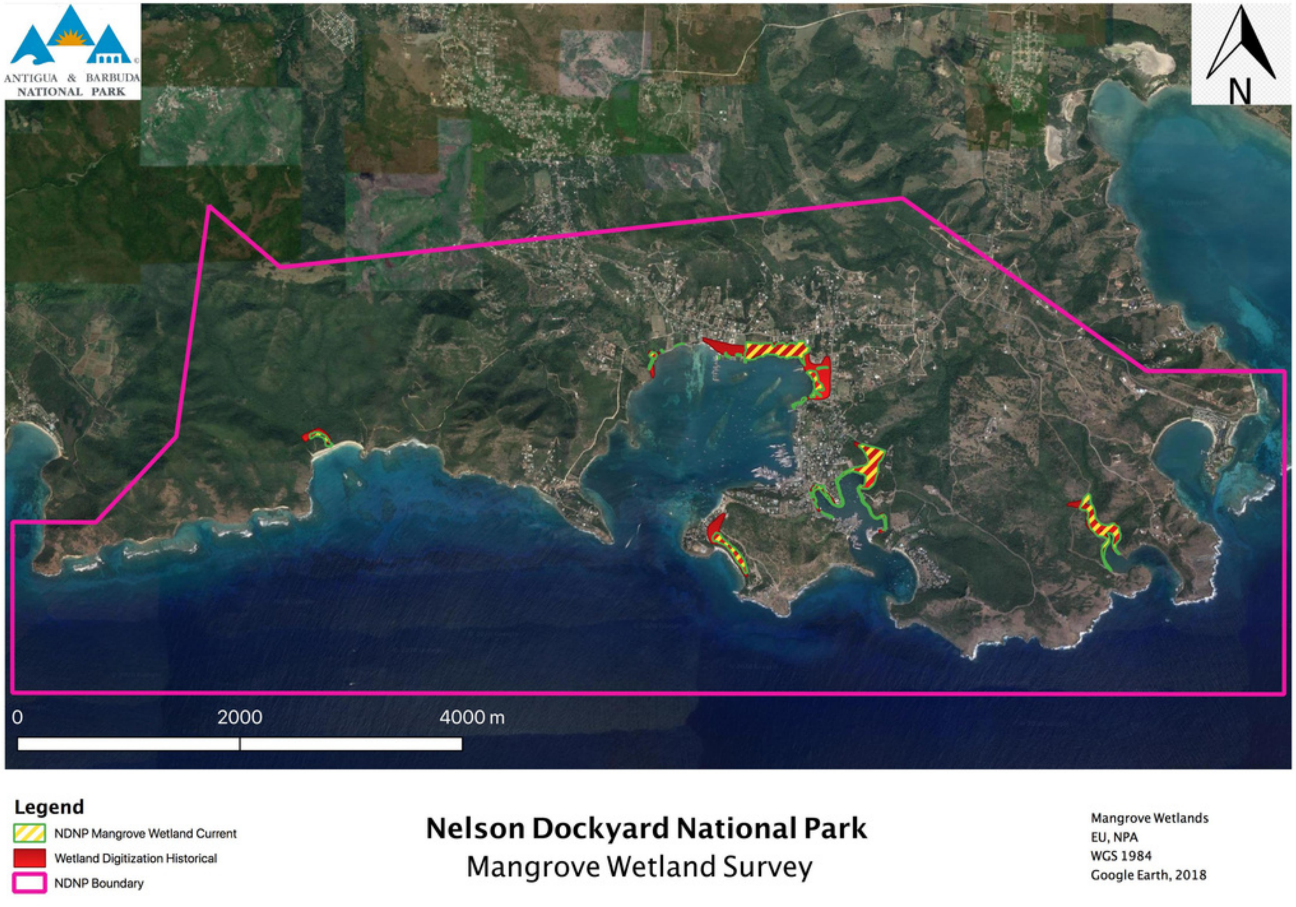


Figure 19: Number of mangrove seedlings by site.

Historical Analysis

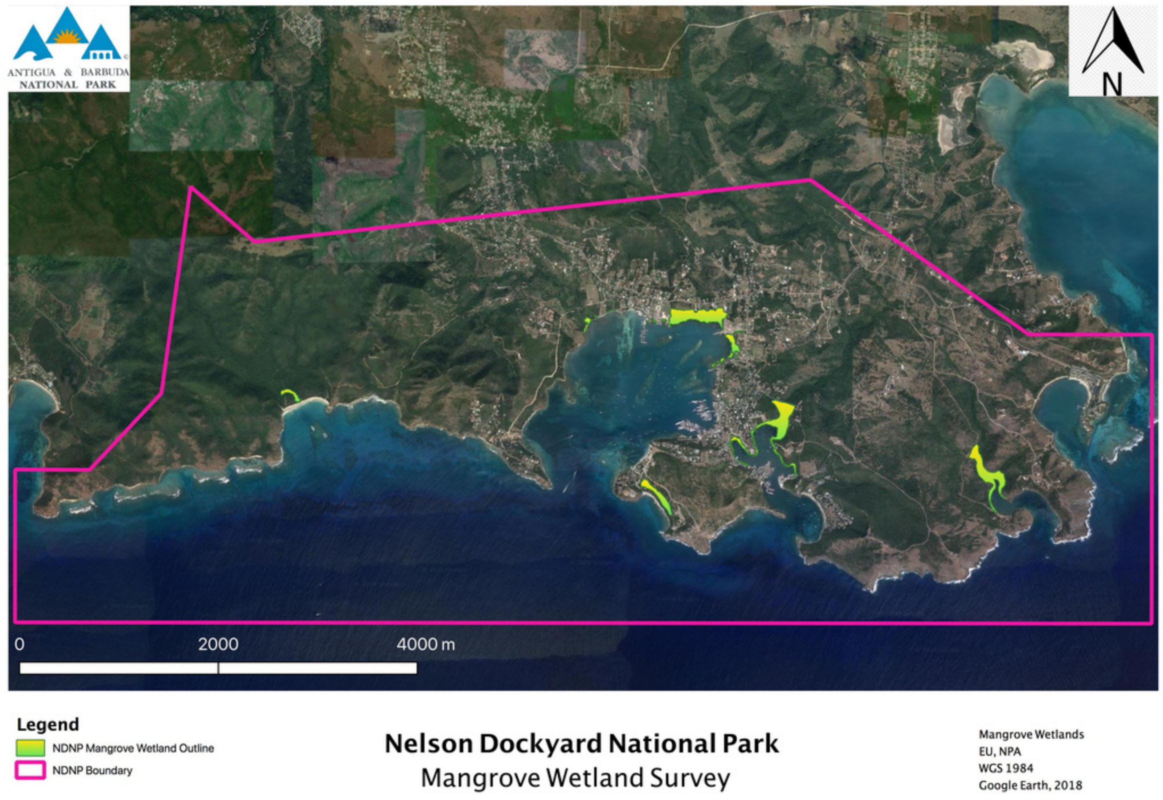
Based on the existing Mangrove Wetland information from the Environment Unit of the NPA, there is currently 260,855m^2 of Mangrove Wetland within the NDNP. The historical analysis of images taken by the US Army Air Corps (1941) and US Navy (1954), and georeferenced unto the 2018 Google Basemap, indicate that in the mid 20th centaury, there were some 359,752m^2 of mangrove wetlands within the NDNP. This represents a loss of 98,897m^2 (27%) of mangrove wetland from within the NDNP boundaries. These losses have primarily come along the northern and westerns parts of the Falmouth harbour area, along with the mangrove wetland system in the Pigeon Point/Windward Bay areas (Map 8).



Map 8: Historical changes in Mangrove Wetlands in the NDNP.

Discussion

The mangrove wetlands assessed during these surveys represent 79.3% (206,778m^2 of 260,855m^2) of the verified mangrove wetlands within NDNP (Map 9). The information generated by these surveys will provide an essential baseline for monitoring and management of the mangrove wetland areas within the park.



Map 9: Mangrove Wetlands within the Nelson's Dockyard National Park.

At all the sites, with the exception being the Marsh Village mangrove wetland, multiple surveys were conducted to capture the distribution and density of mangrove plants from both a coastal and terrestrial perspective. The sites surveyed represent the variety that exists between these mangrove wetland ecosystems, while providing an accurate representation of these ecosystems within the NDNP.

Four of the five mangrove wetland sites were what would be considered "typical" mangrove wetland systems, with one end being bordered by the ocean, the other end secured by land and the entire wetland located at the base of a watershed. In these cases, the distribution of trees also followed the typical pattern of zonation, where the plants closest to the coast were red mangroves and further inland a transition to black and then white mangrove plants was observed.

Tree diversity varied among sites; with the following species present at each location: Red Mangroves (*Rhizophora mangle*), Black Mangroves (*Avicennia germinans*) and White Mangroves (*Laguncularia racemosa*). Buttonwood Mangroves (*Conocarpus erectus*) were not recorded in any of the mangrove survey assessments, but do exist (however, in low density) at some of the selected sites (e.g. back end of Indian Creek). Additionally, buttonwood mangroves are particularly abundant at the Windward Bay mangrove wetland with the National Park, which was not surveyed for the purposes of this report.

Sites such as Indian Creek, Crab Hole and English Harbour, where the wetland originated at the ocean's edge, had red mangrove flora that often-extended outwards over the water's edge, making the initial quadrant have a lower density of plants than the other quadrants. Additionally, a pattern where the tallest red mangrove flora were observed in the second quadrant from the ocean was noted in most of the transects which registered red mangrove plants, with the only exception being seen at the Indian Creek Wetland B transect, where tall trees were continuously recorded to towards the end of the survey.

Average canopy height throughout the wetlands surveyed was 7.6m, with the Diameter at Breast Height (DBH) averaging 8.6cm. Red mangrove plants, are typically the largest plants found in a mangrove wetland, and this was seen throughout the sites within the NDNP. An average height of ~8.5m (DBH:8.6cm), with the largest plants (in terms of both height and DBH) being found at the Indian Creek site (with a maximum average height of 14.1m). Indian Creek was unique for its "wall" of red-mangrove plants, due to the lack of black mangrove plants found in this wetland. Black mangrove plants, on the other hand, averaged a height of 5.3m and DBH of 9.3cm. The largest black mangrove plants were recorded at the English Harbour mangrove wetland, with an average height of 10.0m recorded in one of the transects. These exceptionally large black mangrove plants were found at the back end of the wetland ecosystem. Finally, white mangrove plants averaged 5.2m with a DBH of 7.5cm, with the largest plants recorded at the Crab Hole mangrove wetland site (with a maximum average height of 6.7m).

While the Indian Creek mangrove wetland had the largest red mangroves recorded, there was a noticeable absence of black mangrove flora. The zonation at this site was a transition from red to white mangrove plants, with large amounts of siltation, likely due to run-off from the surrounding watershed. The areas where one would expect to be covered by black mangrove flora was heavily influenced by tidal fluctuations, and appeared highly desiccated, which was likely exacerbated by the lack of floral vegetative cover. Further investigations are needed to determine if black mangrove flora is being biologically excluded from the Indian Creek wetland due to a lack of seed stock, or other biological/physical/chemical reason.

English Harbour and Crab Hole mangrove wetlands both had large areas devoid of plants between the transition from black mangroves to white mangroves (Picture 21), and this was illustrated in the data collected. These areas are likely the result of silt deposition from terrestrial based water runoff, which was captured by the mangrove wetland. This silt would have otherwise directly entered and negatively affected the marine ecosystem, through the reduction of turbidity, which can negatively affect seagrass and coral reef ecosystems.

Picture 25: Open mangrove wetland area at the transition from black to white mangroves. © Ruleo Camacho/NPA

The Marsh Village wetland site had the greatest recorded density of plants, which was likely as a result of the man-made drain at the back of the wetland restricting the natural spread of plants. This likely result in a greater utilization of the space available for growth, resulting in higher densities. The historical analysis (Map 10), highlights the extent to which the Marsh Village mangrove wetland previously extended. Density of plants was otherwise balanced between sites, with areas of lower density of plants dominated by plants which were exceptionally large (e.g. English Harbour B).

The Doig mangrove wetland, which has no direct interaction with the ocean, exhibited a slightly different zonation pattern than the other sites. With no direct interaction with the ocean, the environment necessary to promote red mangrove growth was absent, resulting in no red mangroves being recorded. The wetland at this site was divided by a water basin, likely created by a combination of watershed runoff and wave influxes from the ocean, and landlocked by the Doig beach. It has been observed that during moments of extreme wave action, seawater may wash up over the beach and enter the wetland. However, the regularity of this is unknown and the pH and salinity of this basin was not recorded during the surveys. The edges of the basin had a mixture of black and white mangrove plants, and this continued throughout the wetland. No buttonwood mangroves were observed within the wetland site.

Throughout all sites, larger plants were associated with a lower density per quadrant. This was likely due to the large trees allowing very little growth of additional flora by taking up more than one quadrant with their canopy cover. The exception to this trend was observed in the first transect at the Doig mangrove wetland site (Doig B), where the large size of the basin in comparison to the wetland area meant that the majority of the transect was recorded in the open, thus resulting in no obvious patters in the size and density distribution of the plants. A similar situation was seen at the third transect taken at the Indian Creek mangrove wetland (Indian Creek C). This transect was taken as part of the overall survey of the Indian Creek mangrove wetland ecosystem, however, this area was essentially "land locked" from the ocean, due to the large amount of siltation that occurred. While tidal fluctuations regularly result in water entering the wetland area, this area is likely permanently dry, perhaps only receiving a salt-water influence during the most extreme weather systems (Picture 22). Only white mangrove flora was recorded along this transect, with the size and complexity (shape, amount of slant, etc.) of the trees increasing the closer one moved towards the terrestrial edge.

Picture 26: Indian Creek Tidal Influx. © Ruleo Camacho/NPA

Red and black mangrove seedlings dominated overall in this survey. The majority of the red mangrove seedlings were found where the flora was transitioning from red to black mangrove plants (or in the case of Indian Creek, red to white). This is likely due to the seedlings closer to the water's edge being carried away the currents to “seed” new areas. Transects where this transition point was not encountered did not record as many seedlings. Black mangrove seedlings were present in high numbers among the areas dominated by black mangrove flora, with the largest amounts being seen at English Harbour. White mangrove seedlings were not as prominent throughout the survey sites but were associated with the areas where white mangrove flora was present. Mangrove restoration is a goal of the future work of the Environment Unit of the NPA, and the distribution of seedling information, particularly red and black mangrove seedlings, at some sites can be useful for the implementation of mangrove nurseries to help areas which have had a history of mangrove flora removal to recover.

Trash was recorded throughout the surveys, with the site of greatest concern (the Marsh Village wetland) being the most easily accessed by humans. The trash observed throughout most of the mangrove wetlands consisted primarily of plastic containers, glass bottles, tyres and some kitchen appliances. Most of this trash had been trapped by the pneumatophores and prop roots of the mangrove flora, an illustration of the wetland system conducting an important ecosystem service. Within the Marsh Village wetland, there were discarded animal carcasses, and what appeared to be an oil-like film among the ground within the areas where black mangroves were recorded. This substance was not sampled during these surveys, but should be assessed in the future, to understand its possible implication on the biochemical environment of the mangrove wetland. It was noted that the wetland site, which was least accessible by human action, had the lowest levels of physical pollution. Mangrove wetlands are often regarded as dumbing sites, and efforts should be made to ensure the importance of these wetlands and the negative effects of polluting within them is well publicized within the NPA.

There seems to be a significant number of termites within several of the wetland sites. All sites with red mangrove flora showed evidence of affected trees, with several dead trees observed within the surveys. The termite issue was also present among black mangrove flora, but not much of an effect was observed on the white mangrove flora. The novelty of this as a problem is unknown but being investigated. In addition, an unknown plant disease was discovered to be affecting black mangrove plants within most of the ecosystems surveyed for the purposes of this report (Picture 23).

Affected plants tended to be closer to the terrestrial side of the ecosystem and had either bumps (raised areas) protruding from the surface of their leaves or several scattered holes through their leaves. The type of disease (fungal, bacterial, etc.) and its long-term effect on these mangrove plants are currently unknown.

Picture 27: Diseased black mangrove leaf. © Britney Hay/EAG

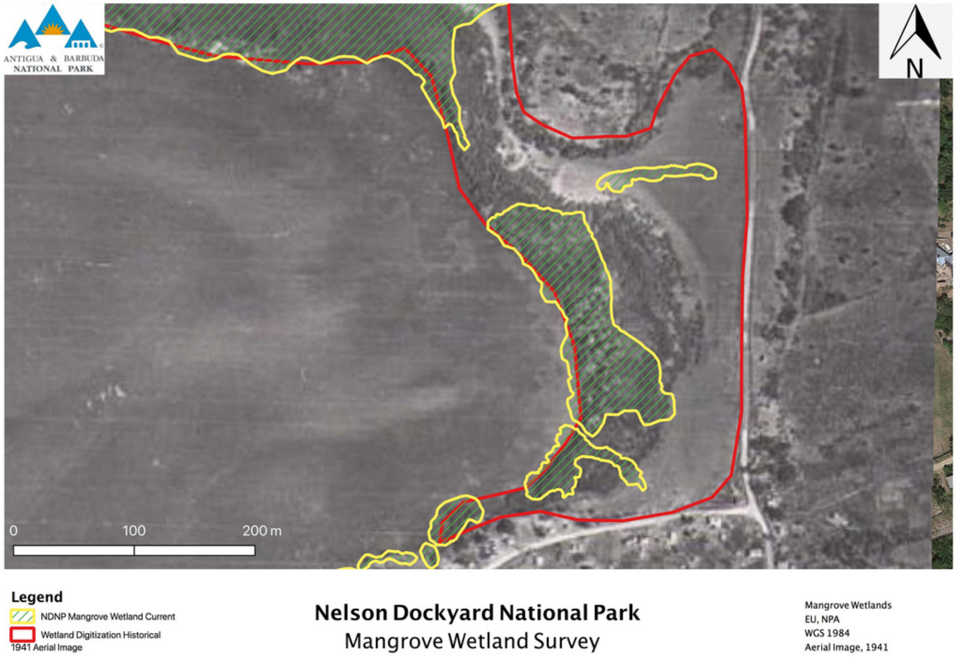
Picture 28: Fiddler Crab observed within the mangrove wetland ecosystem. © Ruleo Camacho/NPA

Few animals were visually observed during the surveys, but this was not of great concern, as there was audible evidence (sound of birds departing, flapping wings, bird calls) of rich avian biodiversity within the wetland. Additionally, the time at which the surveys were conducted, as well as the noise and other disturbances made in accessing the mangrove wetland area was not conducive to bird monitoring. Among the animals that were observed are fish, who were spotted among prop roots in the early quadrants of transects that began close to the water's edge. In addition, many crab holes belonging to Fiddler crabs (*Uca sp.*) were observed on the floor of the wetland, particularly in water-logged areas (Picture 24), and fewer holes belonging to the land crab (*Cardisoma guanhumi*) were observed on the terrestrial side of the wetland.

Several reptilian species were also observed, including Watts' (*Anolis wattsi*) and Spotted Anole (*Anolis leachii*), and Giant Forest Geckos (*Thecadactylus rapicauda*) [Picture 25] were seen at several of the sites.

Picture 29: Giant Forest Gecko observed on a red mangrove tree trunk. © Ruleo Camacho/NPA

This survey would have been enhanced by the collection of bio-chemical environmental parameters such as pH, salinity, Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD). These parameters would have enhanced the data, and the ability to monitor the health of the ecosystem and provide useful information which may help to identify specific threats for which mitigating action is needed. The measuring of these parameters should be included in future assessments of mangrove wetland ecosystems within the NDNP.



Map 10: Historical analysis of the mangrove wetland area currently called Marsh Village Mangrove Wetland, highlighting spatial differences between 1941 (red) and 2019 (yellow).

Loss of mangrove wetlands is not a recent phenomenon in Antigua & Barbuda. Historically, wetlands areas have often been backfilled and otherwise modified to facilitate development (e.g. Jolly Harbour), with little thought of the potential implications that can have on the function of the mangrove wetland and the ecosystem services it provides. A desktop review and historical analysis of wetlands within the NDNP was conducted to determine the temporal changes in the size of the mangrove wetland ecosystems. However, it should be noted that some assumptions as it pertains to spatial distribution were made, as it was not possible to conduct ground-truthing to validate the aerial assessment. The information provided remains highly useful, and such as assessment should be carried out on an island-wide basis, to better understand the historical loss of mangrove wetlands on a nation-level, and the impacts it can have on the ecological and economic development of the country. The NDNP has lost ~27% of its mangrove wetland areas within the last century, with the primary cause being the process of backfilling for developmental related reasons. The majority of mangrove wetland lost was located at the northern and western portions of Falmouth Harbour, along with the Pigeon Point/Windward Bay area (Map 8). This was particularly noticeable along the area surveyed as the Marsh Village Wetland ecosystem, where only a fraction of the wetland remains today (Map 10). The loss of such large quantities of this ecosystem, and the knock-on deliberating environmental effects it has had on ecosystem connectivity (Figure 1) and resilience, has not been measured. Mangrove wetlands are not just important for the ecological services they provide, but also for the economic contributions they make through the provision of healthy pristine environments coastal protection and biodiversity support. It is an area of concern, particularly considering climate change, increasing anthropogenic pressures, and an overall greater need being placed on out environmental resources due to growing population demands. Greater attention is needed to garner a better understanding of the effects of mangrove wetland lost on the ecosystem services they provide not only to sister ecosystems, like seagrass beds and coral reefs, but to the local and wider anthropogenic community.

Picture 30: Doig Mangrove Wetland. © Britney Hay/EAG

This study may serve as a starting point for Antigua and Barbuda to more actively participate in the Ramsar International Convention on Wetlands, more popularly known as the Ramsar Convention. This is an intergovernmental treaty that provides the framework for conservation and wise use of wetlands and their resources ("What is the Ramsar Convention on Wetlands," n.d.). The convention vouches for the sustainable use of all wetlands, and designates wetlands around the world that satisfy specific criteria (that is, being ecologically, botanically, zoologically, limnologically or hydrologically significant) as Wetlands of International Importance under the Convention based on the results of submitted wetland inventories that are in line with the Ramsar Framework for Wetland Inventory. Currently, Antigua & Barbuda only has one (1) site designated as being internationally important under the Ramsar convention, that is, the Codrington Lagoon (3600 hectares) (Ramsar.org: Country- Antigua and Barbuda). This site was selected due to its immense biodiversity, and due to its provision of habitat for the largest gathering of Magnificent Frigate Birds (Fregata magnificens) in the western hemisphere. This international recognition benefits acknowledged countries such as Antigua and Barbuda by increasing publicity and prestige for the designated wetlands which increases the possibility of conservation support and wise use measures, and by making expert advice on national and site-related conservation and management issues accessible. Detailed ecological information on mangrove wetlands within Antigua & Barbuda is difficult to find. There has been several assessments and inventories over the years: Mussington (1983), Lindsay & Horwith (1997), Jarecki (1999), Environmental Awareness Group (1999), Fisheries Division (2013). However, no program has been put in place to regularly monitor and update ecological information on mangrove wetlands around Antigua and Barbuda. It is possible that there are other mangrove wetland areas within the country that are deserving of international recognition and attention based on their ecological contributions. However, wetland inventories must be conducted on a routine basis across the island for recognition under the Convention to be attainable.

This document represents the first in-situ assessment to be executed within NDNP and can provide a template for future mangrove assessments. Importantly, it documents the baseline ecology of these critical ecosystems, while highlighting the unique differences between the mangrove wetlands assessed. The data provided will serve as an instrumental guide in the design and implementation of management interventions for mangrove wetlands within the Nelson Dockyard National Park.

Recommendations

The surveys conducted within NDNP highlighted the diversity of the mangrove wetland ecosystems within the park and several issues that should be addressed in future surveys. This study also provided some insight into the future management needs of mangrove wetlands, both within NDNP and throughout Antigua & Barbuda.

Survey Design

The inclusion of biochemical parameters in future surveys will allows assessors to get a more holistic idea of the health of the mangrove wetland ecosystem. This will not only help with the understanding of the condition affecting the ecology of the mangrove wetland ecosystem, but better identify and mitigate threats like pollution, and better guide management interventions such as mangrove restoration. Additional faunal indicators can also be added to the surveys, including methodologies to better capture the faunal presence within these mangrove wetland systems. This may range from bird surveys to additions to the transect method such as noting number of crab holes along the transect (Jarecki, 1999), which can better capture faunal changes to the mangrove ecosystem from a health perspective.

Health Index

A health index which accompanies the survey results should be developed, which would better assist managers and policy makers to understand the health characteristics of Mangrove Wetlands.

Awareness and Education

A dedicated program should be created to increase the public's awareness of the diversity of mangrove flora and fauna, the ecosystem services mangroves provide, and the impact of anthropogenic activities on the ability of mangrove wetlands to function. Greater signage is needed at all mangrove wetland sites to illustrate the extent of the wetland, and the activities that are allowed within them.

Mangrove Nursery

There is enough seed-source material, particularly of red and black mangrove flora, to establish a mangrove nursery to address the need of areas that have suffered from mangrove loss over the years, or have been identified for mangrove restoration in order to improve the ecosystem function.

Mangrove Monitoring

There is a need for a regularized monitoring of the mangrove wetlands on an annual or biennial basis, to better monitor changes to these valuable ecosystems. Such a program needs to be established not only within the NDNP, but also at a nation-wide level.

Management

There is a need for a management plan which looks at the different mangrove wetlands within the NDNP and addresses their specific needs. This assessment has highlighted that while there are issues that threaten each wetland alike, unique threats also exist which much be addressed individually. Of great concern is the termite issue that is affecting many red and black mangrove plants and determining what mitigation measures can be put in place to halt its spread. Wetland sites like the Indian Creek mangrove wetland should be further assessed to determine the cause for the lack of black mangrove flora at the site, and the effect that that may have on the function of the mangrove wetland ecosystem. The loss of 27% of mangrove wetland, determined from a historical analysis, further supports the need to protect the remaining mangrove wetland areas, as the pressures they face continue to grow, leading to a greater demand on the ecosystems services they provide.

Enforcement

There is evidence of pollution and backfilling of wetlands occurring within the NDNP. These acts are illegal under the EPMA (2019) and need to be addressed to stem the negative impact that this can have on the mangrove wetland ecosystem and the ecosystem services they provide.

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Appendix

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