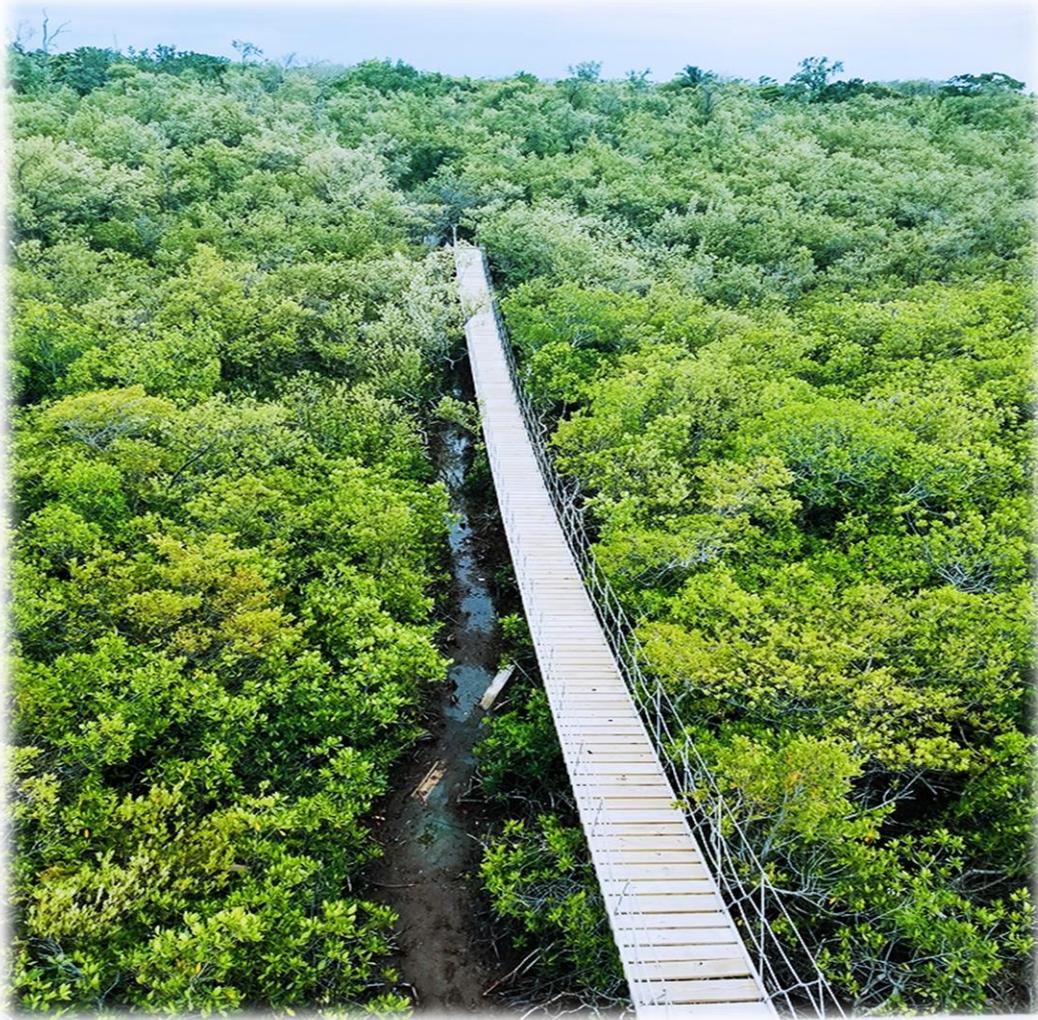# Field Plan for Mangrove Rapid Assessment

Nadia Bood, WWF

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Field Plan for Mangrove Rapid Assessment

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Field Plan for Mangrove Rapid Assessment

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1. Introduction

Mangroves, a remarkable group of diverse plants, have evolved to dominate coastal tidal zones worldwide. These ecosystems vary in form, from 60-meter-tall trees to smaller dwarf shrubs. Adapted to saline and oxygen-deficient environments, mangroves feature unique characteristics like pneumatophores for gas exchange and complex root systems. These adaptations enable mangroves to thrive and create essential habitats for diverse aquatic and terrestrial species. Mangroves are pivotal in preventing soil erosion, enriching the nutrient cycle, and supporting a wide range of biodiversity, including significant marine and terrestrial fauna (Bunting et al., 2018; Chowdhury et al., 2017; Sippo et al., 2018). Their role in carbon dioxide sequestration is increasingly recognized, with their capacity to capture carbon exceeding that of other terrestrial ecosystems, such as tropical rainforests (Hamilton & Friess, 2018; Kauffman & Donato, 2012). The Western Indian Ocean is notable for its diversity, hosting around 52 species and 40% of the global mangrove cover. Latin America, Africa, and Oceania are also key regions, with Latin America alone representing 20% of the world's mangrove area (Ricklefs & Latham, 1993).

In Belize, mangroves are dominated by three species: the red mangrove (*Rhizophora mangle*), the black mangrove (*Avicennia germinans*), and the white mangrove (*Laguncularia racemosa*). Each species contributes uniquely to the ecosystem. All mangroves with their characteristic prop roots are important for coastal protection, water quality, and habitat for diverse wildlife. Despite their ecological importance, Belize's mangroves face significant threats, mainly from human-induced factors like clearing for development, erosion, and the impacts of climate change (Canty et al., 2018; Cherrington et al., 2010). This highlights the urgent need for effective assessment and monitoring strategies to identify local threats and prioritize restoration efforts.

This field plan aims to provide technical guidance for assessing the condition of potential mangrove restoration sites across Belize, including a general understanding of the drivers of loss and degradation and climate vulnerabilities affecting the sites. Drawing upon established literature and the field experience of the authors, this guide describes the different biophysical factors to be measured in the field, outlining specific data collection methods, materials, and field data collection sheets.

2. Background

Belize's nationally determined contributions (NDC) set out targets and actions designed to enhance the resilience of critical ecosystems and populations; including timebound quantitative targets for mangrove protection (an additional 12,000 ha) and restoration (at least 4,000 ha) by 2030. To achieve this, a five-year National Mangrove Restoration Plan for Belize (hereafter the Plan) is being developed which will identify critical areas for restoration on public and private lands as well as contribute to achieving national protection targets. The Plan includes nine stages (Figure 1) and is led by a multi-sectorial working group integrated by the Belize Forest Department, the World Wildlife Fund Mesoamerica, and Griffith University, Australia.

Conducting field studies to verify information on-the-ground is part of stage number four in the development of the Plan. This stage will help validate data on mangrove loss and degradation, and cross-check information on the drivers of loss and climate vulnerabilities that have been identified through the desktop review (stage number two) and community consultations (stage number three). The overarching objective of this field plan is to describe in detail the protocol that will be used to support the field studies required as part of stage number four in the development of the Plan.

Figure 1. The nine stages for developing Belize's National Mangrove Restoration Plan.

National-level community consultations were held during October-November 2023 to gather local knowledge around mangrove loss and degradation, ecosystem services, opportunities for restoration, potential and future threats to mangroves, and previous experiences with restoration. We used participatory mapping to collect this data, where participants used a combination of activity sheets and maps to identify relevant areas in the maps (Figure 2). Consultations included 200 participants across seven workshops, six in-person and one online. Communities represented included: San Pedro, Caye Caulker, Consejo, Chunox, Copper Bank, Sarteneja, Corozal Town, Dangriga, Hopkins, Seine Bight, Placencia Village, Independence, Monkey River, Punta Negra, Punta Gorda Town, Barranco Village and Belize City. Members of local NGOs, community associations and local government representatives were also present during the workshops.

To identify potential restoration sites across Belize we developed a grid consisting of 2,201 hexagons of 200 ha each. This grid overlaps all areas in Belize where there are mangroves according to the Belize Mangrove and Littoral Forest Cover (1980-2019) (CZMAI, 2020). We used this grid during the consultation process to ensure we had a consistent spatial scale at which to assess the restoration potential of different sites across Belize.

Figure 2 Participatory mapping exercise, where local community members provided their input regarding mangrove loss and degradation, ecosystem services, drivers of loss, opportunities for protection and restoration and previous experiences in restoration.

2.1. Site selection

Priority sites to visit were identified through a five-step process:

1. We analyzed remote sensing products together with the community inputs obtained from the participatory mapping exercise described above (Table 1). This baseline information allowed us to identify mangrove condition, drivers of degradation, and insights on the land tenure of potential restoration sites. From the analysis of this information, we identified a total amount of 6,666 ha of degraded mangroves across Belize.

2. We then classified mangrove degradation extent into two categories: within protected areas and inside abandoned shrimp farms (774 ha) and outside protected areas (5,892 ha). The outside protected areas category encompasses areas that require further analysis to assess the feasibility of implementing restoration actions. For this fieldwork, we focused on the category of outside protected areas to better understand the condition and land tenure of those sites.

3. Focusing only on the 'outside protected areas' category, we conducted an Overlapping Features Analysis (ArcGIS pro-3.1) to identify where two or more baseline layers overlapped. As an agreement across the working group, we prioritized visiting sites to validate community perceptions of mangrove restoration opportunity. We identified a total of 1,097 ha (104 hexagons) of degraded mangroves as perceived by the community that overlapped with at least one more of our baseline layers.

4. We selected 42 hexagons as the final sites to visit based on accessibility, representativeness across coastal planning regions, and the avoidance of previous sites from recent ground truthing efforts from the Forest Department and the Smithsonian Institute.

5. Sites visited were classified based on their overall condition (Table 2). Full data collection, as described in section 3 of this document, was only conducted on sites falling under the condition 'degraded', as sites under this condition are considered to have higher probabilities of restoration success relative to the other conditions common in Belize. All other sites were recorded in a separate 'Condition' database (see section 3.2).

Table 1. Layers used to identify mangrove condition across Belize.

| Layer	Source
Abandoned shrimp farms	Dwight Neil (2024, personal communication); Von Unger et al (2021); Coastal Zone Management Authority & Institute (CZMAI, 2020)
Community inputs (previous and future restoration)	Belize national consultation process (2023, undertaken by the authors); Dwight Neil (2024, personal communication); Israel Correa (2024, personal communication)
Cyclone damage in the last five years (measured using NDVI)	Amaral et al (2023)
Previous ground truthing from Blue Carbon analysis	Morrissette et al (2023)
Abandoned coastal infrastructure	Coastal Zone Management Authority & Institute (CZMAI, 2018)
Cleared land that is not adjacent to infrastructure	Von Unger et al (2021)
Community-identified areas of mangrove clearing	National consultation process (2023, undertaken by the authors)

Table 2. Categories describing common conditions of the Mangroves in Belize.

Condition	Definition
Healthy	Low amounts of standing dead and/or leaf damage, no obvious anthropogenic disturbance
Degraded	Relatively healthy individual trees but either sparse or the sites are heavily disturbed by pollution, cutting, palms, debris, and stagnant water
Regeneration	Degraded or cleared but showing natural regeneration
Cleared	Vegetation completely removed with only roots and dead branches remaining
Transitioning	Mostly cleared and transitioning into another ecosystem due to pollution, topographic or tidal flow alterations
Filled	Cleared and filled with material like gravel or sand
Construction	Cleared, and construction is imminent or present

3. Field methodology

3.1. Survey design

For each priority hexagon, we surveyed three square plots (5x5 m) along a transect, each plot was separated by 20 meters, subject to the size of the site. The transects were located in areas that were representative of the vegetation within the hexagon but were constrained by accessibility. Transects were situated preferably perpendicular to the ocean (Figure 3). Within these plots we collected physiographic, biophysical, ecological, and anthropogenic data for an on-the-ground assessment of the condition (Table 3). All measurements were done at low tide.
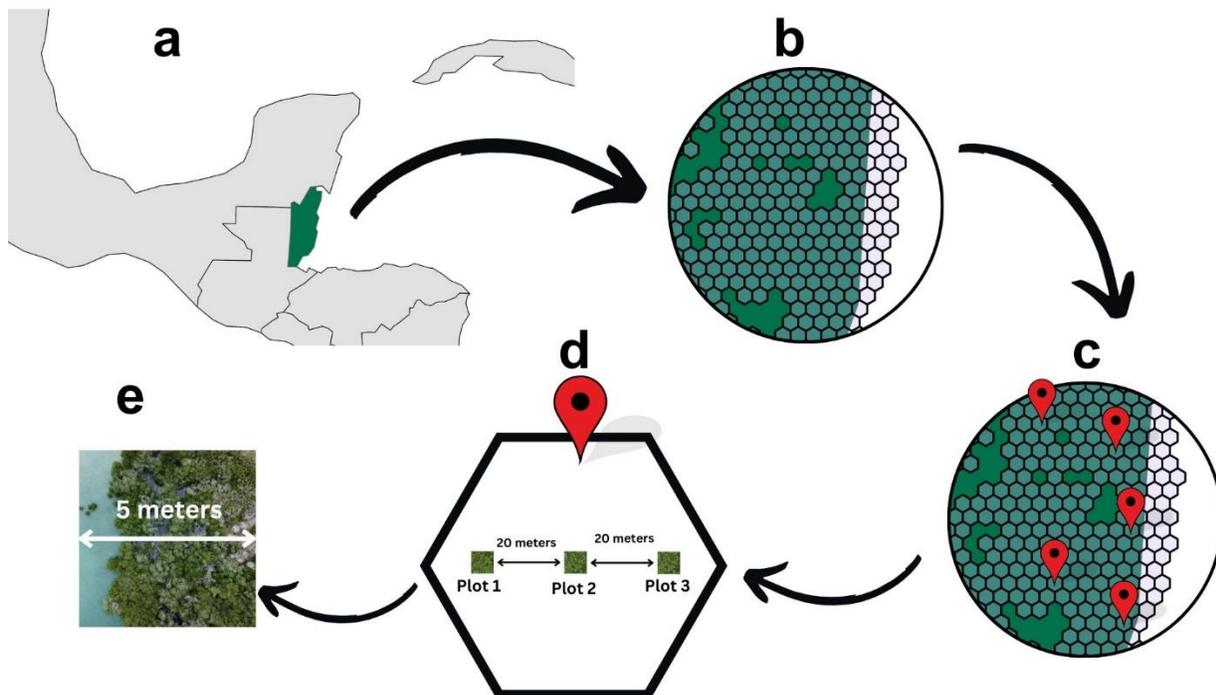
Figure 3 Geographical context and data collection methodology (a) A map showing Belize in dark green within Central America, (b) Pre-made hexagonal units, each covering 200 hectares, (c) Pre-identified priority hexagonal units selected, (d) In each selected hexagon, three plots were deployed for data collection, (e) Each square plot, with a length of 5 meters, was used to collect field data.

3.2 Factors to measure

Table 3. Summary table of factors to measure for each hexagon, definition, and specific categories for assessment.

Factor	Subcategory	Definition		Categories
Geomorphic data	*Carbonate Systems	Site with carbonate substratum.		• Lagoonal (L) • Open coast (O)
	*Terrigenous Systems	Systems influenced by river and land-based sediment, rich in nutrients.		• Deltaic (D) • Estuarine (E) • Lagoonal (L) • Open coast (O)
		**Waterbody influence		• River • Freshwater creek • Tidal creek • Lagoon • Ocean
		**Grain size		• Clay • Sand • Gravel
Physiographic setting	Mangrove types	Types of mangroves distinguished by their specific location and environment		• Fringing (F) • Interior (I) • Overwash (O) • Dwarf (DW)
Biophysical	Redox potential	Oxidation-reduction potential of soil		• Anaerobic: <-100 mV • Anoxic: <o mV • Aerobic: >100 mV
	Salinity	Measurement of salt concentration of water flooding the mangroves		• Holigohaline: 0.5-5 • Mesohaline: 5-18 • Polyhaline: 18-30 • Euhaline: 30-35 • Hyperhaline: >35
	pH	Measurement of acid or basic condition of the soil		• Basic: > 8 • Neutral: 6-8 • Acid: < 6
Ecological	Forest structure	Species Composition	Identification of mangrove species	• Red Mangrove (*Rhizophora mangle*) • White Mangrove (*Laguncularia racemosa*) • Black Mangrove (*Avicennia germinans*)
		Stand age	Frequency of mature versus young trees and saplings	• Old trees (thick, gnarled or scared trunk) • New adults (> 1m tall) • Juveniles (with props, ~ 1m tall) • Seedlings (no props)
		Mangrove height	The approximate average tree height within plot	• Short (<2m) • Medium (2-5m) • Tall (>5m)

	Vegetation Health	Canopy retreat	Presence of dying or dead trees	• 1- none (0%) • 2- low (>0-30%) • 3- moderate (>30%-60%) • 4- severe (>60%)
		Mangrove density	Mangrove trees per area	• Dense (overlapping canopies) • Medium (touching canopies) • Sparse (spaced canopies)
		Seedling density	Number of mangrove seedlings per area.	• none (0/m^2) • few (1-3/m^2) • some (3-10/m^2) • many (>10/m^2)
Pressures	Degradation Factors	- Excavation - Erosion - Highways - Urban development - Clearing - Garbage - Recreation - Storm damage - Direct extraction - Other		Distance • 0- Not present • 1- Inside plot • 2- 5 meters from plot • 3- 6-10 meters from plot • 4- >10 meters from plot Extent
	Barriers to Migration	- Small roads - Agriculture - Aquaculture - Highways - Urban development - Lagoons - Hills or mountains		• 1- <5% of plot • 2- 5-25% of plot • 3- 26-50% of plot • 4- 51-75% of plot • 5- >75%of plot • 6- Outside plot • 0- Not present

*To be identified prior to the fieldwork
**Field categories to cross-check geomorphic spatial dataset

3.2.1 Geomorphic data

Geomorphology is indicative of sediment and tidal influence, and potentially vulnerability to climate change. We used the typology described in Worthington et al. (2020), which divides systems into Terrigenous and Carbonate to pre-identify the geomorphic setting of sites. In the field, we verified the geomorphic setting at the plot level using information on the water body influencing the site (Figure 4) and sediment grain size (Table 4).

Terrigenous systems, influenced by river and land-based sediment, are nutrient-rich and generally dominated by fine mud. Subtypes include:

- **Deltaic**: A delta is a shoreline sedimentary protuberance formed where a river enters an ocean, semi-enclosed sea, estuary, lake, or lagoon. Within a delta, sediment is rapidly supplied into the mangroves.
- **Estuarine**: Semi-enclosed coastal body of water with a free connection to the sea and where seawater is diluted with fresh water derived from land drainage.
- **Terrigenous lagoonal**: A shallow coastal water body separated from the ocean by a barrier, connected at least intermittently to the ocean by one or more restricted inlets, and usually oriented parallel to the shore.
- **Terrigenous open coast**: These areas include curved bays, deeply indented bays with winding shorelines, or narrow, tapering river valleys that have been flooded by the sea.

Carbonate mangrove systems are formed in areas with a calcium carbonate setting. They are characterized by nutrient-poor, clear waters and sandy or gravel sediment. These systems typically host mangroves adapted to low nutrient availability. They are divided into:

- **Carbonate lagoonal**: Low-energy coasts behind barrier islands, spits or bay barriers.
- **Carbonate open coast**: Form on oceanic islands, and behind coral reefs and carbonate banks. The sediment in these areas is formed from mangrove-based peat rather than from terrigenous inputs.
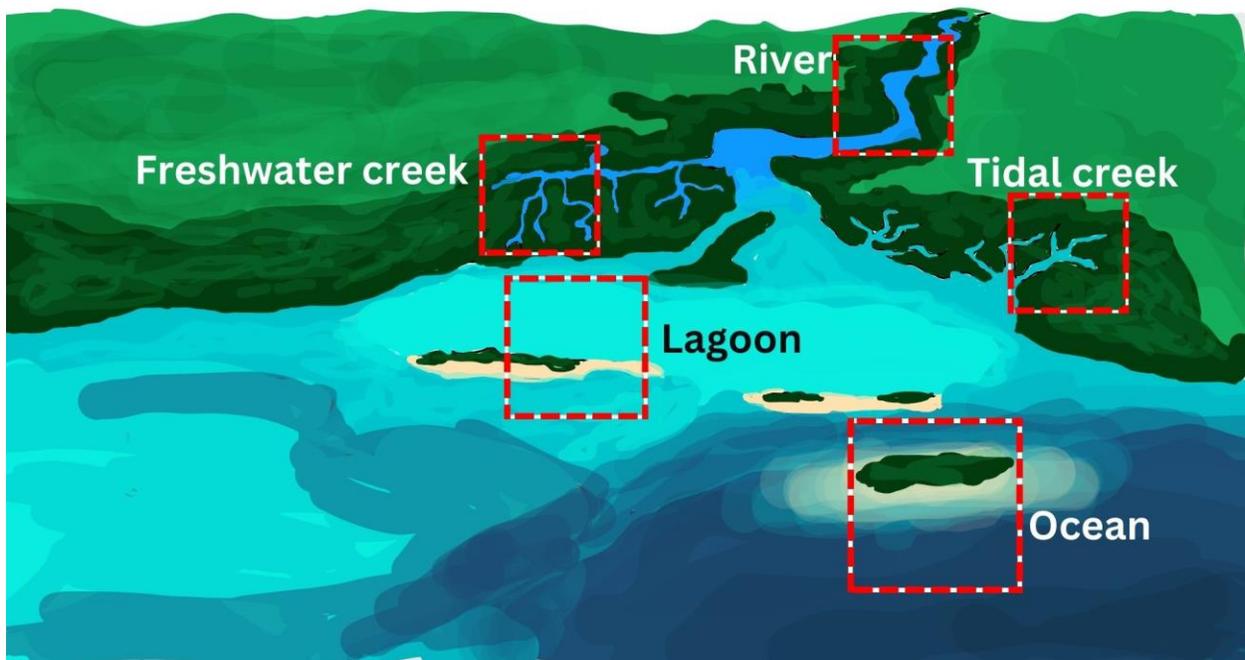
Figure 4 Diagram of mangrove distribution along varying influences of water bodies.

Grain size	Visual guide
Sand	
Clay	
Gravel	
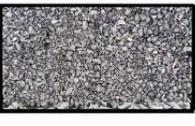
Table 4 Example of sediment with different grain size composition in mangroves.

3.2.2 Physiographic setting

The physiographic setting is shaped by climate factors, tidal amplitude, and the geomorphic context (Table 5). It influences vital ecosystem functions, including carbon storage, coastal protection, and fisheries support. We used the physiographic categories as described in "*The Ecology of Mangroves*" by Lugo and Snedaker (Lugo & Snedaker, 1974):

- **Fringing**: Mangrove forest that develops along shorelines, particularly in areas directly influenced by tidal action. These mangroves are characterized by their close association with water bodies such as estuaries, lagoons, or open coasts, where they are subject to regular inundation by tides.
- **Interior:** Mangrove forest located farther away from the shoreline and less influenced by tidal action compared to fringing mangroves. These mangroves typically form in low-energy environments, such as depressions or basins, where water accumulates and stagnates for longer periods.
- **Overwash**: Mangrove forest that develops on low-lying islands or coastal areas where tides completely inundate the mangroves.
- **Dwarf:** Mangrove forest characterized by stunted tree growth, resulting in relatively short, sparse canopies. These systems are often found in environments with environmental stressors that limit their development, such as nutrient-poor soils, hypersalinity, or extreme hydrological conditions

Physiographic setting	Diagram
Fringing	
Interior	
Overwash	
Dwarf	

Table 5 Physiographic Setting of Mangroves: Physiographic mangrove types (Lugo & Snedaker, 1974).

3.2.3. Biophysical

3.2.3.1 Redox

The soil oxidation-reduction refers to the amount of oxygenation in the soil, which can be indicative of pollution and inundation frequency. We measured redox potential using a redox potential probe (HANNAH instruments, model HI98121, Hannapro, Mexico), which typically consists of a platinum electrode paired with a reference electrode. The probe is inserted into the top 2 cm. Three measurements were required to obtain a final average value for each plot.

3.2.3.2 Salinity

Salinity is indicative of water circulation and water origin (e.g., marine vs groundwater). We measured salinity using a refractometer (Extech instruments, RF20, Teledyne FLIR, USA). Three measurements were required to obtain a final average value for each plot.

3.2.3.3. pH

A pH measurement quantifies how acidic or alkaline solutions are and is indicative of different biogeochemical processes that denote mangrove health, including nutrient availability, carbon sequestration, coastal acidification, and pollution. We measured pH using a sensor (HANNAH instruments, model HI98121, Hannapro, Mexico). Three measurements were required to obtain a final average value for each plot.

3.2.4 Ecological
3.2.4.1 Forest structure

- **Species composition**

  Only individuals with a stem diameter of >2.5 cm within the plot were counted.

  Red mangrove (*Rhizophora mangle)*:

  Characteristics: This species is distinguished by its prop roots, which offer stability in soft sediments and aid in gas exchange. Adapted to a range of water conditions, it thrives in brackish, fresh, and hypersaline environments. Mature trees can be from 6 to 15 meters tall. This species can be found in brackish to hypersaline conditions.
  Habitat: Predominant in the lower to mid-intertidal zones along shoreline edges.
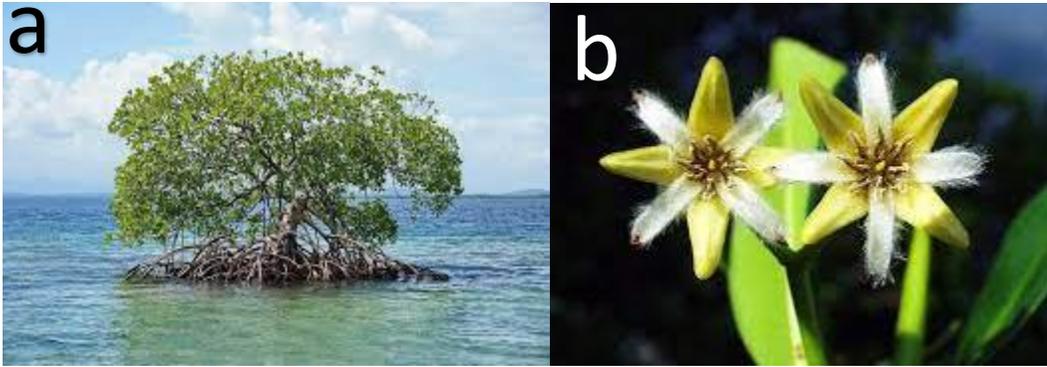
Figure 4 Adult red mangrove (a) and flower (b).

White mangrove (*Laguncularia racemosa*):

Characteristics: This species is identifiable by its light bark, small leaves, and small yellow flowers. It often develops pneumatophores. This species often develops pneumatophores and healthy mature trees are between 9-12 meters.

Habitat: Often found in freshwater but tolerates low salt concentrations, found at slightly higher elevations on the shore compared to other mangrove species.
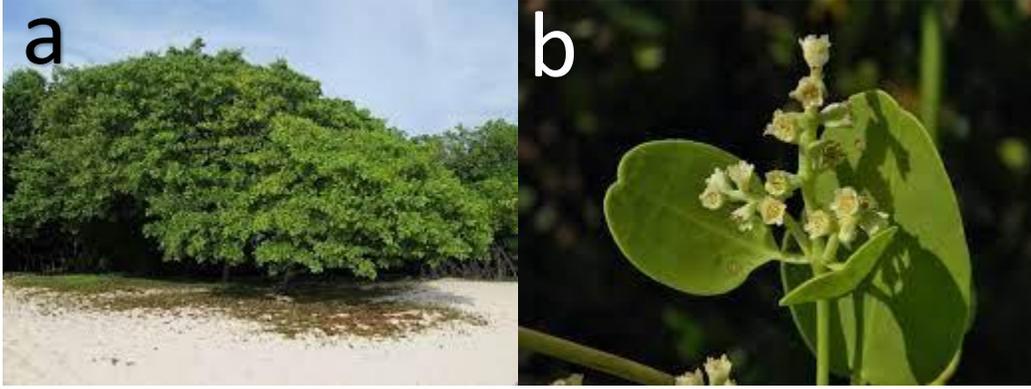
Figure 5 White mangrove depicted in its adult form (a), identified by its 5-15 cm long leaves, and small yellow flowers (b).

Black mangrove (*Avicennia germinans*):

Special Characteristics: dark bark and leaves with a silvery underside, it features pencil-like pneumatophores up to 30 cm above the soil, coupled with a salt excretion mechanism for high salinity tolerance, visible salt crystals can be seen on the underside of the leaves.
Habitat: Brackish waters and can survive in hypersaline conditions, usually located at higher elevations in the upper intertidal zone.

Figure 6 Adult black mangrove (a) with pencil-like pneumatophores, and leaves with a silvery underside (b).

- **Forest structure:** We estimated the average proportion of mangrove age categories per plot. We classified age categories as:

  o **Old trees** (thick, gnarled or scared trunk)
  o **New adults** (> 1m tall)
  o **Juveniles** (with props, ~ 1m tall)
  o **Seedlings** (no props)

- **Mangrove height:** We estimated and recorded the average canopy height in each mangrove area using the laser rangefinder ARTBULL, model L5-650, China. We classified height as:

  o **Short** (<2m)
  o **Medium** (2-5m)
  o **Tall** (>5m)

3.2.4.2. Vegetation health

Based on the assessment of mangrove health in the "State of the Mangroves Report 2008" by Mackenzie and Duke (2011):

- **Canopy retreat**: This condition involves thinning or diminishing of the tree canopy, evident through fewer leaves and dying branches. It signals ecosystem stress, typically due to environmental changes like water quality, salinity, temperature, or physical disturbances. Assessment involves observing and categorizing the extent of dead trees in the area.

    - **1** none (0%), no signs of retreat in the mangrove canopy.
    - **2** low (>0 to 30%) proportion of the canopy within plot shows retreat.
    - **3** moderate (>30% to 60%) proportion of the canopy within plot shows retreat.
    - **4** severe (>60%) proportion of the canopy within plot shows retreat.

- **Mangrove density:** Assess space available between trees and canopies into the following categories:

    - **Dense** overlapping canopies
    - **Medium** visible spacing between stems with touching as opposed to overlapping canopies.
    - **Sparse** clear spacing between individual trees and canopies. Note that sparse densities may not mean disturbance but mangrove type (e.g., scrub forests).

- **Seedling density**: Assess the density of mangrove seedlings (trees of less than 0.5m in height) within 1 m^2 of the plot centre. Classify seedling density as:

    - **none** (0/m^2)
    - **few** 1-3/m^2)
    - **some** (3-10/m^2)
    - **many** (>10/m^2)

3.2.5 Natural and anthropogenic pressures

3.2.5.1. Degradation threats

Degradation categories include excavation, erosion, highways, urban development, clearing, garbage, recreation, storm damage, and direct extraction.

To measure impact we collected information on the distance and extent of impact within the plot:

Distance:

- **0:** Not present
- **1:** Inside the plot
- **2:** 5 meters from plot
- **3:** 6-10 meters from plot
- **4:** >10 meters from plot

Extent:

- **1**: <5% of coverage of plot
- **2:** 5-25% of coverage of plot
- **3:** 26-50% of coverage of plot
- **4:** 51-75% of coverage of plot
- **5:** >75% of coverage of plot
- **6:** Outside plot
- **0:** Not present within the plot

3.2.5.2. Barriers to mangrove migration

Human-made barriers include agricultural areas, small roads, highways, and urban developments. Natural barriers encompass features like sand dunes, hills or mountains, and lagoons.

To measure impact we collected information on the distance and extent of impact within the plot as described in section **3.2.5.1**

3.3. Materials

3.3.1. Field equipment

In field surveys the following equipment will be used:

- 5m, 50m tape
- 2 ribbons 5m long
- 4 sticks with ribbons on tops
- printed datasheets
- pencils
- sharpener
- eraser
- clipboard folders
- chalk
- $1m^2$ quadrant (maybe a ribbon one that can be extended)
- redox meter
- salinity meter
- spray bottle with fresh water
- cloth
- icepack
- laser rangefinder
- GPS

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5. Annex 1– Data collection sheets

Date:	Start time:	Finish time:	**Overall condition in the surroundings of the plot** (note things like turbid/clear water, water stagnation/flow, few surviving trees, garbage, leaf condition). Continue at the back of page if necessary.
Hexagon ID:	**Lat/Long:**		
Plot number:	**Tide** (low or high):		
GPS ID:	**Observers:**		

Water body influence (tick if near or adjacent to the plot):

☐ River   ☐ Ocean
☐ Tidal creek
☐ Lagoon
☐ Freshwater creek

Physiography (tick all that apply):

☐ Fringing   ☐ Dwarf
☐ Interior   ☐ Not dwarf
☐ Overwash

Stand age (percentage within plot of each category):

.... Old trees   .... Juveniles

.... New adults   .... Seedlings

Grain size (tick one):

☐ Sand
☐ Clay
☐ Gravel

Mangrove density (of old and new adults):

☐ Dense (overlapping canopies)
☐ Medium (touching canopies)
☐ Sparse (spaced canopies)

Salinity (ppt) (three measurements per plot):

1)   2)   3)

Redox (mV) (three measurements per plot):

1)   2)   3)

pH (three measurements per plot):

1)   2)   3)

Seedling density (no props roots developed, within 1m² of plot)

☐ 0 (none)
☐ 1-3 (few)
☐ 3-10 (some)
☐ >10 (many)

Mangrove height (average within plot of old and new adults):

☐ Short (<2m)
☐ Medium (>2-5m)
☐ Tall (>5m)

Canopy retreat (dying branches, few leaves, thinning canopy) (average within plot):

☐ None (0%)
☐ Low (>0-30%)
☐ Moderate (>30%-60%)
☐ Severe (>60%)
☐ NA

Species composition (specify for old trees, new adults, juveniles and seedlings):

Black mangrove:

Count:

....

Red mangrove:

Count:

....

White mangrove:

Count:

....

Degradation threats (tick if near or within the plot and write extent within plot):

	Extent	Distance
☐ Excavation	....	....
☐ Erosion	....	....
☐ Highways	....	....
☐ Urban development	....	....
☐ Clearing	....	....
☐ Garbage	....	....
☐ Recreation	....	....
☐ Storm damage	....	....
☐ Direct extraction	....	....
☐ Other	....	....

Migration barriers:

	Extent	Distance
☐ Small roads	....	....
☐ Agriculture	....	....
☐ Aquaculture	....	....
☐ Highways	....	....
☐ Urban development	....	....
☐ Lagoons	....	....
☐ Hills or mountains	....	....

Extent categories:

1- <5% of plot
2- 5-25% of plot
3- 26-50% of plot
4- 51-75% of plot
5- >75%of plot
6- Outside plot
0- Not present

Distance categories:

0- Not present
1- Inside plot
2- 5 m from plot
3- 6-10 m from plot
4- >10 m from plot

5. Annex 1– Data collection sheets

Condition categories:

- "Healthy" = Low amounts of standing dead and/or leaf damage, no obvious anthropogenic disturbance
- "Degraded" = Relatively healthy individual trees but either sparse or the sites are heavily disturbed by pollution, cutting, palms, debris, and stagnant water
- "Regeneration" = Degraded or cleared but showing natural regeneration
- "Cleared" = Vegetation completely removed with only roots and dead branches remaining
- "Transitioning" = Mostly cleared and transitioning into another ecosystem due to pollution, topographic or tidal flow alterations
- "Filled" = Cleared and filled with material like gravel or sand
- "Construction" = Cleared, and construction is imminent or present

Hexagon ID	Plot ID	GPS ID	Lat/ long	Condition	Land tenure	Area

5. Annex 1– Data collection sheets

Field rules of data collection

For the "Condition categories" datasheet:

1. Fill the 'Condition categories' datasheet <u>first and for all visited sites</u>.
2. An example of a 'Degraded' site is like the one next to UNO gas, with just a few, scattered mangroves poorly growing.
3. An example of a 'Cleared' site is like the long but thin strip of land in front of UNO gas, where you could still see the roots and branches of the mangroves and <u>has not</u> been filled with material or flattened.
4. An example of a 'Regeneration' site is like the mangroves that are growing in the shrimp ponds inside Captain's Hook shrimp farm. The difference between this site and 'Degraded' is that inside the shrimp pond you can see that the seedling density is much higher, indicating that the conditions are appropriate for mangroves to grow if they let them grow.
5. An example of a 'Transitioning' site is like patches next to the Western highway with grass and ferns taking over mangroves.
6. An example of a 'Filled' site is like the patch on Chetumal Road belonging to the Ministry of Finance and Economic Development, that has been flattened and filled with material.
7. Write as much information as possible about the land tenure of each of the sites, write information of the real estate agency if a sign is present, or any other information that can indicate possible owner or purpose of the land.
8. If possible, measure the area of the patch under the specified condition or provide an approximation.
9. Take photos of all sites
10. Check the cases were there is a mismatch between having distance and extent entries

For the full datasheet:

1. Continue to full data collection of sites that fall within the 'degraded' category.
2. Transect should be perpendicular to the water (either a channel or the ocean).
3. Start transect a couple of meters from the water edge.
4. The transect should aim to be representative of the overall condition of the site (do not try to bias data collection to 'healthier' parts of the site, but something that looks representative of the level of degradation of the site).
5. Aim to complete 3 plots per site, but if the area that is degraded is small then do as many as possible.
6. Aim to take measurements of salinity, ph and redox of as many sites as possible if it doesn't compromise too much on time.
7. Aim to complete a linear transect, but direction between plots could be at an angle if needed.
8. Individuals are counted only if trunk is inside the plot, not the roots.
9. When assessing canopy retreat include what is already dead inside the plot.
10. 'juveniles' are plants that already have props, but are still about 1 m tall. New Adults are more than 1 m tall but >2.5 cm stem diameter. In the case of dwarf mangroves, we only distinguish between seedlings and adults.
11. Canopy retreat: when there is no canopy because the site has been degraded and there's only juveniles present and really sparse then select NA
12. Clean redox and salinity meter after each measurement. Calibrate often.
13. Take redox and salinity measurements of undisturbed water (water where you havent stepped on).
14. Think about where you are going to collect the redox and salinity measurement from before you start measuring the plot to avoid disturbing all water inside the plot).

5. Annex 1– Data collection sheets

1. Mangrove distribution across varying influences of water

Freshwater creek

River

Lagoon

Tidal creek

Ocean

4. Mangrove density

Sparse
Clear spacing between trees

Medium
Visible spacing, canopies touching

Dense
Canopies overlapping

DENSE

MEDIUM

SPARSE

5. Mangrove species

RED MANGROVE
Rhizophora mangle
- Reddish bark and yellow and white flowers
- Common in lower to mid-intertidal zone, along shorelines
- Height is between 6-15 meters

RHIZOPHORA MANGLE

WHITE MANGROVE
Laguncularia racemosa
- Small flowers and lighter color bark
- Located at slightly higher elevations in upper intertidal zone
- Height is between 9-12 meters

LAGUNCULARIA RACEMOSA

BLACK MANGROVE
Avicennia germinans
- White flowers and black bark
- Located in hypersaline conditions and at higher elevations in the upper intertidal zone
- Height is up to 12 meters, but can be dwarf

AVICENNIA GERMINANS

2. Physiographic setting

Fringing:
- Edges of protected shores & islands.
- Heavily influenced by tide
- Well-developed prop roots that trap debris

Overwash:
- On smaller islands & land projections (shallow bays & estuaries)
- Submerged during high tides.

Interior:
- Away from regular tidal influence
- Older, smaller mangroves suggesting limited nutrient availability

Dwarf:
- Found on flat coastal fringes
- Small stature & plants often quite old.

FRINGING

OVERWASH

INTERIOR

DWARF

3. Grain size

Sand
Coarse and often fine particles

Clay
Akin to mud and dirt, keeps shape when molded

Gravel
Loose aggregation of water-worn stones

SAND

CLAY

GRAVEL

6. Canopy retreat

1: (0% of canopy retreat)
Twigs and branches in individual trees are mostly covered with leaves in their entirety AND/OR most trees within the plot show extensive presence of foliage and naked twigs and branches are due to leaves falling at a natural rate

1

2: (>0-30% of canopy retreat)
Naked twigs and branches in individual trees are more noticeable but do not represent more than 30% of the canopy condition of individual trees AND/OR trees in the plot still retain 70% of their leaves.

2

3: (>30-60% of canopy retreat)
Substantial amount of main branches in individual trees are devoid of foliage, representing around half of the condition of individual tree AND/OR trees in the plot still retain over 40% of their leaves.

3

4: (>60% of canopy retreat)
Less than half of the twigs and branches of an individual tree have foliage AND/OR less than half of the trees in the plot have less than 40% of their leaves, with mostly naked twigs and branches.

4