Corozal Bay Wildlife Sanctuary

Research and Monitoring Plan



SACD | Sarteneja Alliance for Conservation and Development

Wildtracks

Corozal Bay Wildlife Sanctuary, Belize

Corozal Bay Wildlife Sanctuary

Research and Monitoring Plan

Acknowledgments

This plan summarises two years of work by the staff of the Sarteneja Alliance for Conservation and Development, particularly Joel Verde (Executive Director), Marcelo Cruz, Leomir Santoya and Andonys Arrivillaga (the Patrol Team), and Jamilee Cruz and Noe Verde (the SACD Interns), Zoe Walker (Wildtracks) and Jen Chapman (Blue Ventures).

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Wildlife Conservation Society

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Corozal Bay Wildlife Sanctuary

Introduction

This Monitoring Plan provides an integrated framework for implementation of research and monitoring activities for Corozal Bay Wildlife Sanctuary, by Sarteneja Alliance for Conservation and Development activities, under their co-management agreement with the Forest Department. Activities are guided by the Vision, Mission, Objectives and guiding principles of the organization and focused on providing information for improving the viability of Corozal Bay Wildlife Sanctuary as a functional protected area within Belize's and the region's marine protected area network.

Section 1 provides a brief introduction to Corozal Bay Wildlife Sanctuary.

Section 2 highlights the conservation targets that SACD and the stakeholder communities have identified as conservation priorities, their baseline status (2012), and the threats that impact these. This information has been used to develop the biodiversity and environmental monitoring activities considered critical within CBWS. A quality assurance plan is also included for each monitoring sub-programme. **Section 3** assesses monitoring requirements for effective decision making for climate change adaptation, and **Section 4** provides background on the Sarteneja Alliance for Conservation and Development, the co-management partner for Corozal Bay Wildlife Sanctuary.

The plan should be reviewed, evaluated and updated at the end of every two years to ensure that the current target status remain relevant, and any additional monitoring requirements can be integrated.

Contents

1.0 Corozal Bay Wildlife Sanctuary

Situated in the north east of Belize, Corozal Bay Wildlife Sanctuary was established in 1998 as part of Belize's National Protected Areas System, as one of three protected areas highlighted as critical for the maintenance of Belize's population of West Indian manatee (*Trichechus manatus*). The area acts as a settling basin, removing sediment before the estuarine waters reach the sea, assisting in the maintenance of the Belize reef. It is also important for its mangroves and shallow coastal lagoons, its nursery functionality for commercial fish species and bull sharks, and its bird nesting colonies and stromatolites.

This national protected area encompasses approximately 178,000 acres (72,000 hectares) of the Belize portion of the Mesoamerican Reef's largest estuarine system, and much of the northern shelf lagoon behind Ambergris Caye. The Wildlife Sanctuary has been identified as an important transboundary drainage system, shared by Mexico and Belize, and one of the principle areas with transboundary issues (GEF, 2001).

The Sarteneja Alliance for Conservation and Development (SACD) is currently strengthening the transboundary collaboration with SEMA (Secreteria de Ecologia y Medio Ambiente), the management authority for Santuario del Manati in Mexico, and with ECOSUR (El Colegio de la Frontera Sur), with particular focus on the Research and Monitoring Programme.

Location of Corozal Bay Wildlife Sanctuary in the conservation landscape

Corozal Bay Wildlife Sanctuary

As an estuarine system, the biodiversity of the Bay is heavily influenced by the physical parameters – particularly currents, salinity, temperature, turbidity and water depth. With tidal influence being minimal, seasonal changes in these parameters are driven primarily by the wind direction, with the predominant winds being from the south-east or north. The south east winds from February / March to November push water into the Bay, with a corresponding increase in water depth. This then switches to strong northerly winds from November to February, pushing the water southwards, out of the Bay, bringing colder temperatures and reduced water depth.

Seagrass, the predominant benthic ecosystem of the Bay, thrives within a specific range of salinity, temperature and water clarity conditions. Seagrass distribution will in turn influence the foraging patterns of West Indian manatees. Commercial fish species populations fluctuate within the Bay dependent on the changing physical parameters, as do those of sharks and rays. The latter enter the estuary in the dry season to pup.

With so much dependent on these physical parameters, their monitoring is a centre point for the Research and Monitoring Programme, providing the context within which the majority of the other Conservation Targets change. Understanding the changes in the water body of the estuary system is critical to understanding the natural fluctuations in biodiversity. It is also critical in being able to monitor change over time as the impacts of climate change become more evident, assisting in the formulation of adaptation strategies.

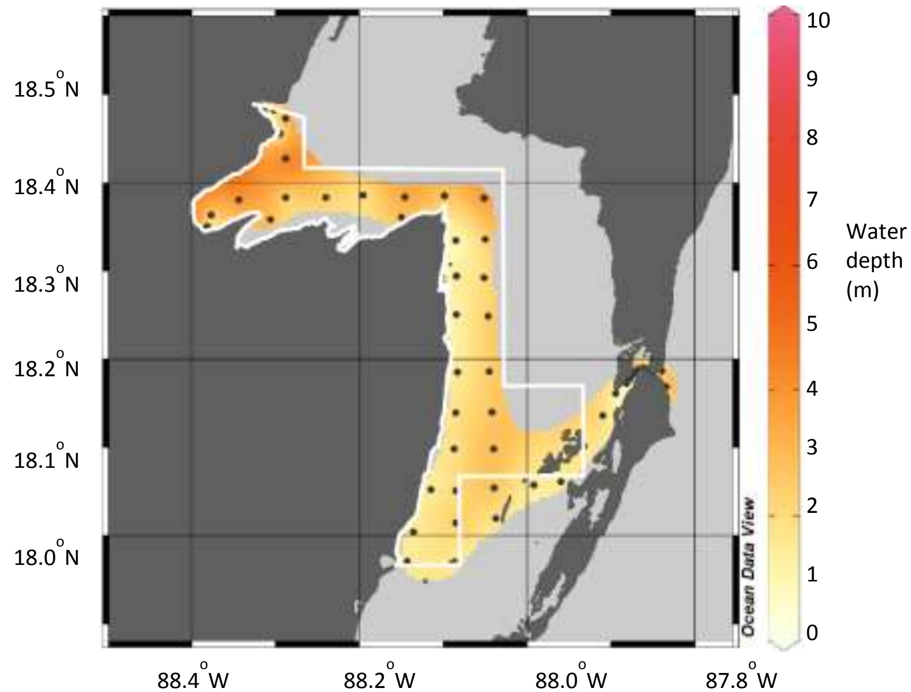


Figure 1: Water Depth in Corozal Bay Wildlife Sanctuary (Norther Season, 2013)

Corozal Bay Wildlife Sanctuary – a regionally important estuarine area of seagrass beds, mangroves and cayes, supporting livelihoods, threatened species and providing ecosystem services…

2.0 Conservation Targets

Eight key conservation targets have been identified for effective biodiversity management of Corozal Bay Wildlife Sanctuary.

- West Indian Manatee
- Local Fish species
- Bird Nesting Colonies
- Mangroves and other Coastal Ecosystems
- Seagrass
- The Estuarine Environment - Water Quality
- Sharks and Rays
- Stromatolites

The Research and Monitoring Programme is focused on providing information for effective management of the identified conservation targets, and through them, of the natural resources within the Wildlife Sanctuary, with outputs feeding back into the adaptive management regime.

2.1 West Indian Manatee

The West Indian manatee (*Trichechus manatus*) is recognized as a globally Vulnerable species under the IUCN Redlist (IUCN, 2008). Of the two sub-species, the Antillean manatee (*Trichechus manatus manatus*) is found in Belize, and protected under the Wildlife Protection Act, No. 4 of 1981). Corozal Bay Wildlife Sanctuary was designated as one of three core areas in Belize considered important for maintaining viable populations of manatees, and is highlighted as particularly important for mating and calving (Auil, 2008). Despite these designated protected areas, and the laws that protect manatees, the national population is being impacted as a result of the boat collisions, loss of seagrass areas and continued poaching, exacerbated by limited law enforcement due to limited resources.

Corozal Bay is contiguous with Chetumal Bay to the north, on the Mexican side of the border, and manatees, not recognizing international borders, have been tracked moving from one side of the bay to the other (Auil, 2008; Castelblanco et al., 2012). Both protected areas (Corozal Bay Wildlife Sanctuary and Sanctuario del Manati) were established as part of a transboundary initiative to protect this species. During the management planning process for Corozal Bay Wildlife Sanctuary, community meetings were held in Sarteneja, Chunox and Copper Bank to identify those areas particularly important for the manatee population, for informed creation of no-wake zones, guiding targeted patrols and providing a focus for monitoring activities.

***Management Goal**:* Protection of the West Indian Manatee through improved information, focusing on maintaining and improving the manatee population within Corozal Bay Wildlife Sanctuary, whilst reducing potential threats to this species.

Manatee: Viability	Current Rating	Goal	Justification
	GOOD	**GOOD**	***Justification:*** Reproducing population – mother and calves, relatively few strandings, Population is relatively stable. Aerial surveys show at least 40 resident to 100+ with mating itinerant males. Poaching for last year was 0, reduced generally over last 4 years. Majority of users are aware of boat impacts on manatees and respect no-wake zones
	Functioning within its range of acceptable variation; **may require some human intervention**	Functioning within its range of acceptable variation; **may require some human intervention**	***Indicators:*** ▪ Tri-Annual aerial survey results ▪ Results from resting holes monitoring ▪ Stranding results (live and carcass) ▪ Community survey results on population ▪ Seagrass indicators


Photo: Annelise Hagan

West Indian Manatee

Current Status:

The current population size of West Indian manatee within the Corozal Bay Wildlife Sanctuary is estimated at between 100 to 150 individuals, extrapolating from the highest count of 59 individuals in one survey flight. Population counts fluctuate during the year, with highest numbers being recorded during the norther season (January / February).

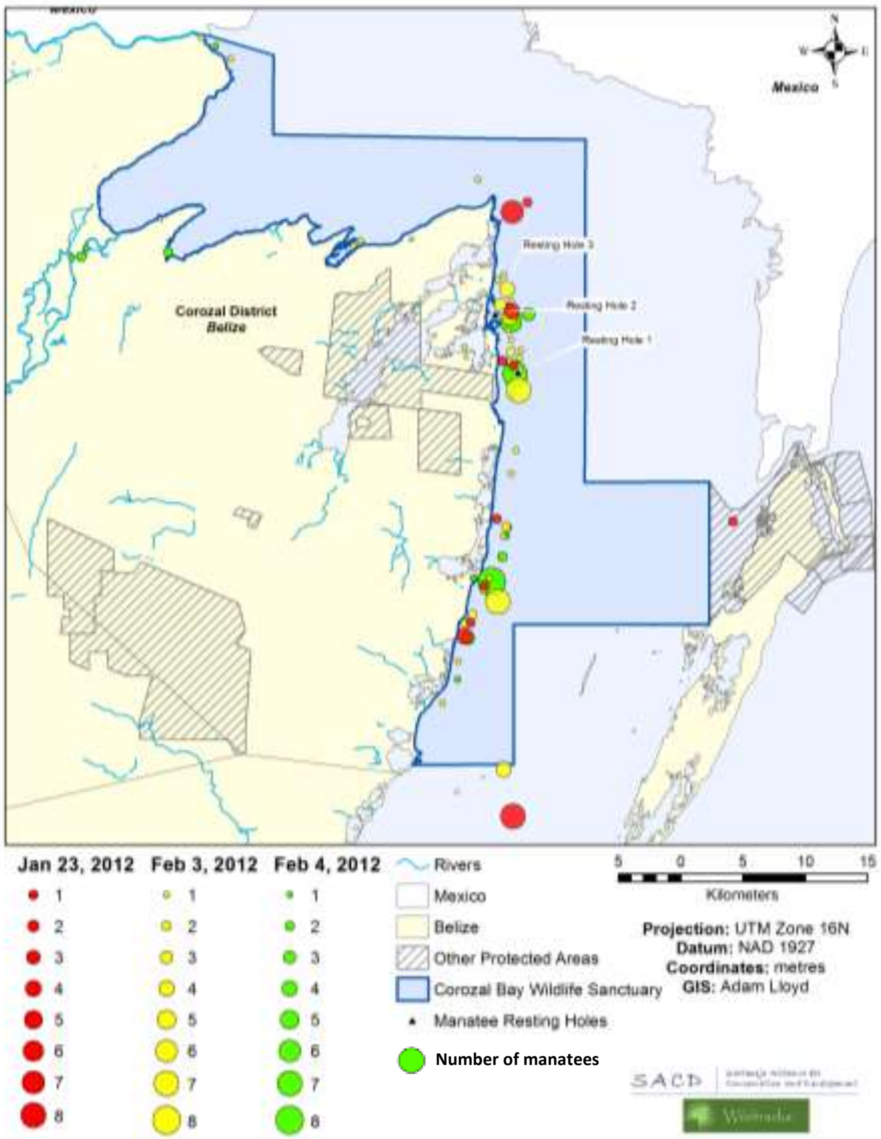
The importance of three resting sites along the eastern coastline has been confirmed, with as many as 16 individuals being seen at one site at any one time.

Aerial Surveys: A series of aerial surveys have been conducted with LightHawk to provide baseline information, scheduled for dry, wet and norther seasons, with three replicates per season.

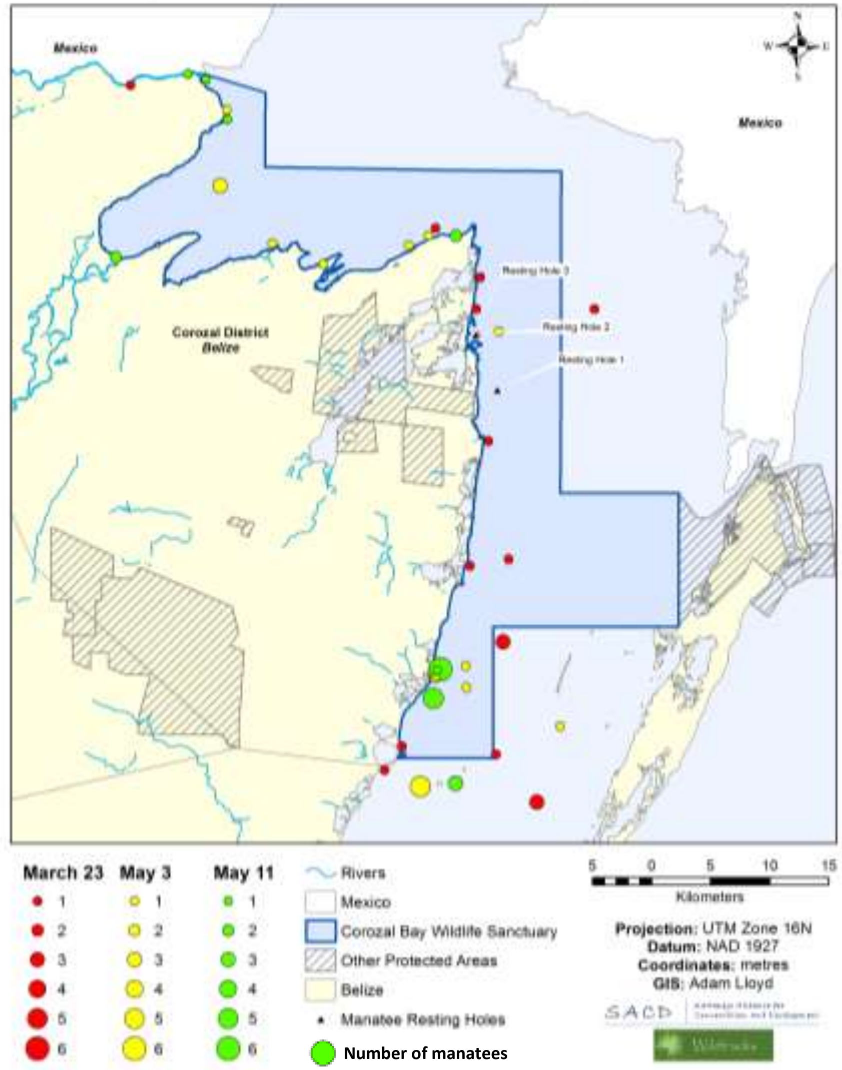
Resting Holes: Manatees are monitored at the three resting holes on the east coast – these are characterized by depressions in the substrate, often in areas that experience slower currents, protection from wave action, abundance of seagrass and less boating traffic. The physical characteristics of these, as well as the number of manatees that are using them, are being monitored on a regular basis.

Opportunistic sightings: Opportunistic sightings are recorded during patrols and other water-based activities.

	Ecosystem requirements	Details
Basic needs	Seagrass and other aquatic vegetation beds	Condition of seagrass, micronutrients, diversity of diet, preference of one species over another, etc.
	Shelter – quiet places for resting	Resting holes/areas, calving/new-born areas, shelter from catastrophic events, nursery areas, etc.
	Fresh water	River mouths and upstream, salinity measures in the Bay
	Clean water	Away from nutrient loads from agricultural and chemical run-off, free of parasite-causing agents
	Warmer temperature	Lagoon temperature can go down to 16°C, manatees will move to warmer waters
Also need to consider…	Travel corridors	Safe passage between areas of usage (within & outside the CBWS)
	Juxtaposition of resources	Reasonably close areas of seagrass, resting, fresh water, etc.
	Resources for expansion	If populations recover and grow, resources should be identified based on the ecosystem requirements above



Norther Season



Dry Season

Figure 2: Combined aerial survey results for Norther and Dry seasons, 2011 / 2012 (3 replicate flights per survey)

West Indian Manatee

Impacts

Three primary threats were identified during planning for conservation of the West Indian manatee:

- **Coastal development** (mangrove clearance, sedimentation /runoff, dredging)
- **Pollution** (agro-chemical and sewage, toxins/ bioaccumulation of toxins, plastics)
- **Poor use practices** (nets, boats, tourism)

Whilst past reports suggested manatees were slaughtered within the Wildlife Sanctuary for their meat, this practice is thought to have stopped in the last four to five years. However a recent, unconfirmed report of meat for sale in Caye Caulker (J. Galves, 2012) suggests that this may still be an active threat.

Calves are occasionally caught in beach traps, but released unharmed by the fishermen. SACD has an agreement with the beach trap fishermen for removal of all beach traps by the end of the season, in November, thereby preventing manatees becoming accidentally caught when beach traps are not visited on a regular basis.

Entanglement in nets is also perceived as a threat, with gill nets being left out overnight, sometimes without the constant presence of the fisher.

Stranding Protocol

As a member of the Belize Marine Mammal Stranding Network, SACD responds to manatee and dolphin strandings within the Corozal Bay area. Strandings can be either live or dead animals. If alive, it is either an orphaned calf or injured animals thought to require assistance. When arriving at a stranding site, the site should be secured, preventing the general public from approaching the stranded animal.

You will need:

- Clip board and data sheets
- Camera
- Necropsy kit

Basic data to be collected from a dead animal includes:

- Location / date
- Sex
- Length
- Girth
- Scars / wounds
- Cause of death (if determined)

If someone trained in performing necropsies is available, a necropsy should be done following the "Manual of Procedures for the Salvage and Necropsy of Carcasses of the West Indian Manatee" (Bonde, Shea and Beck, 1983).

If it is a live stranding, keep the animal wet (particularly the eyes) and call Wildtracks for assistance…650-6578.

West Indian Manatee

Protocols: Aerial Surveys

Aerial surveys are conducted during dry, wet and norther seasons, During the preliminary surveys (2011 and 2012), three replicates were conducted to ensure data consistency and for strengthening the initial baseline and monitor changes.

1. Surveys should be conducted once a season:
   - Dry Season
   - Wet Season
   - Norther Season

2. The survey flight should be at a consistent height of 150m above sea level, and when parallel to the coast, approximately 400m from the coastline, and travelling at 180km/hr, with each observer scanning a 400m-wide transect band. Each survey follows the same pre-planned route (Figure 3).

3. The survey team consists of two observers (one on each side of the plane), and two data recorders, working as two teams. Each data recorder should have a GPS and clipboard / paper to record the observations of their designated observer.

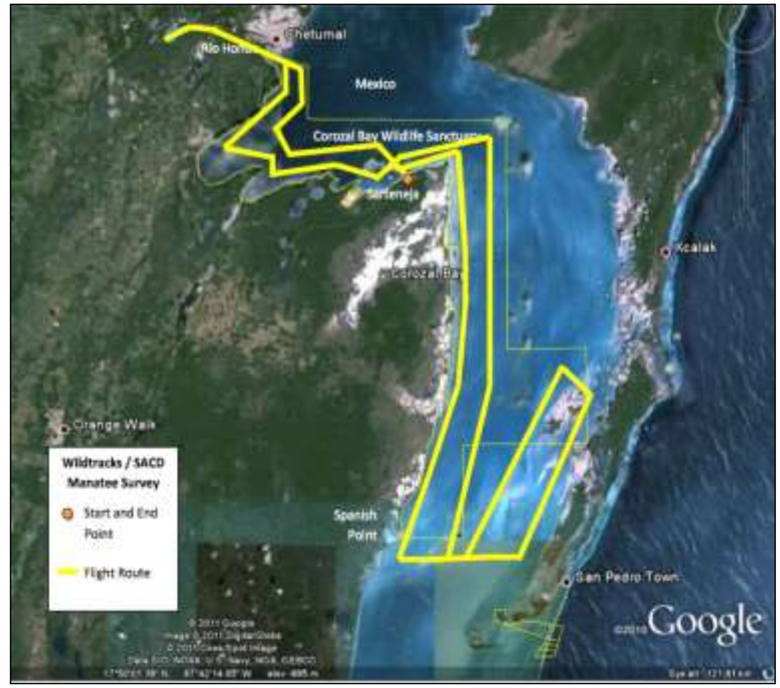


Figure 3: Aerial Survey route - CBWS manatee aerial surveys

4. As each manatee is spotted, the observer reports the sighting to the recorder, who marks the point on the GPS and notes the waypoint number and sighting information on the paper.

5. The data is entered and saved into an Excel file, and points mapped per flight using ARCGIS (Wildtracks)

All monitoring information should be collated in the monthly and quarterly reports

Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Norther Season			*Dry Season*			*Wet Season (excl. August)*					*Norther*

West Indian Manatee

Protocol: Resting Hole Observation

Resting Hole surveys should be conducted monthly where feasible

1. Reduce engine power 1.6km from the hole, and idle until near enough to turn off the engine (If a pole is available it is recommended that it is used when the boat is 20 metres from the site). Ensure that the boat is stopped at least 15 metres from the manatee resting hole and lay the anchor.

2. Divide the surrounding sea into quadrants that correspond to the number of people on the team. Each team should watch their assigned portion for possible manatee sightings for 30mins.

3. When an observer sees a manatee, this should then be confirmed by another member of the team and all data recorded.

4. If no manatee is observed, pole the boat to the sink hole and take the following measurements at intervals of 0.5m depth:
    - Sample Depth (m)
    - Salinity (ppt)
    - Temperature (°C)
    - Dissolved Oxygen (mg/L and % saturation)

5. If a manatee is observed in the sink hole DO NOT proceed any further. Instead estimate the information required for the data sheet and try to obtain the required measurements

Protocol: Opportunistic Sightings

If an opportunistic sighting of a manatee during patrols, research and monitoring trips or site visits, stop the boat and observe its behaviour. **DO NOT** follow the manatee.

Record the following information in the patrol log where feasible:

- Recorder
- GPS coordinates
- Weather conditions
- Number of manatees
- Size, condition and behaviour of manatee
- Any visible scars

If the sighting is during a non-patrol activity, data should still be collected if possible, for addition to the patrol data on opportunistic sightings.

Opportunistic sightings of dolphins should be recorded using the same protocol.

IMPORTANT!!

- **IT IS MORE IMPORTANT TO NOT STRESS THE ANIMAL THAN TO GET THE DATA**
- **DO NOT FOLLOW THE MANATEE TO GET THE DATA**
- **DO NOT ENTER THE WATER WITH THE MANATEE**

West Indian Manatee – Quality Assurance Plan	
Method	***Seasonal Aerial Survey***
References	León David Olivera-Gómez and Eric Mellink (2002). Spatial and temporal variation in counts of the Antillean manatee (*Trichechus m. manatus*) during distribution surveys at Bahia de Chetumal, Mexico. Aquatic Mammals 2002, 28.3, 285–293
Quality Control	Two spotters with at least two survey flights experience. Two recorders with adequate GPS experience. GIS mapping of outputs (Wildtracks). Ensure GPS used are set to UTM Central NAD27, and have fresh batteries.
Environmental Impact Mitigation	
Data Storage and Analysis	Storage: Hard copies and Excel file Analysis: Seasonal and annual variations in numbers
Reporting / Dissemination	Post survey report integrated into quarterly report to Forest / Fisheries Departments GIS mapping of outputs Annual Monitoring Report
Method	***Manatee Resting Hole Monitoring***
References	Manatee Resting Holes Observation Protocol (developed by C. Self-Sullivan for SACD). Marie-Lys C. Bacchus (2006). Characterization of Resting Holes and Their Daily and Nightly Use by Antillean Manatees (*Trichechus manatus manatus*) in the Drowned Cayes, Belize.
Quality Control	Two experienced spotters.
Environmental Impact Mitigation	**NO PERSON SHOULD ENTER THE WATER WHEN MANATEES ARE PRESENT** **THE BOAT SHOULD NOT APPROACH THE MANATEE HOLE IF MANATEES ARE PRESENT** **THE BOAT SHOULD NOT APPROACH OR FOLLOW MANATEES NEAR THE HOLE**
Data Storage and Analysis	Storage: Hard copies and Excel file Analysis: Correlation of numbers of manatee to seasonal variations in water parameters
Reporting / Dissemination	Post survey report integrated into quarterly report to Forest / Fisheries Departments Annual Monitoring Report

West Indian Manatee – Quality Assurance Plan	
Method	***Necropsy***
References	Bonde, Shea and Beck (1983). Manual of Procedures for the Salvage and Necropsy of Carcasses of the West Indian Manatee.
Quality Control	The necropsy should only be performed by trained Marine Mammal Stranding Network members (for Corozal Bay, this would be Wildtracks), or a qualified vet. Photographs should be taken at all phases of the necropsy, as well as a written log of animal and organ condition, as per Bonde et. al., 1983.
Environmental Impact Mitigation	**FOR HEALTH AND SAFETY REASONS, NO MEMBER OF THE PUBLIC SHOULD TOUCH THE CARCASS** Once the necropsy has been completed, the carcass should be towed to a shoreline at least 1km from the nearest habitation.
Data Storage and Analysis	Storage: Photographs stored on Research and Monitoring computer. Necropsy notes written up as a report, with integrated photographs Analysis: Number of stranded animals per year, cause of death (where determinable)
Reporting / Dissemination	Necropsy report submitted to Forest Department and the Manatee Working Group GIS mapping of stranded animals Annual Monitoring Report

Fishermen assist with rescue of a stranded manatee – a young calf caught in a fish trap is freed and reunited with its mother

West Indian Manatee: Strategic Actions		**Desired Status**
Research and Monitoring Programme		
Baseline information on the West Indian manatee population of Corozal Bay Wildlife Sanctuary	▪ Identification of key manatee feeding and resting areas ▪ Aerial surveys in the three seasons of the year ▪ Monthly monitoring of manatee resting hole numbers	▪ Information on manatee population of Corozal Bay Wildlife Sanctuary and key resting and feeding areas ▪ Established baseline against which to measure population fluctuations
Other Research and Monitoring Activities	▪ Recording of opportunistic sightings of manatees during patrols and other activities ▪ Active stranding response ▪ Collaboration with Wildtracks in tracking released rehab manatee(s) / tracking data ▪ Collaboration with J. Galves (CZMAI) on movements of Belize City manatees in CBWS ▪ Collaboration with ECOSUR on transboundary manatee movements ▪ Collaboration with Blue Ventures on information on Bacalar Chico manatees ▪ Linked with other monitoring targets – water quality, seagrass	▪ Additional information on manatees collected on an opportunistic basis, on which to base management strategies ▪ Information collated on manatee deaths in Corozal Bay Wildlife Sanctuary ▪ Strengthened collaboration within Belize and with Mexico for more effective conservation of manatees
Natural Resource Management Programme		
Increase knowledge of identified threats: ▪ Boat traffic ▪ Coastal Development ▪ Hunting for meat ▪ Unregulated tourism ▪ Poor water quality ▪ Reduction of seagrass habitat	▪ Identification of key boat impact areas ▪ Erect no-wake signs in key manatee / boat conflict areas ▪ Identification of communities / people targeting manatees for meat, slaughter ground and markets (if occurring) ▪ Strategic patrols of key manatee tourism sites within Corozal Bay Wildlife Sanctuary ▪ Recording and reporting of dredging activities within the Wildlife Sanctuary	▪ Identification of current and potential threats, guiding spatial and temporal surveillance and enforcement activities, and collaborative partnerships

2.2 Commercial Fish Species

Fishing within the Corozal Bay Wildlife Sanctuary has been identified as a traditional resource-use activity, practiced from generation to generation, generating an income for families, and providing an important protein source in stakeholder communities. However, community consultations indicate that commercial fish stocks within the Wildlife Sanctuary have fallen significantly since the arrival of gill nets twenty to thirty years ago, with the near extirpation of species such as the goliath grouper and the small-tooth sawfish over the last fifteen years.

Management Goal: Improved commercial fish populations and viability within Corozal Bay Wildlife Sanctuary, with a sustainable fishery supporting traditional artisanal fishermen.

Current Status: An estimated 33 to 35 fishermen and their families are considered to be dependent or largely dependent on the small scale fishery of Corozal Bay Wildlife Sanctuary. The majority of these are from Sarteneja, with the highest dependency, whilst those from Corozal and Consejo have lower dependency with greater opportunities for non-fishing related employment.

Mapping exercises in the stakeholder communities demonstrate that there is a loose division of the fishing area per community, with Sarteneja using the largest percentage of the Wildlife Sanctuary. Fishing activities are almost exclusively within 300m of the shore, focused on species that move up and down the coastline, using a variety of fishing methods and equipment.

Fourteen species are regularly fished from Corozal Bay Wildlife Sanctuary for commercial or home-use purposes, with four of these considered key targets for fishery management.

- Striped Mojarra
- Yellow-fin Mojarra
- Grey Snapper
- Great Barracuda

A baseline for the beach trap fishery was established for 2011, with results summarised in the SACD report "Planning for a Sustainable Fishery" (SACD, 2012).

Commercial Fish Species: Viability	Current Rating	Goal	Justification
	FAIR	**GOOD**	***Justification***: Reduced fish populations due to unsustainable fishing practices and transboundary incursions
	Requiring **urgent human intervention** to restore numbers to viable levels	Functioning within its range of acceptable variation; **may require some human intervention**	***Indicators:*** ▪ Average size of catch per year per beach trap

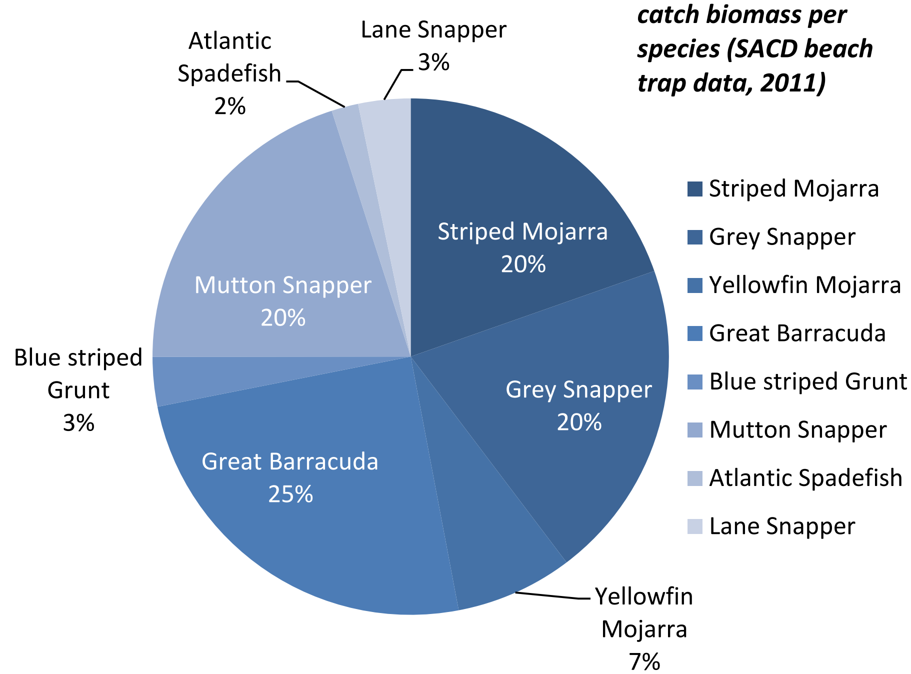
Commercial Fish Species

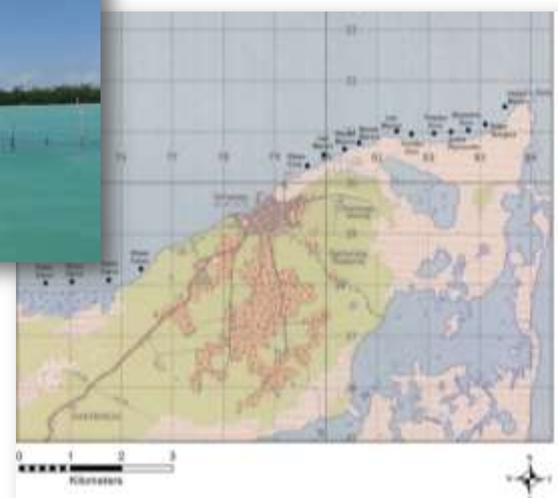
Sarteneja Beach Trap Fishery

Sarteneja is the only community of CBWS to have beach traps (with one exception – a permanent trap positioned by Deer Caye, operated from Corozal). These consist of a line of wooden sticks spaced 2 feet apart extending 250-300ft from shore, leading into a circle 25-30ft in diameter, targeting species that move parallel to the shore. This is a traditional fishing method for the area, with traps being passed from father to son. 10 trap fishermen man 15 traps, set in permanent locations along the coastline east and west from Sarteneja. Fishing is seasonal, with traps opened in mid-April and removed in mid-November. The take is very discriminatory, with fish netted live and sorted at point of capture. By-catch (non commercial species / undersized) is thrown back alive.

A baseline of catch per species has been developed from data collected in 2011, with striped mojarra (*Eugerres plumieri*), yellow-fin mojarra (*Gerres cinereus*) and grey snapper (*Luthanus griseus*) making up the majority of the catch (Figure 4).

Figure 4: Percentage catch biomass per species (SACD beach trap data, 2011)





Types of Fishermen - Sarteneja	
Commercial	▪ Beach Trap ▪ Gill Net ▪ Seasonal Gill Net ▪ Sport Fishing
Non-Commercial	▪ Cast Net ▪ Hook and line

Commercial Fish Species: Mojarra

Two species of mojarra (striped mojarra (*Eugerres plumieri*) and yellow-fin mojarra (*Gerres cinereus*)) are preferentially targeted by the Corozal Bay fishery.

Striped mojarra (Eugerres plumieri)

Striped mojarra ('chiwa' (*Eugerres plumieri*))

- Locally preferred, this is also the most frequently caught species, representing 40.9% of the sampled catch. Size ranged from 15cm to 32.2cm in length, with a mean total length of 23.3cm and mode of 22cm.
- The total sampled catch is estimated at 23.7% of the total catch biomass.
- All fish under 15.0cm are returned live to the water at point of capture, during the catch sorting process, as part of the traditional fishing practice.
- This species matures at a total length of between 18.0 cm and 22.0 cm (7.0 to 8.5 inches).
- Based on an estimated average maturity at 20.0cm total length, the majority of individuals in the catch (88.5%) are reported to be in the range where at least 50% of the population is thought to be sexually mature (L_{50}).
- Striped mojarra are present throughout the beach trap season, but have a very seasonal abundance, peaking in July, with 47.9% of the sampled catch being caught in one trap event. July brings the first major rains of the wet season, reducing the salinity of the estuarine system.

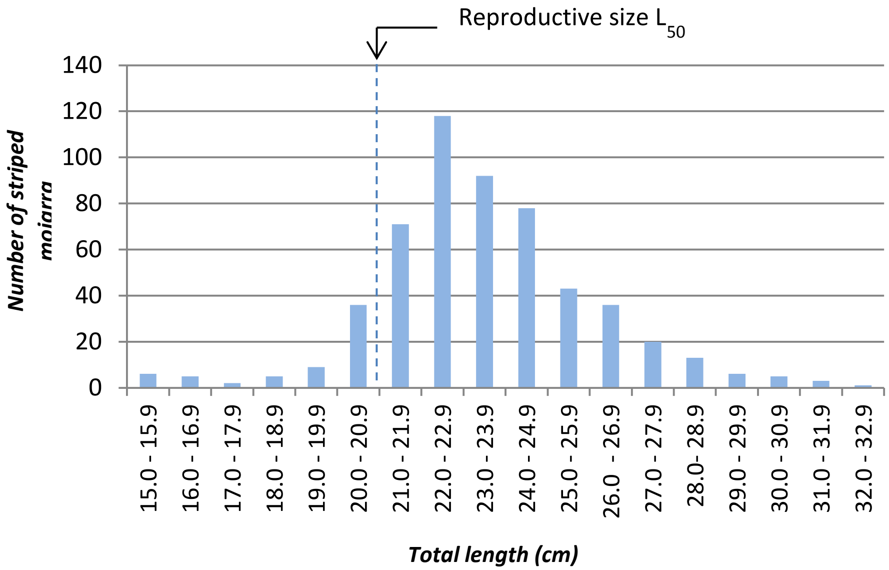


Figure 5: Size range of Striped mojarra (Eugerres plumieri) sampled from beach traps, total catch data, 2011

Commercial Fish Species: Mojarra

Yellow-fin mojarra ('mojarra' (Gerres cinereus))

- Yellow-fin mojarra (*Gerres cinereus*), the second preference as a food fish in Sarteneja, represents 14.9% of the total sampled catch.
- Yellow-fin mojarra ranged from 19.0cm to 44.9cm in total length, with a mean size of 24.1cm and mode of 22.0cm.
- The total sampled catch is estimated at 17% of the total catch biomass.
- All fish under 19.0cm are returned live to the Bay as by-catch, as part of the traditional fishing practices.
- Total length at maturity is estimated at between 17.0 cm and 20.0 cm (approximately 7.0 to 8.0 inches).
- Based on an averaged length at maturity of 19.0cm, 99.0% of individuals in the catch are reported to be in the range where at least 50% of the population is considered sexually mature (L_{50}).
- Yellow-fin mojarra, like the striped mojarra, are present throughout the beach trap season, but are very seasonal in abundance, peaking in July with the advent of the first major rains of the wet season

Yellow-fin mojarra (Gerres cinereus)

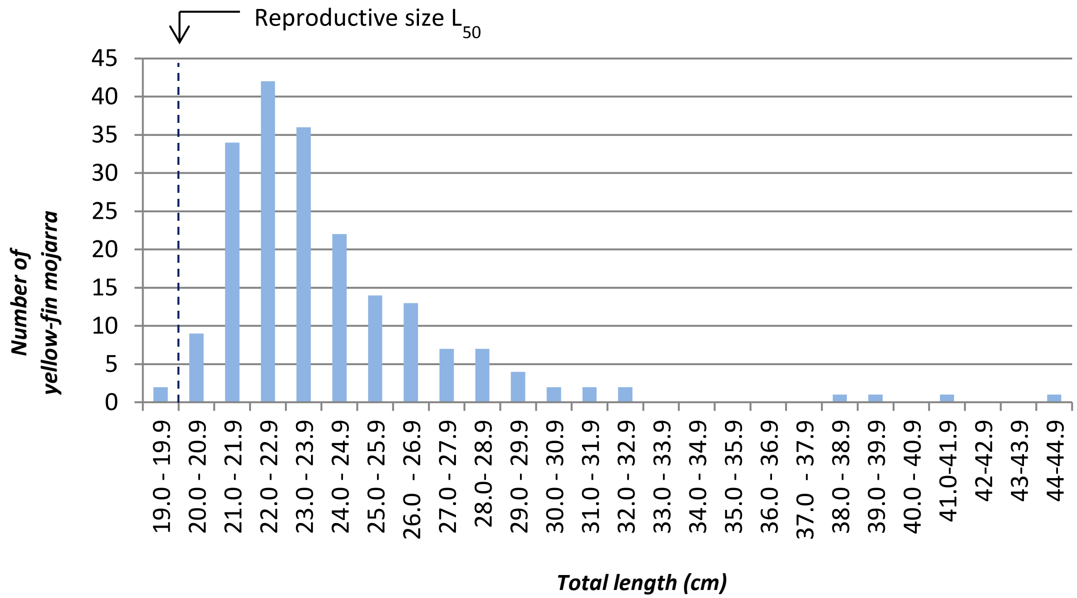


Figure 6: Size range of yellow-fin mojarra (Gerres cinereus) sampled from beach traps, total CBWS catch data, 2011.

Commercial Fish Species: Snapper

Three species of snapper were represented within the catch, with 79% of the snapper catch being grey snapper (*Lutjanus griseus*). 15% of the snapper catch was mutton snapper (*Lutjanus analis*), with the remaining 6% being lane snapper (*Lutjanus synagris*). Mutton snapper were the most seasonal, all individuals being caught in November, whilst lane snapper occurred in catches from June to August.

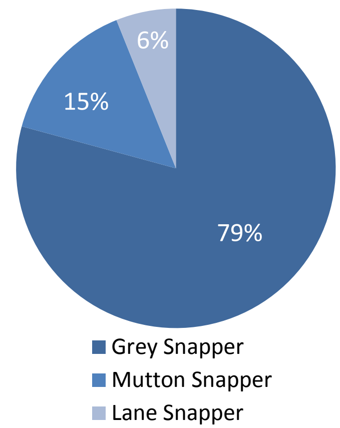


Figure 7: Relative abundance of snapper species in catch samples

Grey snapper

- Total length ranged from 20.0cm to 40.3cm, with a mean size of 29.0cm and mode of 28.0cm.
- The total sampled catch forms an estimated 20% of the catch.
- Grey snapper matures at a size of 18.0 – 33.0 cm (7.0 – 13.0 inches; Allen, 1985).
- Based on an average length at maturity of 25.0cm, the majority of individuals in the catch (88.7%) are considered to be in the range where at least 50% of the population is thought to be sexually mature (L_{50}).
- Whilst present throughout the beach trap season, grey snapper are more abundant in the catch towards the start of the season, with the average number of fish caught per trap event gradually reducing through the year.

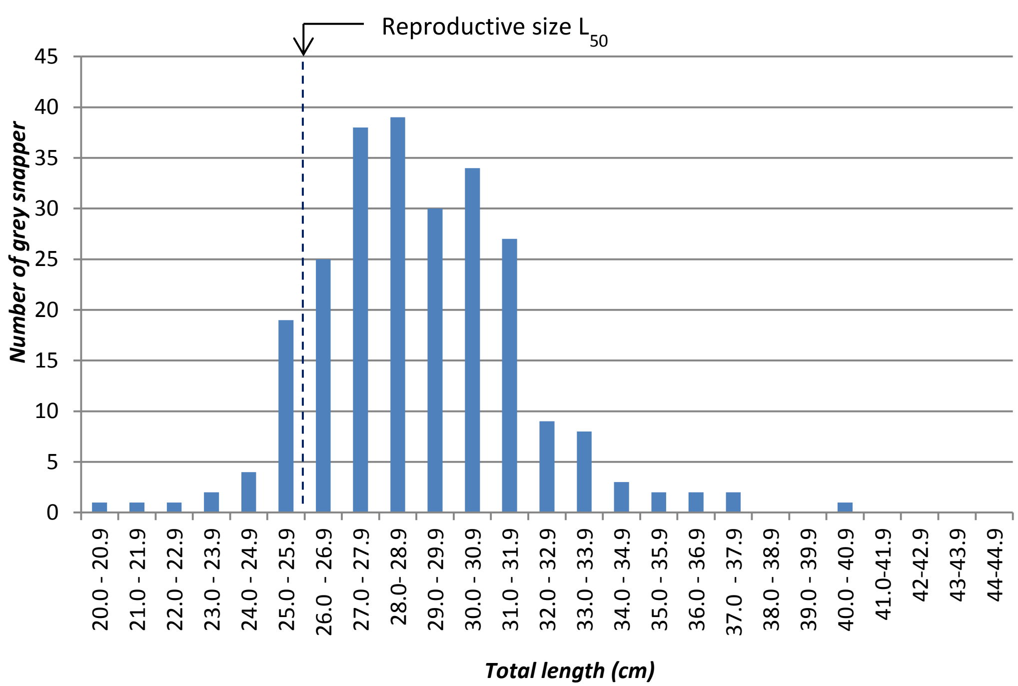


Figure 8: Size range of grey snapper (Lutjanus griseus) sampled from beach traps, total CBWS catch data, 2011

Information and Information Gaps

Current Baseline Information (SACD, 2012)

- Characterisation of the fishing industry of CBWS
- Characterization of fishing effort – Sarteneja fish traps
- Trap catch sample data for 2010 and 2011
- Size range and L_{50} for catch for 2011:
- Striped mojarra
- Yellow-fin mojarra
- Grey snapper
- Estimate of annual catch per trap / per species
- Estimate of annual catch value

Identified Priority Information Gaps

- Site specific length-age and length-weight data
- A complete season of trap sampling at least once a week from April to November to provide the full season of data
- Four years of consecutive data – a time series of catch data - to provide information for developing sustainability guidelines
- Assessment of spatial catch associated with the locations of the different fish traps
- Assessment of other fishing sectors – the gill net fishers, sport / recreational fishers and cast net catch
- Weather data for identification of trigger points for fish movements
- Data on water parameters (particularly salinity) for identification of trigger points
- Identification of important fish nursery areas and spawning grounds
- Better understanding of key species life histories and migration patterns, providing basic information towards identifying the separate stock units

Impacts

The four most critical threats to the Commercial Fish Species have been identified as:

- Unsustainable Fishing
- Mangrove Clearance
- Water Pollution
- Transboundary Fishing

Unsustainable fishing is the highest ranked threat for the system. It occurs throughout the area and is happening now, so is therefore considered urgent, and it is reported to be having a substantial effect on local fish populations.

Whilst the majority of target fishery species are not considered in threat of immediate local extinction, past fishing has reduced goliath grouper to a currently non-viable population, and smalltooth sawfish (*Pristis pectinata*), once present in large numbers, have been extirpated from the system, as a result of unsustainable fishing practices and illegal, transboundary fishing incursions.

Commercial Fish Species

Protocols: Catch Data

Sampling of current fish catch and fishing effort is recognised as the most realistic mechanism for sampling fish catch with the human and financial resources available.

1. Sampling is at point of extraction, with two recorders accompanying the fishermen to the traps in the early morning

2. The date, name of recorders, weather conditions, and fisherman / trap location are recorded

3. As fishermen empty their nets, the catch is divided by species, and where feasible, non-commercial by-catch is listed as it is returned to the sea

4. Undersized commercial fish should be stored in a wet-box, and measured and released as soon as possible

4. All commercial fish within the catch are identified, and measured using a fish measuring board, with species and total length (TL) recorded per individual fish in cm, to the nearest 0.5cm, on the data sheet

5. Where feasible, weigh each individual to provide site specific length / weight ratios

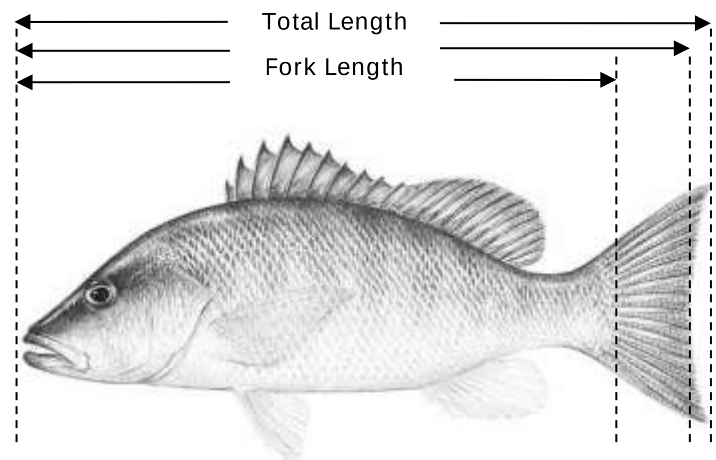


Figure 9: Measuring a fish – 'Total Length' is used

Figure 10: Sampling fish

Equipment:
Fish measuring board
Balance
Wet-box
Clipboards and pencils
Data forms
Identification Guides

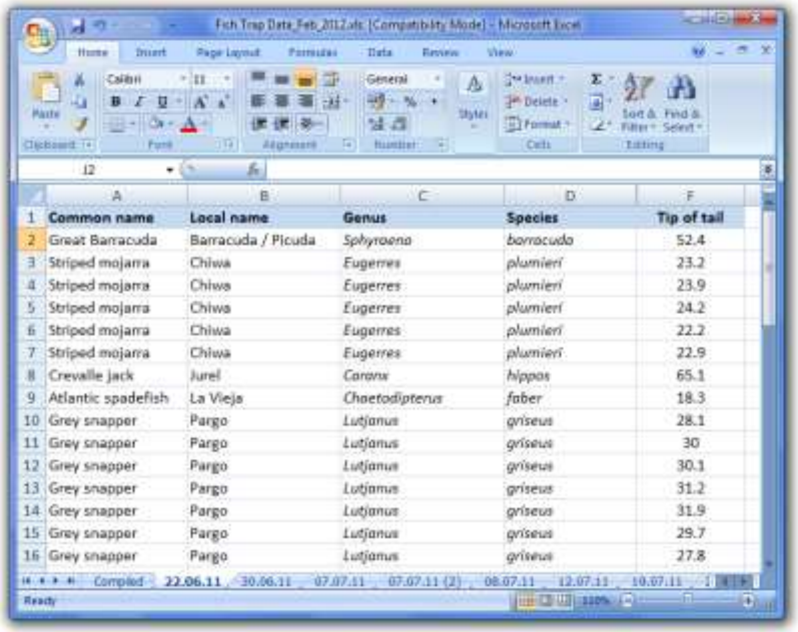
Personnel:
Fish handler
Fish measurer
Data Recorder

Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
		←				*Beach Trap Season*				→	

Commercial Fish Species

Data Management

1. Data is stored electronically in an Excel sheet with each trap data stored as a separate sheet, then compiled for analysis (Figure 11).



Common name	Local name	Genus	Species	Tip of tail
Great Barracuda	Barracuda / Picuda	Sphyraena	barracuda	52.4
Striped mojarra	Chiwa	Eugerres	plumieri	23.2
Striped mojarra	Chiwa	Eugerres	plumieri	23.9
Striped mojarra	Chiwa	Eugerres	plumieri	24.2
Striped mojarra	Chiwa	Eugerres	plumieri	22.2
Striped mojarra	Chiwa	Eugerres	plumieri	22.9
Crevalle jack	Jurel	Caranx	hippos	65.1
Atlantic spadefish	La Vieja	Chaetodipterus	faber	18.3
Grey snapper	Pargo	Lutjanus	griseus	28.1
Grey snapper	Pargo	Lutjanus	griseus	30
Grey snapper	Pargo	Lutjanus	griseus	30.1
Grey snapper	Pargo	Lutjanus	griseus	31.2
Grey snapper	Pargo	Lutjanus	griseus	31.9
Grey snapper	Pargo	Lutjanus	griseus	29.7
Grey snapper	Pargo	Lutjanus	griseus	27.8

Figure 11: Fish Trap Data management

2. Length-weight conversions are used to calculate the estimated weight per species. Fish weight is calculated using the power function: **W = aL^b**, where W is the weight (grams), L is the length (cm), and a and b are parameters estimated by linear regression of logarithmically transformed length-weight data.

Fish Biomass Conversion Functions per Species

Scientific name	Common name	a	b
Chaetodipterus faber[2]	Atlantic Spadefish	0.0314	3.0700
Haemulon sciurus[1]	Bluestriped Grunt	0.0194	2.9996
Caranx hippos[23]	Crevalle Jack	0.0156	2.9400
Caranx latus[2]	Horse Eye Jack	0.0156	2.9400
Lutjanus analis[1]	Mutton Snapper	0.0295	2.8146
Lutjanus griseus[1]	Gray Snapper	0.0232	2.8809
Lutjanus synagris[1]	Lane Snapper	0.0295	2.8146
Eugerres plumieri[2]	Striped mojarra	0.0071	3.1900
Gerres cinereus[2]	Yellowfin Mojarra	0.0142	2.9400
Mugil cephalus[24]	Striped Mullet	0.0132	2.8900
Mugil curema[2]	White Mullet	0.0132	2.8900
Sphyraena barracuda	Great Barracuda	0.0050	3.0825

[1] Marks and Klomp (REEF and AGGRA); [2] De la Hoz et al (2009)
[3] Model is horse eye jack ; [4] Model is white mullet
Fish Biomass Conversion Functions per Species (J. Chapman / Blue Ventures)

Commercial Fish Species– Quality Assurance Plan	
Method	***Fish Trap Assessments***
References	Halls, A.S.; Arthur, R.; Bartley, D.; Felsing, M.; Grainger, R.; Hartmann, W.; Lamberts, D.; Purvis, J.; Sultana, P.; Thompson, P.; Walmsley, S. (2005). Guidelines for designing data collection and sharing systems for co-managed fisheries. Part 2: Technical guidelines. FAO Fisheries Technical Paper. No. 494/2. Walker, Z. (2012). Planning for a Sustainable Fishery: Corozal Bay Wildlife Sanctuary. Produced by Wildtracks for the Sarteneja Alliance for Conservation and Development. Fish Biomass Conversion Functions per Species (J. Chapman / Blue Ventures), based on REEF and AGGRA, and De la Hoz et al., 2009 Caballero-Vasquez J. A., H. C. Gamboa-Perez and J.J Schmiter-Soto (2005). Composition and spatio-temporal variation of the fish community in the Chacmochuch Lagoon system, Quintana Roo, Mexico. Hidrobiologica 15 (2 Especial): 215-225
Quality Control	One person with good knowledge of the fish species. Metric measuring boards should be used, and measurements should be to the nearest 0.5cm.
Social and Environmental Impact Mitigation	Ensure that if measuring undersized fish, that they are placed in a wet-box, and measured and released as fast as possible after capture. Always show respect for both the fishermen and the fish being surveyed. Minimize interruption of fishing effort. No-one should enter the trap unless approved by the fisherman. Ensure the outboard engine is functioning well, no oil leaks. Dispose of all lube containers and garbage appropriately.
Data Storage and Analysis	Storage: Hard copies and Excel file Analysis: Seasonal, spatial and annual variations in numbers and species. Analyse with respect to variations in climate and water parameters (particularly salinity)
Reporting / Dissemination	Post survey report integrated into quarterly report to Forest / Fisheries Departments Summary report to fishermen Annual Monitoring Report

Commercial Fish Species: Strategic Actions		Desired Status
Research and Monitoring Programme		
Baseline information on the commercial fish species of Corozal Bay Wildlife Sanctuary	▪ Four full seasons of consecutive catch monitoring for the beach trap fishery (April to November) to provide information for developing a total allowable catch ▪ Development of site specific length-weight data ▪ Weather data collection for identification of trigger points for fish movements ▪ Monitor water parameters (particularly salinity) for identification of trigger points for fish movements ▪ In-water salinity loggers by traps ▪ Assessment of by-catch (juvenile / undersized) ▪ Assessment of spatial differences in catch with distance from Rocky Point ▪ Identification of important fish nursery areas and spawning grounds ▪ Characterization of the gill net fishery ▪ Characterization of the cast net fishery ▪ Characterization of the sport fishing / recreational activities	▪ Knowledge of fish species using CBWS, seasonality, spawning areas etc. available to guide location of provisional management zones and surveillance and enforcement activities ▪ Better understanding of fish movements in relation to salinity / season ▪ Characterization of artisanal fishing of Chunox, Copper Bank, Corozal, Consejo and San Pedro
Other Research and Monitoring Activities	▪ Monitor lionfish expansion / seasonality within CBWS and in coastal lagoon nursery areas ▪ Full fish species list for CBWS ▪ Integration of fish distribution observations in seagrass ground truthing	▪ Fish species list for CBWS ▪ Knowledge of spread of lionfish within CBWS for targeted mitigation activities ▪ Species distribution data related to water parameters
Natural Resource Management Programme		
	▪ Identify and implement mechanisms to ensure the continuity of sustainable traditional fishing for the stakeholder communities ▪ Increase participation of traditional fishers in management of the fishery	▪ Support of long term sustainable, community managed, traditional fishing in CBWS

2.3 Colony Nesting Waterbirds

The status of colonial nesting bird colonies, their size and nesting success, indicate Corozal Bay's ability to support foraging of nesting birds – the availability and quality of fish and/or invertebrates available in the surrounding landscape/seascape, and management activities to mitigate human impacts.

Management Goal: Information on the species using the bird nesting colonies within Corozal Bay Wildlife Sanctuary, seasonality and impacts, to reduce current and potential threats.

Current Status*:* Nesting colonies are still persisting on Cayo Falso, on the east coast, on the caye between Corozal and Consejo, and in Bulkhead Lagoon, adjacent to CBWS. The white ibis colony on Shipstern Caye (Cayo Conejo) has never recovered following the destruction of nests and collection of eggs by a local fisherman more than ten years ago. Other nesting colonies have not been the focus of monitoring efforts, so past population fluctuations are unknown.

Impacts*:* Natural disasters have had a huge impact on the nesting islands over recent years, with Hurricane Dean (2007), in particular, doing structural damage to mangrove canopies, temporarily reducing nest site availability. Other, human-based impacts have also been identified:

- constant threat of development on even the smallest cayes, removing their value as colony nesting sites.
- harvesting of eggs and nestlings as a food source or for sale in Sarteneja or Mexico – particularly targeting birds nesting on the East Coast cayes and the wood storks of Bulkhead Lagoon
- fishing activities and poor tour guiding practices near the nesting cayes may disturb the birds during the nesting season, affecting reproductive success.

Key Species Nesting on the Mangrove Cayes in Corozal Bay Wildlife Sanctuary

Magnificent Frigatebird
Brown Pelican
Boat-billed Heron
Black-crowned Night Heron
Yellow-crowned Night Heron
Tricoloured Heron
Reddish Egret
Cattle Egret
Great Egret
Great Blue Heron
White Ibis
Roseate Spoonbill
Double-crested Cormorant
Neotropical Cormorant

Training Resources

- Bird ID training presentation for SACD Rangers and Volunteers
- Birds of Belize, by Lee Jones

Colony Nesting Waterbirds

Protocols: Boat Surveys

All surveys of colony nesting species should respect the relative fragility of the nesting colony. Disturbance should be avoided as much as possible to minimize the possibility of nest failure and/or colony abandonment in response to the survey activities. The monitoring team should not be close enough to flush birds off the nests. If birds do leave the nests, they should be off the nest no more than 10-30 minutes.

1. For each colony, establish survey points around the caye, at sufficient distance to not flush birds from nests. The points should be located at sufficient intervals around the colony to allow for counting the maximum number of nests while minimizing the risk of double-counting nests.

2. Allocate two paired counters and recorders before approaching the colony, to reduce need for conversation within the colony vicinity

3. Conduct 2 minute survey counts at each point, recording:
   - species
   - the number of nests,
   - status of nests, and fledging state

   Each counter should provide the above data to the recorders, for writing on the survey sheets

4. A high quality photograph should be taken of the caye from the survey point

Protocols: Aerial Surveys

Aerial surveys are used primarily for assessing the nesting population at the Bulkhead wood stork colony, and should also be used for Cayo Falso and other identified colony nesting cayes

1. A single pass is made over the caye at 150m above sea level, and photographs are taken using a 50mm lens, or overlapping, close-up photos of colonies (using a 200mm or 300mm lens.

2. The clearest image is selected and copied into a Word document, to fill the page, and a grid superimposed over the top using "*insert table*"

3. The number of birds per quadrant is then recorded, and the table copied to an Excel file, for calculation of total number.

4. This should be repeated with two more images, and the maximum count recorded

Figure 11: Count of Wood Storks in Bulkhead Lagoon, SACD 2011 (with Lighthawk). A minimum of 330 nesting birds were recorded on the caye.

Colony Nesting Waterbirds – Quality Assurance Plan

Method	***Nesting Caye Assessments***
References	Steinkamp, M., B. Peterjohn, V. Byrd, H. Carter, and R. Lowe (2003). Breeding Season Survey Techniques for Seabirds and Colonial Waterbirds throughout North America Frederick P., T. Towles, R. J. Sawicki and G. T. Bancroft (1996). Comparison of Aerial and Ground Techniques for Discovery and Census of Wading Bird (Ciconiformes) Nesting Colonies. The Condor 98: 837-841
Quality Control	Two people with good knowledge (90% identification accuracy) of the bird species being monitored, and trained in the monitoring technique
Social and Environmental Impact Mitigation	**DO NOT APPROACH CLOSER TO THE NESTING CAYES THAN ABSOLUTELY NECESSARY** **DO NOT CONDUCT THE MONITORING MORE FREQUENTLY THAN ONCE EVERY TWO WEEKS** **IF BIRDS START TO TAKE FLIGHT, MOVE FURTHER FROM THE CAYE** **ENSURE THAT NOISE AND BODY MOVEMENTS OR OTHER DISTURBANCE ARE KEPT TO A MINIMUM NEAR THE CAYE**
Data Storage and Analysis	Storage: Hard copies and Excel file Analysis: Seasonal, spatial and annual variations in numbers and species.
Reporting / Dissemination	Post survey report integrated into quarterly report to Forest / Fisheries Departments Annual Monitoring Report

White ibis of Corozal Bay Wildlife Sanctuary (R. Graham)

Colony Nesting Birds - Strategic Actions		Desired Status
Research and Monitoring Programme		
Baseline information on bird nesting colonies of Corozal Bay Wildlife Sanctuary	▪ Identification and mapping of colony caye locations (boat and aerial surveys) ▪ Bird species identified as using each caye ▪ Nesting season for each species – months when eggs / nestlings / fledglings are observed	▪ Information on key nesting locations and times for increased protection activities. ▪ Baseline against which to measure annual fluctuations
Identification of important feeding areas for dispersing fledglings	▪ Identification of feeding wetlands for newly fledged birds ▪ Identification of threats to key feeding areas	▪ Identification of important feeding areas, threats and stakeholders to be targeted for awareness activities
Research Requirements	▪ Identification of dispersal sites also important to viability of these species – eg. Crooked Tree Wildlife Sanctuary, Blue Creek rice fields ▪ Collaboration with relevant co-management agencies	▪ The viability of the nesting colonies will be affected by impacts on the adult birds at other sites. Fluctuations of numbers at one may be explainable by impacts at another.
Natural Resource Management Programme		
Increase knowledge of identified threats: ▪ Harvesting of eggs / squabs ▪ Coastal Development ▪ Unregulated tourism	▪ Identification of communities / people targeting bird colonies for extraction of eggs / squabs ▪ Information on when the colonies are being targeted ▪ Identification of the market location for eggs and nestlings ▪ Strategic patrols of key nesting and feeding sites for identification of potential development activity ▪ Erect signs near bird nesting cayes raising awareness of regulations protecting birds, and presence of surveillance activities	▪ Knowledge of potential threats will guide the spatial and temporal surveillance and enforcement activities, and community awareness activities

2.4 Mangroves and Other Coastal Ecosystems

The north east of Belize has some of the most extensive mangrove habitat in Belize. These mangroves are a major contributor to the CBWS marine environment, supporting a diverse range of birds, mammals, crustaceans and fish. In their multifunctional capacity, they form the basis of a complex marine food chain, creating breeding habitat, establishing sheltered waters that offer protection for maturing offspring in the shallow, coastal lagoons, stabilizing bottom sediments, and protecting shorelines from erosion. They also have an important role in preserving water quality through reducing pollution by filtering suspended material and assimilating dissolved nutrients.

Mangroves grow along the Belize coastlines, lagoons and estuaries - areas that are attractive to foreign investors and the retirement sector. There is therefore an increasing threat of significant reduction of their extent, from land reclamation and land development of waterfront property. The majority of the coastal mangrove so important to the integrity of the ecosystem functionality of Corozal Bay Wildlife Sanctuary does not, unfortunately, lie within the protected area, which only stretches to the high water mark, and does not include the fragile coastal lagoon systems. Initial satellite imagery provides some indication of the level of impact.

Management Goal: Maintenance of mangrove areas identified as critical for shoreline protection, and for nursery functionality for commercial fish species and structural support for bird nesting colonies.

***Current Status**:* Baseline mapping of the coastline vegetation has been completed (SACD Report: Corozal Bay Wildlife Sanctuary: Coastal Mapping; Lloyd et al., 2011).

90.47% of the coastline of the Wildlife Sanctuary consists of ecosystems containing a mangrove component.

Corozal Bay Wildlife Sanctuary Coastal Mapping, A. Lloyd et al. 2011

Mangroves and Other Coastal Ecosystems

Each ecosystem is defined by its characteristic plant community and extent along the coastline.

Ecosystems of the Corozal Bay Wildlife Sanctuary Coastline	Length (km)	%
Brackish/Saline lake	0.21	0.14
Caribbean mangrove forest: coastal fringe mangrove	27.42	18.78
Caribbean mangrove forest: dwarf mangrove scrub	12.62	8.65
Caribbean mangrove forest: mixed mangrove scrub	26.55	18.19
Caribbean mangrove forest; tall mixed mangrove (basin mangrove)	2.14	1.46
Coastal fringe mangrove with *Casuarina*-dominated beach ridge	0.52	0.36
Mangrove dominated beach ridge vegetation, backed by marine salt marsh with mangroves	2.65	1.81
Marine salt marsh rich in succulents	1.49	1.02
Prominent beach ridge vegetation (not mangrove dominated), backed by dwarf mangrove scrub flats	13.36	9.15
Prominent beach ridge vegetation (not mangrove dominated), backed by marine salt marsh with mangroves	7.14	4.89
Red and black fringing mangroves (with occasional coconuts) backed by tropical evergreen seasonal broad-leaved lowland forest on calcareous soils	39.68	27.18
River	0.22	0.15
Tropical evergreen seasonal broad-leaved lowland forest on calcareous soils	1.06	0.72
Urban	10.93	7.49

Caribbean mangrove forest: mixed mangrove scrub

- Not permanently inundated
- Mixed mangrove communities
- All three mangrove species occur: *Avicennia germinans*, *Laguncularia racemosa*, and *Rhizophora mangle*.
- Other frequent species include *Acoelorraphe wrightii, Acrostichum aureum, Conocarpus erectus, Eragrostis prolifera, Myrica cerifera* and *Rhabdadenia biflora.*

Mangroves and Other Coastal Ecosystems

Level of Disturbance		
Classification		Description
1	Very light clearance	Vegetation nearly entirely in its natural state
2	Under brushed	Most natural vegetation remaining, particularly large trees
3	Moderate clearance	Distinctly altered, but still maintaining some natural structure
4	Heavily impacted/trees removed	Significantly altered, for example including cutting of most trees. May be in regeneration from complete clearance (i.e. abandoned)
5	Cleared/developed: no natural vegetation	No natural vegetation remaining; entirely cleared. May be filled, sea-walled, built upon, used for agriculture, etc.

Number of Disturbances of Each Different Level			
Level	Number of disturbances	Total length (m)	Length as % of total coastline
1	26	1761	1.21
2	28	2618	1.79
3	26	4277	2.93
4	43	9466	6.48
5	36	10128	6.94
Total	159	28250	19.35
Undisturbed			**80.65%**

Baseline Stats:
11.51 km of sea wall
78 jetties / wharfs

Point Features	Number
Boat ramp/slipway	25
Bridge	1
Canal Mouth	4
Caye	22
Creek mouth	20
Fish camp	10
Fish trap	12
Net	3
Pole	30
Sewage/drain pipe	6
Sign	3
Other	5

Baseline: A. Lloyd et al. 2011

Mangroves and Other Coastal Ecosystems

Protocols: Biennial Coastal Survey:

Equipment:

- GPS
- Camera
- Clipboard and survey sheets

1) Print out coastal maps from previous assessment

2) Starting at the mouth of the Rio Hondo, travel slowly southwards along the coast, perpendicular to the coastline.

3) Where disturbance is noted, compare with previous assessment maps. If disturbance is new, complete relevant survey sheets (see Corozal Bay Wildlife Sanctuary: Coastal Mapping (Lloyd, 2011)

4) Update Access data files, with training from Wildtracks

Protocols: Patrols

1) Whilst on patrol, take photos and coordinates of any new disturbances or structures (docks, dredging, fish traps, seawalls etc.). Note in patrol log.

2) Check permits and licenses associated with the work (Mangrove clearance permits, dredging permits, etc.). Take photographs of paperwork

3) On return to SACD office, pass information onto the Natural Resource Manager – **AS SOON AS POSSIBLE**

4) If report requires further follow-up, Natural Resource Manager should take the required steps – contact Forest Department and /or Department of the Environment

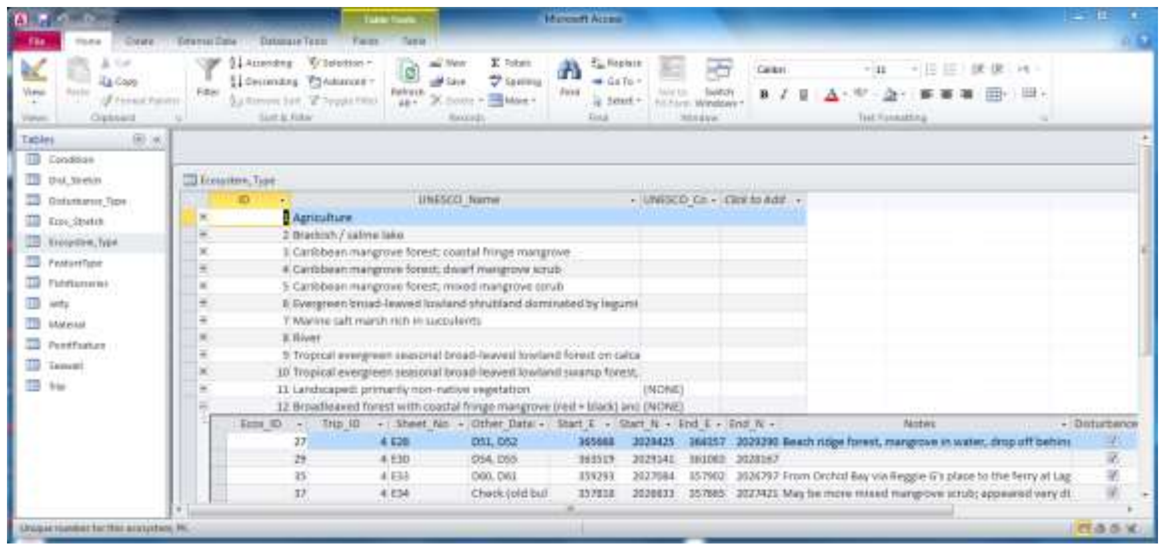


Figure 12: Coastal Ecosystem Data management

Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
		←	***Biennial Coastal Survey***	→							

Mangroves and Other Coastal Ecosystems – Quality Assurance Plan

Method	**Coastal Mapping**
References	Lloyd A. and K. Lloyd (2011). Corozal Bay Wildlife Sanctuary: Coastal Mapping. SACD / Wildtracks. (Including annex of baseline and data collection sheets).
Quality Control	Two people with good knowledge of GPS use, and trained in the ecosystem and disturbance categories, and in the data collection techniques. Data to be analysed using GIS, through Wildtracks / Adam Lloyd
Social and Environmental Impact Mitigation	Ensure the outboard engine is functioning well, no oil leaks. Dispose of all lube containers, equipment batteries and garbage appropriately. Ensure all cable ties are removed from water. Ensure that where mapping is being done in front of private property, communication with property owners is polite and non-confrontational, as well as informative and engaging.
Data Storage and Analysis	Storage: Hard copies and Excel file Analysis: Original databases are maintained as an ESRI personal geo-database containing all spatial features, and a separate Microsoft Access database containing an electronic copy of the data gathered on the data sheets. Analysis will be through comparison of new data against the baseline.
Reporting / Dissemination	Where urgent action is considered necessary, per disturbance reports should be submitted to the Forest Department and Department of the Environment Annual updated coastal mapping report to Forest / Fisheries Departments Annual Monitoring Report

Dolphins of Corozal Bay Wildlife Sanctuary

Mangroves: Strategic Actions		Desired Status
Research and Monitoring Programme		
Baseline information on mangrove and other coastal ecosystems of Corozal Bay Wildlife Sanctuary	▪ Mapping of mangrove and coastal ecosystems found in the coastal area ▪ Identification of location of critical mangrove areas in terms of ecosystem functionality	▪ Accurate baseline ecosystem mapping of mangroves and other coastal ecosystems (completed, 2011)
Other Research and Monitoring Activities	▪ Biennial survey of coastline to map rate of change in comparison with baseline	▪ Accurate, updated information on rate of land use change on the coastline ▪ Information available for planning strategies related to development of a sustainable fishery for Corozal Bay
	▪ Identification of critical areas (high-value fish nursery areas, bird-nesting cayes etc.).	
Natural Resource Management Programme		
Increase knowledge of identified threats: ▪ Coastal Development	▪ Identification of potential human impacted areas during patrols (survey lines, new clearance)	▪ Identification and mapping of current human-impacted areas (completed, 2011) ▪ Early identification of human impacts or potential for impacts in key mangrove areas
Education and Outreach Programme		
Increase awareness of mangroves and environmental services provided by stakeholders – particularly with reference to climate change	▪ Increase stakeholder awareness of the importance of mangroves in climate change adaptation / coastal protection, nursery habitat for commercial fish species, and filtration of land based pollutants ▪ Development of collaborative relationships with land owners for protection. Increasing stakeholder awareness of the importance of mangroves	▪ Greater awareness in the communities will result in early notification of potential threats to mangroves

2.5 Seagrass

Seagrass forms an important, highly productive ecosystem, supporting the traditional fishing industry, and providing nurseries, shelter, and food for a variety of commercially, recreationally, and ecologically important species, including manatee, fish, sea turtles, seahorses, and crustaceans. Seagrasses filter nutrients, contaminants, and sediments from the estuarine waters of CBWS before they reach the reef. There is currently no information on the extent, distribution, relative species composition or health of the seagrass that supports these populations.

This target is also inclusive of the other benthic plant species of the Corozal Bay Wildlife Sanctuary.

Management Goal: To maintain and improve seagrass viability within CBWS in the face of ongoing development, increasing tourism, pollution and climate change.

Current Status: Seagrass is thought to be found throughout Corozal Bay Wildlife Sanctuary, though in differing densities, ranging from very sparse to dense, thought to be dependent primarily on salinity. This ecosystem has, to date, been difficult to map using remote sensing. The baseline mapping is therefore being developed using aerial photographic coverage. The first transects were conducted in February, 2013, producing geo-referenced images to guide ground truthing which will be conducted throughout 2013, through randomised quadrat analysis using basic SeagrassNet monitoring protocols.

SACD also has a SeagrassNet monitoring site near Manatee Resting Hole 1. This has not been monitored, however, since being covered by sediment during Hurricane Dean.

Seagrass: Viability	Current Rating	Goal	Justification
	GOOD	GOOD	Justification: Seagrass is known to be present in varying densities throughout the CBWS and in lagoon systems, but there has been no baseline study. There is currently only limited dredging activity / development in coastal areas. Nutrient and other inputs from rivers could affect quality and health of seagrass beds. Community input suggests major decline in seagrass presence in front of Sarteneja
	Functioning within its range of acceptable variation; may require some human intervention	Functioning within its range of acceptable variation; may require some human intervention	Indicators: ▪ Extent of seagrass beds ▪ % cover and density of seagrass ▪ Seagrass biomass

Seagrass communities are considered to be the most productive ecosystems in the world. They provide a protected nursery and foraging area for many marine species, and their root system aids in water clarity. They also serve as indicator species because they are very sensitive to changes in water quality. Monitoring these habitats is the best way to determine the overall health of the aquatic environment."

Department of Environmental Protection, Florida

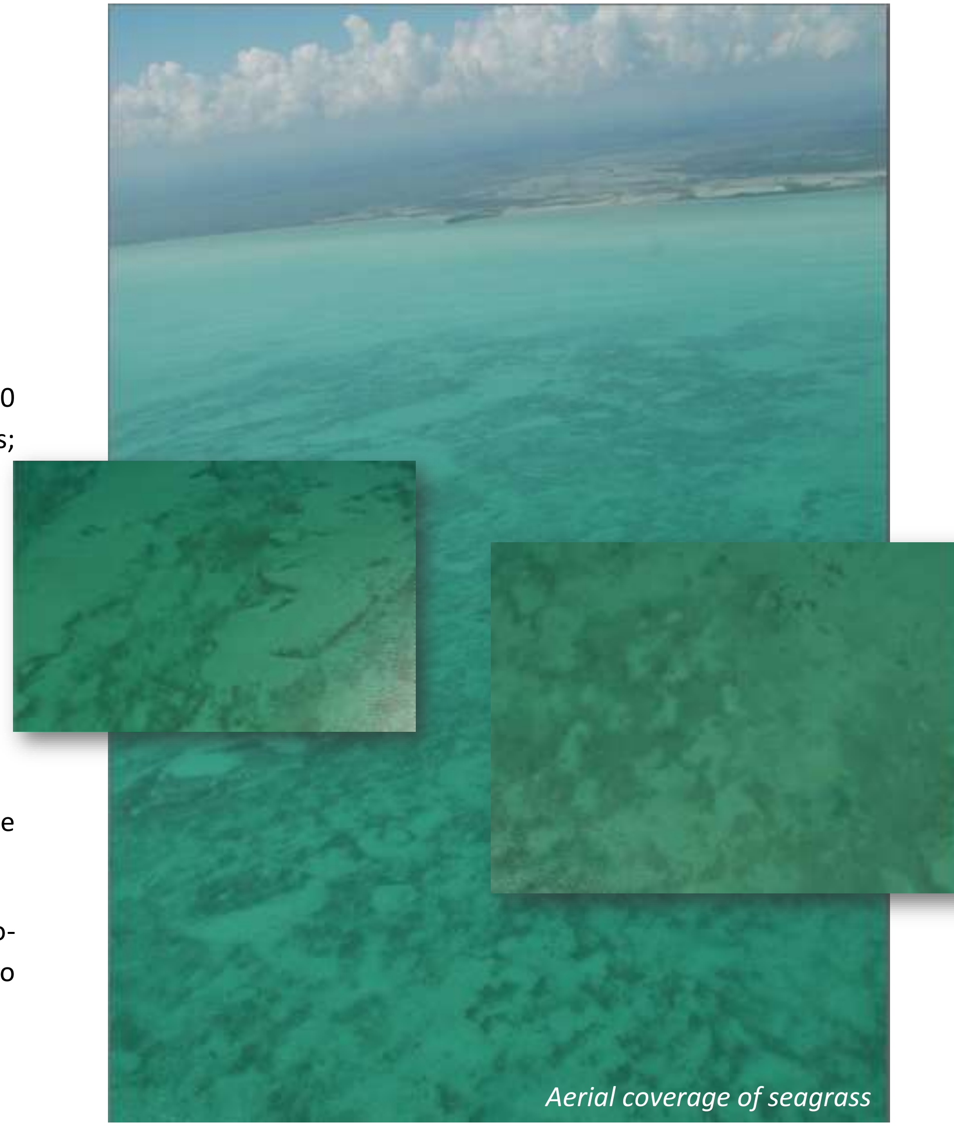
Seagrass

Aerial Photography: Protocol

Equipment

- GPS linked – camera (Wildtracks), 18mm focal length
- Second GPS to mark route
- Transect start and end coordinates

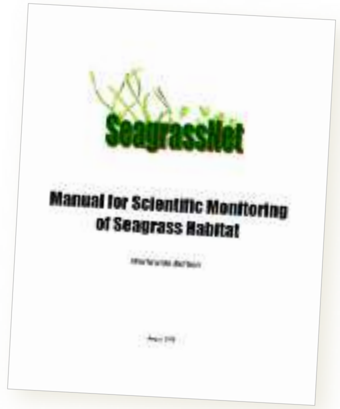
1) The plane is maintained at 650m altitude, travelling at between 80 and 100 knots. (Total path length = 466km (not including turns; Distance between paths = 2.227km
2) 1 photo is taken per 1.5km along each transect, allowing for 15% overlap
3) The individual images are geo-referenced to give a mosaic of GeoTIFF landscape images covering the survey area (Wildtracks GIS Officer).
4) A GIS shapefile is then produced to provide a base map for the seagrass in-water validation surveys
5) Seagrass in-water validation surveys are conducted using geo-referenced 1m quadrats, and following SeagrassNet protocols, to assess seagrass density and biomass.



Aerial coverage of seagrass

Seagrass

Protocol: Baseline Ground-truthing



Equipment

- GPS
- Underwater camera
- 1m quadrat
- YSI ProPlus Quattro Multimeter
- Secchi Disc
- Depth sounder
- Corer
- Plant collection jars (fill with seawater)
- Seagrass percentage cover photoguide
- Plant ID sheets
- Data sheets

1) Locate GPS point and lay out 1m quadrat on sea floor

2) Measure water conditions (depth, turbidity, salinity, pH, temperature, dissolved oxygen)

3) Take a photograph of the quadrat from above

4) Assess species composition of benthic flora in quadrat –

5) Estimate seagrass cover (total cover and then cover by each species) on a percentage cover scale (0-100%), using the "Seagrass percentage cover photo guide" in the SeagrassNet Manual

6) Collect one specimen per species for identification. Place in water filled collecting jar. When back in the SACD office, photograph each species and identify where feasible. Create a photo ID library of benthic flora.

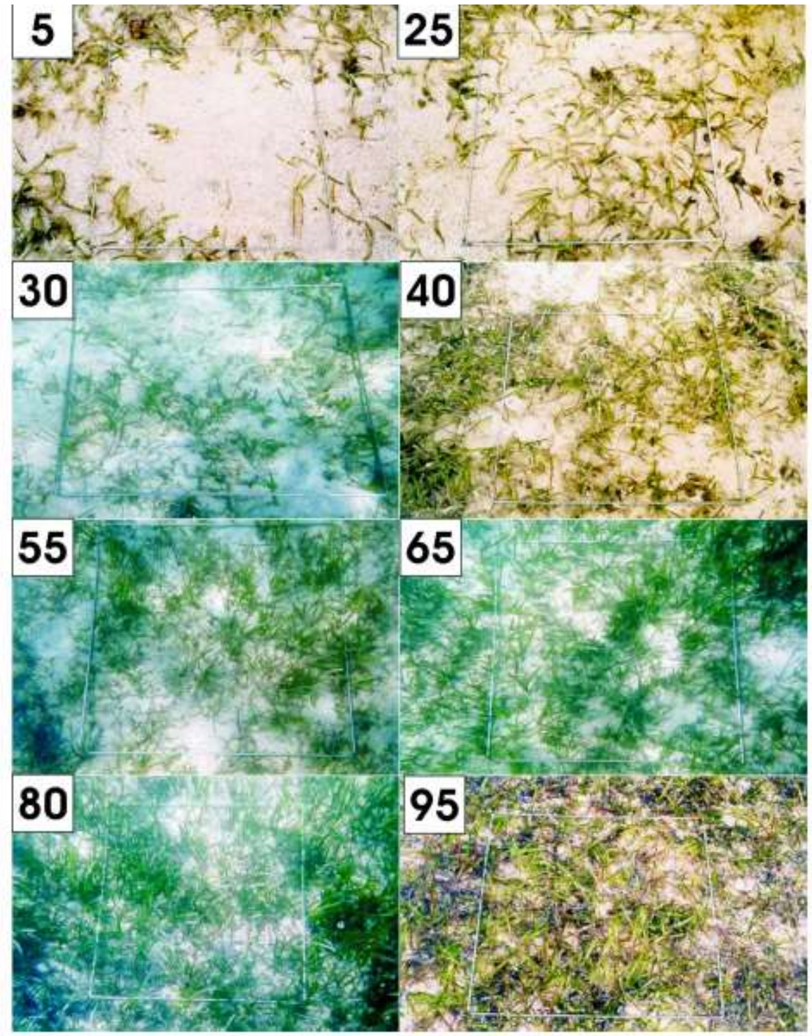


Figure 13: Seagrass % cover photoguide (SeagrassNet)

Seagrass

Protocol: Baseline Ground-truthing

6) Measure canopy height and identify any grazing evidence.

7) For large seagrass species (e.g., large *Thalassia* plants) a 25 cm x 25 cm quadrat is placed in the quadrat, and all shoots of the large species in the quadrat area are counted.

8) Take a biomass core to 10cm depth inside each quadrat. Place the core over the selected shoots, making sure that leaves rooted in the core are on the inside of the core and those rooted outside are outside of the core

9) Note any fish species in the area

10) Wash the sediments from the core sample, noting sediment type.

Preparing Seagrass

11) Separate into leaves, stems, and root-plus-rhizome. When processing, scrape epiphytes from the leaves and rinse the leaves in a weak acid if calcareous epiphytes are present.

12) Count the number of leaf meristems (points of leaf initiation on the shoot) occurring within the core sample and enter this number as the shoot count on the biomass data sheet.

13) Count the number of flowers, fruits and seeds or flowering stems in a core for all seagrass species. Express results as flower/fruit/seed per area.

14) Rinse plant parts in fresh water, dry to constant wt (60° C for 24hr) and weigh. Calculate biomass (g dry wt m-2), enter on data sheets

Whilst at each site, record the fish species observed.

Turtle Grass
Thalassia testudinum

Seagrass – Quality Assurance Plan

Method	***Seagrass Mapping***
References	Seagrass Net (2006). Manual for Scientific Monitoring of Seagrass Habitat. Hernandez-Cruz L.R., S.J. Purkis and B.M. Riegl (2006). Documenting Decadal Spatial Changes in Seagrass and *Acropora palmata*. Cover By Aerial Photo graphy Analysis in Vieques , Puerto Rico : 1937–2000. Bulletin of Marine Science, 79 (2): 401-414. Fourqurean J. W., J. N. Boyer, M. J. Durako, L. N. Hefty and B. J. Peterson (2003). Forecasting responses of seagrass distributions to changing water quality using monitoring data. Ecological Applications, 13(2)
Quality Control	Aerial photography to be conducted by photographer experienced in mapping for analysis, using a GPS linked camera. Ground truthing to be conducted by personnel trained in monitoring techniques. Water parameters to be measured using YSI WQM protocols
Social and Environmental Impact Mitigation	Ensure the outboard engine is functioning well, no oil leaks. Dispose of all lube containers, equipment batteries and garbage appropriately. Ensure that where mapping is being done in front of private property, communication with property owners is polite and non-confrontational, and informs and engages.
Data Storage and Analysis	Storage: Hard copies, Photo library of GeoTIFF landscape images on SACD Research and Monitoring computer, Excel file of geo-referenced information Analysis: Data to be analysed using GIS, through Wildtracks / Adam Lloyd.
Reporting / Dissemination	Seagrass Mapping report for Corozal Bay Wildlife Sanctuary Annual Monitoring Report

Seagrass: Strategic Actions		Desired Status
Research and Monitoring Programme		
Baseline information on seagrass of Corozal Bay Wildlife Sanctuary	▪ Benthic mapping of Corozal Bay Wildlife Sanctuary ▪ Identification of extent and health of seagrass in Corozal Bay Wildlife Sanctuary	▪ Accurate baseline ecosystem mapping of seagrass and other benthic communities (on-going, 2013/2014)
Other Research and Monitoring Activities	▪ Develop benthic ID sheet based on preliminary benthic surveys ▪ Develop ID sheet of primary benthic species ▪ Identification of critical areas (high-value seagrass areas) ▪ Data collection for carbon sequestration valuation	▪ Benthic assessment is assisted through provision of field ID information for benthic type classification and plant ID ▪ Carbon sequestration value of seagrass of Corozal Bay Wildlife Sanctuary ▪ Targeted surveillance of high value seagrass areas
Natural Resource Management Programme		
Increase knowledge of identified threats: ▪ Coastal Development	▪ Identification of potential and actual human impact areas during patrols (dredging activity, boat scars)	▪ Identification and mapping of baseline human-impacted areas affected by dredging and boat traffic
Education and Outreach Programme		
Increase awareness of seagrass and environmental services provided – particularly with reference to climate change	▪ Increase stakeholder awareness of the importance of seagrass in climate change adaptation / coastal protection, nursery habitat for commercial fish species, and filtration of land based pollutants	▪ Greater awareness in the communities will result in early notification of potential threats to seagrass

2.6 The Estuarine Environment -Water Quality

Corozal Bay Wildlife Sanctuary contains a significant portion of the largest estuarine system emptying onto the Meso-American reef. As a transitional zone between fresh and salt water, it has a wide variety of rapidly changing environments, both over space and time. Salinity, for example, changes with distance from the rivers (New River and Rio Hondo) in the north and the open coastal shelf to the south, and fluctuates with changing seasons.

With the shallow conditions, the estuary is heavily influenced by the wind direction. The strong winds of the norther season push the water southward out of the bay, reducing both water level and water temperature.

During the wet season, fresh, warm water from the rivers has a greater influence on conditions throughout the northern portion of the estuary, resulting in lower salinity. In the dry season, salinity is higher, as is the water level, as conditions are influenced by the strong south-east wind, blowing sea water into the Bay.

Extreme weather events will also have significant effects on the physical conditions, mixing the water body, breaking up halo- and thermoclines. These events will also cause sediment to be stirred, releasing nutrients into the water column and decreasing water clarity, with potential knock-on effects on seagrass beds.

Management Goal: Maintenance and improvement of water quality in the Corozal Bay Wildlife Sanctuary, and greater understanding of the links between water quality and movement and the distribution and health of conservation targets.

Current Status: Baseline surveys of salinity, temperature, pH dissolved oxygen and turbidity took place in Corozal Bay North in the dry and wet seasons (4th April and 3rd August, 2012), and throughout the entire Wildlife Sanctuary in the norther season (11th January, 2013). Permanent loggers for water depth, temperature and salinity were also deployed.

SUMMARY	MAXIMUM					MINIMUM					AVERAGE				
Location	Salinity (ppt)	Temp (°C)	DO %	DO (mg/l)	Secchi (cm)	Salinity (ppt)	Temp (°C)	DO %	DO (mg/l)	Secchi (cm)	Salinity (ppt)	Temp (°C)	DO %	DO (mg/l)	Secchi (cm)
Bay CBWS	21.38	32.10	111.00	8.70	286.50	1.95	26.00	55.00	4.20	43.00	8.11	28.32	98.73	7.36	139.13
East CBWS	35.86	29.70	122.00	8.70	380.00	6.94	25.80	90.00	6.10	46.00	18.96	26.89	108.18	7.77	110.37
New River	10.43	32.20	109.00	8.60	269.00	0.33	26.20	21.00	1.60	23.00	3.06	28.35	69.93	5.46	88.09
Rio Hondo	5.78	31.30	105.00	8.30	215.50	0.69	26.10	51.00	3.80	43.18	1.48	28.47	77.91	6.05	131.92
Average	**18.36**	**31.33**	**111.75**	**8.58**	**287.75**	**2.48**	**26.03**	**54.25**	**3.93**	**38.80**	**7.90**	**28.01**	**88.69**	**6.66**	**117.38**

Water Quality: Salinity

What is salinity?

Salinity is a measure of the saltiness of water and is a key factor affecting the physical characteristics of the Bay. Salinity is defined as the total amount of dissolved salts per 1000 units of water, expressed in parts per thousand (ppt ‰), the measurements used in interpreting data from the YSI monitorin equipment. In general, freshwater communities have salinity levels below 0.5 parts per thousand (ppt), Estuarine communities have salinity levels between 0.5 and 30 ppt, and marine communities have salinity levels between 30 and 37 ppt. Since the Bay is an estuary consisting of brackish water (a mix of salt and fresh) we would expect the salinity values to range between 0.5 and 30ppt, with the lowest salinity readings in the rivers, and the highest in the south, where Corozal Bay Wildlife Sanctuary meets the coastal shelf of Belize.

Salinity is often measured as conductivity, in microsiemens. This is considered more accurate than parts per thousand. Fresh water will have a level of less than 100 µS/cm conductivity. Very brackish water is considered to be around 27000 µS/cm., and seawater around 54000 µS/cm. The permanent loggers provide data as microsiemens. A conversion calculator is used to convert conductivity to salinity (J. Douglas / based on 1983 Technical Paper from UNESCO, "Algorithms for computation of fundamental properties of seawater").

The presence of salts increases water density, the lighter freshwater tends to remain at the surface, while the saltier water sinks to the bottom, forming a halocline. However, winds and tropical storms can cause mixing of bottom and surface waters, particularly in shallow areas, breaking up this stratification

Why measure salinity?

The majority of estuarine organisms are affected by the changing salinity of the marine protected area. It affects the distribution of seagrass, which in turn will affect the distribution of manatees and juvenile fish reliant on the seagrass ecosystem. The variation in salinity is important in the life cycles of important fish species, triggering migration and reproduction, with juveniles growing in an environment free of several predators found in more saline waters.

Because it is so important in the characterization of the physical environment, it is needed for interpreting the amount of dissolved oxygen available in the water. As salinity increases, the amount of oxygen that water can hold decreases.

Salinity can also result in increased turbidity, when freshwater meets salt water, reducing light availability for photosynthesis.

What affects salinity?

Salinity can vary widely by season and is affected by rainfall and evaporation, currents, and temperature. Salinity in Corozal Bay declines in the rainy season, both from direct rainfall and when freshwater flow into the bay from groundwater and rivers increases.

Water Quality: Salinity

To date, only one set of data is available for the entire Marine Protected Area – for the Norther Season (January, 2013). Two partial surveys also provide data for the Wet and Dry Seasons for Corozal Bay North.

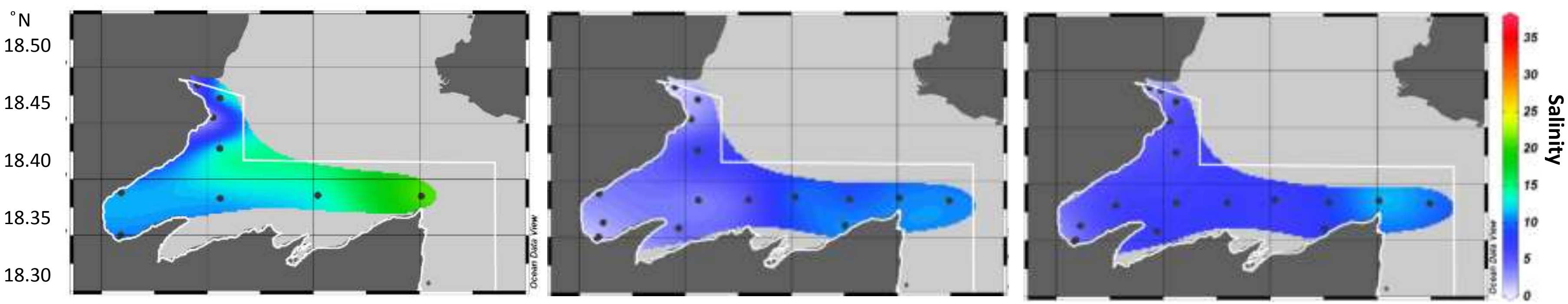
The salinity in the Corozal Bay Wildlife Sanctuary varies from a minimum of 0.84 ppt at the two river mouths in the Wet Season to a maximum of 35.86 ppt in the south east of the Wildlife Sanctuary during the Norther Season, where the estuary enters the sea. There is significant spatial and seasonal variation.

Dry Season: Salinity in Corozal Bay North is much higher in the Dry Season than at other times of year as a result of greater seawater influence. Water from the reef lagoon south of Ambergris Caye is forced into the Bay by the strong south easterly winds, and there is a reduced influence of the rivers. Salinity at the New River mouth is recorded as 9.98ppt, with a gradation to 20.95ppt by Rocky Point, to the east

Wet Season: Salinity in Corozal Bay North is influenced primarily by the increased freshwater flow from the rivers during the Wet Season, with the river mouths varying from 0 to 2ppt. This increases eastwards to 10.6ppt at Rocky Point. The combined influence of the New River and Progresso Lagoon would appear to exceed the influence of the Rio Hondo at this time of year.

The lagoons along the east coast are also thought to influence salinity, reducing salinity around the creeks draining into the Bay. To the south, there is still significant marine influence, with salinity being highest in the shallow Bulkhead Shoals area.

Salinity (ppt)	River mouth	Rocky Point	Spanish Point
Dry	9.84	20.95	-
Wet	0.84	10.6	-
Norther	1.12	10.21	35.86



(a) Dry Season **(b) Wet Season** **(c) Norther Season**

Figure 14: Horizontal transect of northern component of CBWS bay - Salinity (ppt) in (a) the Dry Season, (b) the Wet Season and (c) Norther Season (River entry points are to the west).

Water Quality: Salinity

Norther Season: As expected, salinity increases from west to east in Corozal Bay North, and north to south in Corozal Bay East, with a salinity of 1.12ppt at the mouth of the Rio Hondo and 3.36ppt at the mouth of the New River, increasing to 10.21ppt at Rocky Point, and becoming increasing saline moving southwards. There is still a significant influence from water flowing out of the coastal lagoons in Corozal Bay East, with salinity increasing with distance from the coast – at High Bluff, coastal salinity is 10.36ppt, increasing to 23.78ppt to the east. The highest salinity, 35.86ppt, is recorded in the Bulkhead Shoal area, in the relatively deep water channel that crosses the shoal, funnelling water into the estuary.

Haloclines: A distinct halocline is seen in all seasons in Corozal Bay North, as the river water meets the incoming seawater. This is disrupted by tropical storm activity, which mixes the water column. Saltwater intrudes through the deep-water channel that bisects Bulkhead Shoals, leading to a second distinct halocline in the deeper waters of Corozal Bay East.

Information Gaps: The seasonal influence of water flowing through the Zaragoza Canal and Bacalar Chico channels are not yet fully understood, remaining an information gap. More information is also needed for the vicinity of northern Deer Caye, though it would appear that salinity stabilizes between the coast and Deer Caye in the Bacalar Chico area, with some freshwater influence from the lagoons at the back of Ambergris Caye.

Also in question is the influence of groundwater seepage into the estuary, especially with the limestone nature of the Yucatan platform.

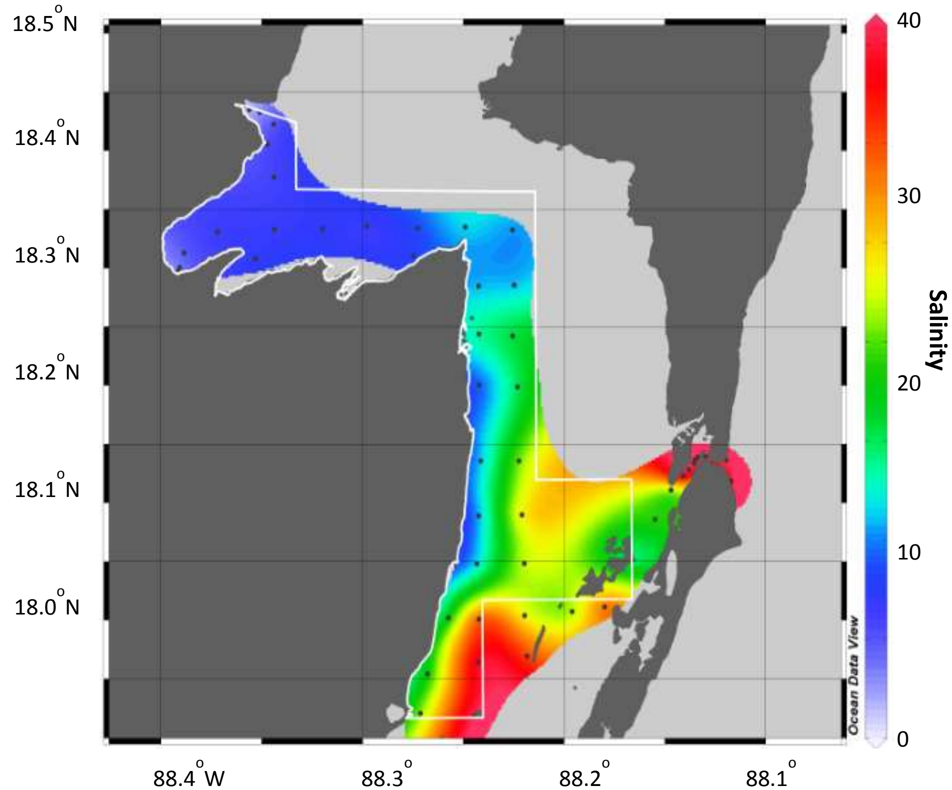
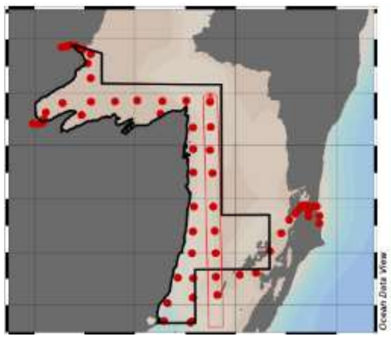


Figure 15: Surface salinity during the Norther Season, Corozal Bay Wildlife Sanctuary (ODV)



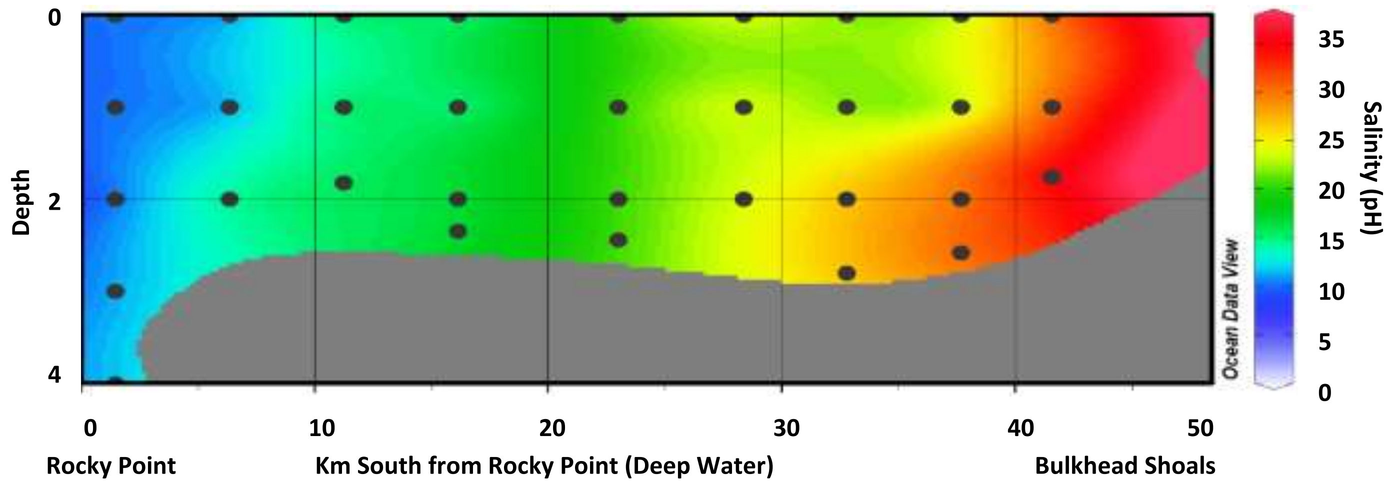


Figure 16: Deep Water North-South Transect for Corozal Bay East – Salinity, clearly demonstrating the gradient in salinity moving southwards from WQ0 (Rocky Point (deep) to Bulkhead Shoals, and the halocline as salt water enters from the south.

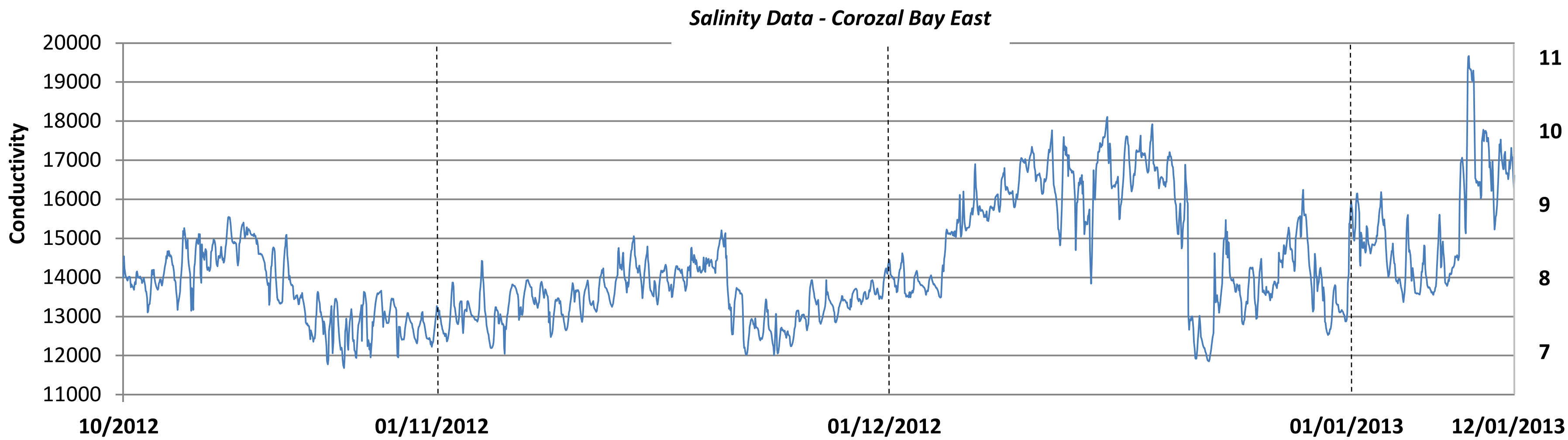


Figure 17: Permanent logger – Conductivity (microsiemens/cm)) / Salinity (pH) in Corozal Bay

Salinity and Aquatic Organisms

Salinity levels significantly affect the types of plants and animals that can live in Corozal Bay Wildlife Sanctuary, and their distribution. Drastic changes in salinity, such as those at the start of the rainy season, require organisms to be highly adapted, either to be able to withstand the changes, or to be able to move in response.

Of the Conservation Targets, three are considered to be the most affected by changes in salinity – Commercial Fish Species, Seagrass and Sharks and Rays.. The primary Commercial Fish Species of the Wildlife Sanctuary are those that migrate to estuaries to reproduce, with juveniles growing in the estuarine conditions, sheltered from predators of the reef.

Salinity can also result in increased turbidity, when freshwater meets salt water, reducing light availability for photosynthesis.

Conservation Target	Preferred Salinity Parameters	Comments
Commercial Fish Species		
Striped Mojarra (*Eugerres plumieri*) Yellowfin Mojarra (*Gerres cinereus*)	20 – 30 ppt (24ppt)	▪ Salinity preferences from E. Buck, 2011 ▪ Spawn at high salinities ▪ Known to extend into both freshwater and more saline water
Mangrove (Grey Snapper) (*Lutjanus griseus*)	9 – 23 ppt	▪ Salinity preferences from Serrano et al., 2010 ▪ Gross growth efficiency of small (2·5–5 cm LT) *juvenile L. griseus* was significantly decreased at salinities ≥35 (Wuenschel et al. , 2004) ▪ Juveniles are found in salinities of as low as 1ppt. Adults generally utilize nearshore and offshore waters where salinity is 35 ppt (Smithsonian report)
Lane Snapper (*Lutjanus synagris*)	19 – 35 ppt	▪ Salinity preferences from Springer et al., 1960 ▪ Juveniles are known to utilize estuaries with lower salinity and high daily or seasonal salinity fluctuations. ▪ Adults utilize offshore waters where salinity approaches 35 ppt (Springer et al., 1960)
Seagrass		
Turtle Grass (*Thalassia testudinum*)	20 – 40 ppt	▪ Will not grow in 17 ppt or less, and begins to die when salinity is 20 ppt or lower ▪ Intolerant of salinities 45 ppt or higher for extended periods
Sharks and Rays		
Bull Shark (*Charcharinus leucas*)	10 – 30 ppt	▪ Salinity preferences from Curtis et al., 2011 ▪ Juveniles generally avoid areas with salinity <7 and had an affinity for areas with salinities from 7 to at least 20

Water Quality - Temperature

Measuring the water temperature is an important basic component of the water monitoring programme, with many biological, physical, and chemical processes in the Corozal Bay affected by temperature.

Temperature and oxygen content: Cold water can hold more oxygen than warm water. In hot weather, fish kills can occur when water temperatures get too high, as they are unable to access sufficient oxygen.

Temperature and nutrient mixing: The temperature of water determines its density or weight. Heavier, colder water sinks to the bottom while warmer, lighter water rises to the top. Such density differences lead to 'thermal stratification' or layers of temperatures (thermoclines). As the northers start in October / November, the surface water temperatures begin to cool and the surface layer of water becomes denser and drops to the bottom. It pushes up the previous bottom layer to the surface. This mixing action can bring nutrients essential to the growth of organisms from the bottom into higher water levels. The turn-over makes the nutrients available to phytoplankton and other organisms inhabiting the upper water levels.

To date, only one set of data is available for the entire Marine Protected Area – for the Norther Season (January, 2013). This demonstrates that at this time of year, surface temperatures in Corozal Bay North are relatively constant, whilst those of Corozal Bay East show greater temperature range, with the shallow coastal waters being warmer than those further off-shore (Figure 18). Temperatures in the northern section of Corozal Bay Wildlife Sanctuary vary from a minimum of 25.8°C to the east of the transect during the Norther Season to a maximum of 32.2°C in the Wet Season, at the mouth of the New River, and to a lesser extent, the Rio Hondo. The general temperature gradient is from a high in the north-west to lower to the east in the north, then decreasing from Rocky Point southwards.

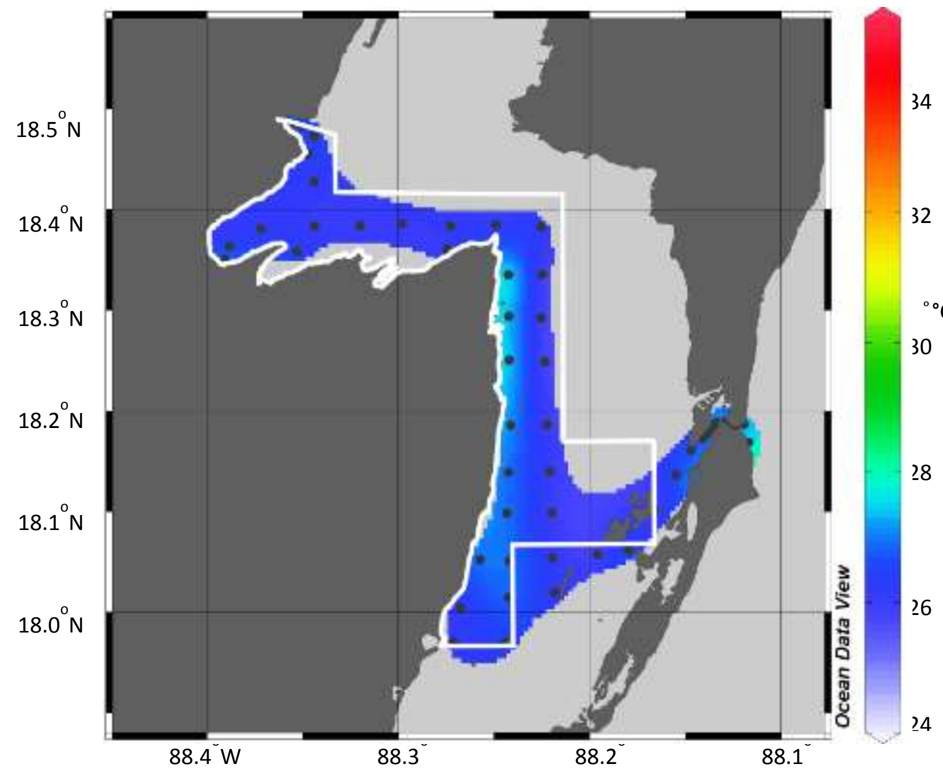


Figure 18: Surface temperature during the Norther Season, Corozal Bay Wildlife Sanctuary (ODV)

Water Quality - Temperature

Two partial surveys also provide data for the Dry and Wet Seasons for Corozal Bay North. It should be noted that this is a single survey per season, and only assumed to be representative of the seasons.

Dry Season:

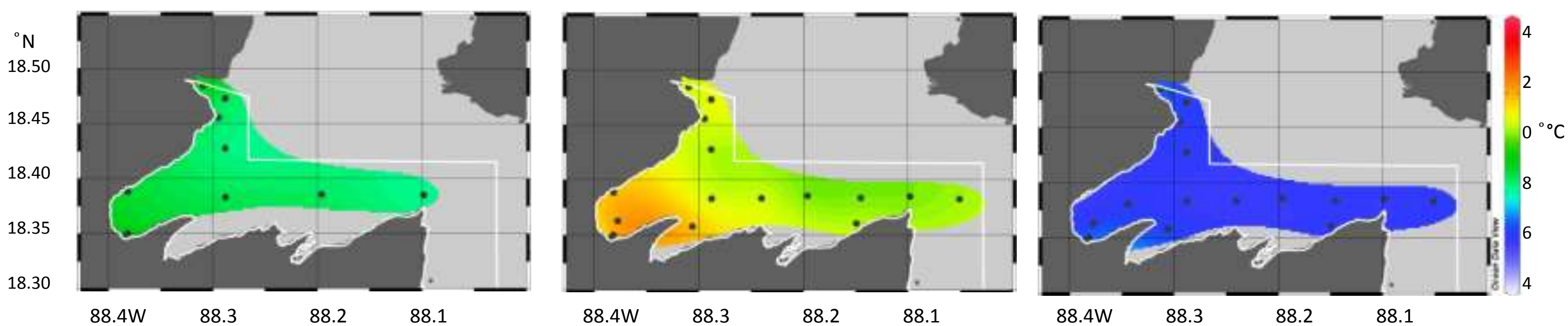
Water temperatures are relatively constant in Corozal Bay North in the Dry Season, with temperatures highest at the river mouths (New River: 29.7°C). Temperatures decrease eastwards towards Rocky Point, with a surface temperature of 28.2°C.

A horizontal transect demonstrates the presence of a significant thermocline, with heavier, colder water lying beneath the warmer, fresher river water, stretching 15km to 20km eastwards towards Rocky Point.

Wet Season: Temperatures in Wet Season are higher than those of the Dry Season, particularly by the mouths of the New River and Progresso Lagoon systems. Both these have extensive, shallow lagoons and flood inundation areas that elevate water temperatures during the summer months, with significant influence on the temperature of Corozal Bay North. A similar temperature increase, though to a lesser extent, is also observed at the mouth of the Rio Hondo.

High temperatures are around 32.2°C at the mouth of the New River – 2.5°C higher than during the Dry Season, with the temperature falling to 30.3°C in the east, by Rocky Point.

Norther Season: The cooler, strong north winds of the Norther Season reduce the water temperature and provide greater mixing, resulting in a more constant water temperature across Corozal Bay North. Temperatures range from 27.0°C at the mouth of the New River to 26.1°C at Rocky Point.



(a) Dry Season **(b) Wet Season** **(c) Norther Season**

Figure 19: Horizontal transect of northern component of CBWS bay - Temperature (̊C) in (a) the Dry Season, (b) the Wet Season and (c) Norther Season (River entry points are to the west).

Water Quality - Temperature

Permanent data loggers have been installed in two locations in the Wildlife Sanctuary to monitor temperature. To date, three months of data has been downloaded, demonstrating the expected decreasing water temperatures seen as Belize moves from the Wet season to the Norther season. The logger installed by the manatee hole, Corozal Bay East, demonstrates a maximum temperature of 30.3°C on 18th October, 2012, dropping to a minimum of 24.1°C on 23rd December, 2012 (Figure 20). This decrease in temperature corresponds to the colder winds that blow from the north during the Norther Season.

Water Temperature and Aquatic Organisms

Temperature affects the feeding, reproduction, and metabolism of aquatic animals. The distribution and abundance of aquatic organisms depends on the spatial and temporal temperature fluctuations. With increased temperatures, the metabolic rates (body processes) of fish and aquatic creatures increase, resulting in greater consumption of dissolved oxygen in the water. Higher temperatures also increase the rate of decomposition, which also consumes oxygen, lowering the concentration of dissolved oxygen in the water.

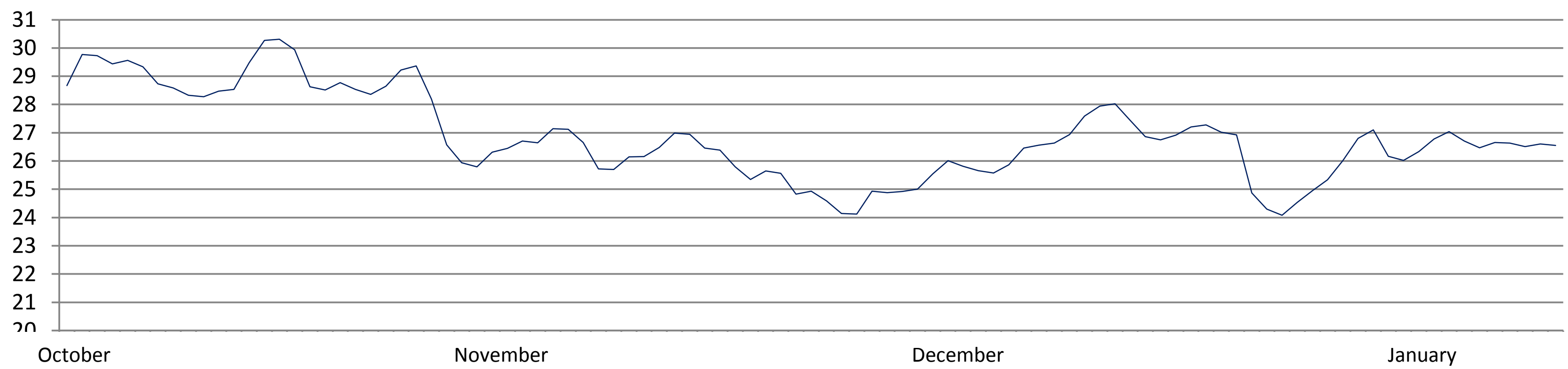


Figure 20: Water temperature fluctuations in Corozal Bay East, October to January, 2012

Water Temperature and Aquatic Organisms

High temperatures may make shallow water areas unsuitable for sensitive aquatic organisms, even if temperatures are within tolerable levels throughout the rest of the year. Optimum habitat temperatures may also change depending on the stage of life – for example, fish larvae and eggs usually have stricter temperature requirements than adults.

Conservation Target	Preferred Temperature Parameters	Comments
Mangrove (Grey) snapper) (*Lutjanus griseus*)	18.3 – 27.2 °C	Grey snappers occur in waters where temperatures range from 18.3 – 27.2 °C, with a mean of 21.7°C (Rivas, 1970). Juveniles stop feeding below 11.3 °C
Lane snapper (*Lutjanus synagris*)	16.1 – 28.9 8°C	Lane snappers occur in waters ranging in temperatures from 16.1 – 28.9 8°C, with a mean of 24°C
West Indian manatee (*Trichechus manatus*)		Manatees will be prone to cold stress if the water temperatures falls below 20°C,
Turtle grass (*Thalassia testudinum*)	<43°C	Temperatures exceeding 43°C will adversely affect tropical seagrass
Red mangrove (*Rhizophora mangle*)	25°C - 35°C	Temperature preferences from Mcleod et al. 2006 Most mangroves produce maximal shoot density when mean air temperature rises to 25°C and stop producing leaves when the mean air temperature drops below 15°C Temperatures above 35°C can lead to thermal stress affecting mangrove root structures and seedling establishment. At leaf temperatures of 38-40°C, almost no photosynthesis occurs

Water Quality – Dissolved Oxygen

Dissolved oxygen (DO) is important in biological processes, with access to DO being a basic requirement for the majority of aquatic organisms, whether plants or animals, within the Wildlife Sanctuary. Oxygen enters the water during photosynthesis of aquatic plants or from the atmosphere, and dissolves in the water body (the main source of oxygen in seawater is from the atmosphere, with the sea surface expected to be near saturated – 100% concentration). DO is a very important indicator of a water body's ability to support aquatic life. Fish "breathe" by absorbing dissolved oxygen through their gills. Oxygen is also removed from the water by respiration of other aquatic organisms, and through the decomposition of organic matter.

Dissolved Oxygen content is a measure of the ability of waters to support aquatic life. Dissolved Oxygen results are presented in two ways:

- ***mg/l : milligrammes of oxygen per litre of water***
  - A measure of how much oxygen is physically present in the water
  - Total possible range of 0 to 20 mg/L
  - Warm water has a lower oxygen capacity than cold water, i.e. the warmer the water, the less oxygen it is able to hold.
  - Oxygen content less than 5 mg/L is considered to be poor.
  - >9 mg/L is considered optimal for high fish diversity
  - Very few species, even those adapted to hypoxic conditions, are able to survive in <3 mg/L
- ***% : percentage saturation***
  - A measure of how much oxygen is present in the water in comparison to the maximum the water could hold at that temperature.
  - Super-saturation (>100%) occurs when water is fast moving or air bubbles form/are present.
  - 80-120% is considered to be good.
  - <60% and >120% is considered to be poor.
  - The DO concentration for 100% air-saturated water at sea level is 8.6 mg/L at 25°C.

What affects Dissolved Oxygen content?

There is an inverse relationship between the solubility of oxygen, and temperature and salinity. This is particularly important in a shallow estuarine system such as Corozal Bay Wildlife Sanctuary, where higher temperatures increase metabolic rates of organisms, yet reduce dissolved oxygen availability. The shallow nature and limited flushing of the system, and its function in settling organic matter and pollutants as they enter the estuary, results in the potential for low oxygen availability. Conversely, the strong north and southeast winds result in mixing of oxygen in the surface water layer, with concentrations as high as 100%, and sometimes above (super-saturation).

Salinity and turbidity will also affect the water’s ability to take up oxygen - oxygen is more easily dissolved into water with low levels of dissolved or suspended solids. Waters with high amounts of salt, such as the ocean (which contains about 35 grams of salt for each 1000 grams of water) have lower concentrations of DO.

Water Quality – Dissolved Oxygen

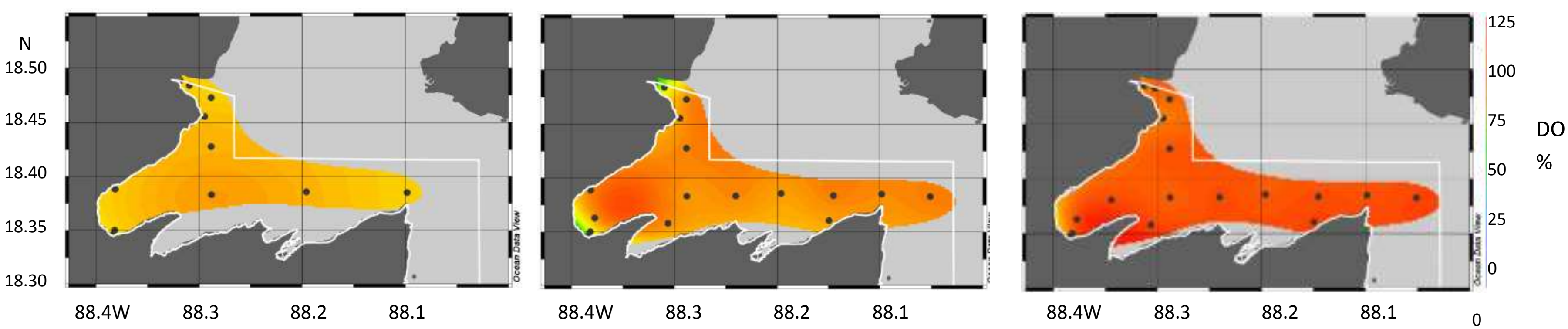
The salinity and temperature gradients found in Corozal Bay Wildlife Sanctuary, and the way they affect the dissolved oxygen content, results in a spatial and temporal variation of physical water conditions across the Wildlife Sanctuary that determine species density and distribution within the estuary.

What levels of Dissolved Oxygen are optimum?

- DO percent saturation values of 80-120% are considered to be excellent and values less than 60% or over 125% are considered to be poor.
- DO concentration of 4 – 5 mg/L and above are considered acceptable for estuarine environments (U.S. Environmental Protection Agency),
- Concentrations below 5 mg/L may adversely affect the functioning and viability of aquatic communities. Concentrations below 2 mg/L will lead to mortality of aquatic organisms.

Dissolved Oxygen levels in Corozal Bay Wildlife Sanctuary

During the surveys, the surface DO levels (mg/L and %) of the Corozal Bay North and East never fell outside of thresholds considered suitable for supporting healthy marine life. In the Norther season, with the strong winds whipping up the waters of Corozal Bay North, DO levels are high, then falling during the Dry Season. In the Wet Season, however, surface DO throughout Corozal Bay North was reduced. In all seasons, an influence from warmer water entering from the rivers was noted – this was particularly significant during Wet Season decreasing the DO content near to critical levels by the river mouths.



(a) Dry Season **(b) Wet Season** **(c) Norther Season**

Figure 21: Horizontal transect of Corozal Bay North – Dissolved Oxygen concentration (% saturation) in (a) the Dry Season, (b) the Wet Season and (c) Norther Season (River entry points are to the west).

Water Quality – Dissolved Oxygen

Dissolved oxygen readings from the New River were consistently low just inside the river mouth, falling below 3.mg/L (45%) in the deepest water in the Wet Season. This decreased even further – to 1.6mg/L (21 and 22%) - in the stretch between 1 and 2km upstream. The surface temperatures during this season are also below minimum requirements for healthy ecosystems, being around 1.8mg =/L (23%). In contrast, the DO concentrations as Rocky Point are high – between 6.0 and 8.1mg/L (88 and 107%), both on the surface and at the bottom of the water quality – well within the requirements of aquatic organisms of the estuary.

Surface DO	River mouth (WQ11)	1km upstream (WQ12)	2km upstream (WQ NEW)	Rocky Point (CBWS 1)
Dry	85 / 6.2	89 / 6.4	-	90 / 6.2
Wet	90 / 6.5	25 /-	23 / 1.8	99 / 7.0
Norther	102 / 8.1	96/7.3	66 / 5.2	107 / 8.1
TS Ernesto	50 / 3.3	30 / 2.3	-	97 / 7.3

Bottom DO	River mouth (WQ11)	1km upstream (WQ12)	2km upstream (WQ NEW)	Rocky Point (CBWS 1)
Dry	84 / 6.1(3m)	88 / 6.2(3m)	- (4m)	88 / 6.0 (2.8m)
Wet	45/3.3	21 / 1.6	22/ 1.6	98 / 6.9
Norther	100 / 7.8	94 / 7.5	76 / 6.3	105 / 8
TS Ernesto	70 / 4.8	29/2.3	-	92 / 6.9

In the Norther Season, with strong winds mixing the water column and stirring the surface, dissolved oxygen is generally between 10.0 and 12.0 mg/L. Areas with lower DO levels are, as in other seasons, the river mouths.

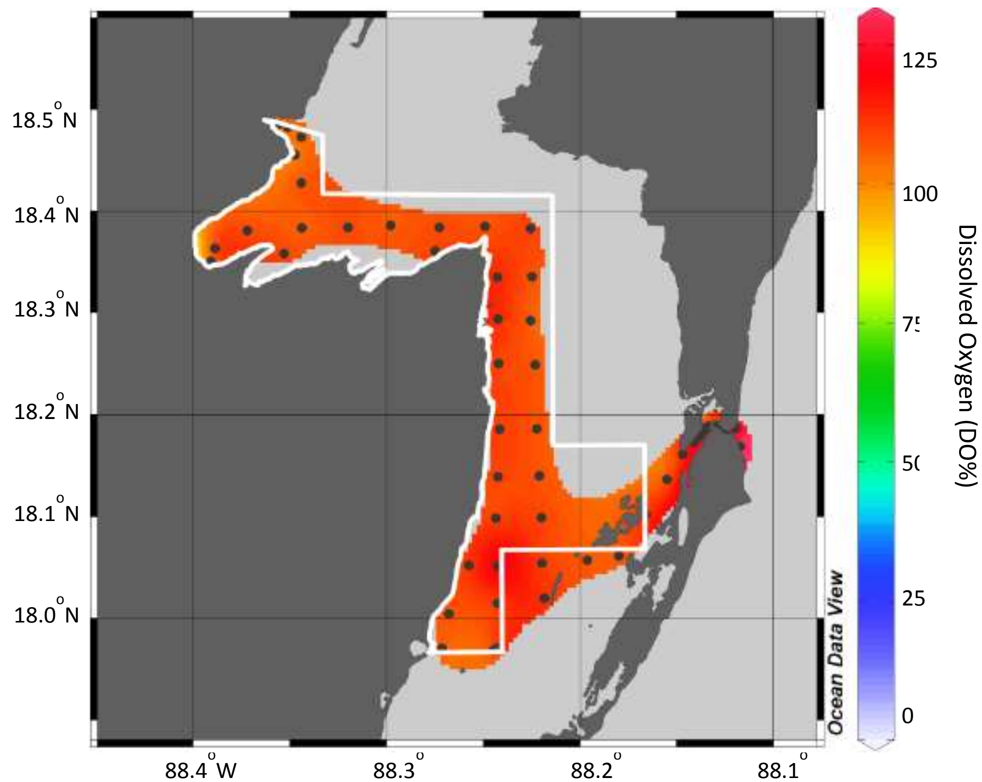


Figure 22: Surface % Dissolved Oxygen levels during the Northern Season, Corozal Bay Wildlife Sanctuary (ODV)

Water Quality – Dissolved Oxygen

How does this affect biodiversity?

When there is a strong stratification of the water column, with distinct thermoclines, water near the surface (the epilimnion) is too warm for fish to thrive, while the water near the bottom (the hypolimnion) is anoxic, with too little oxygen, or with no dissolved oxygen (anoxic). These hypoxic conditions in deeper areas, such as the river mouth, are the result of deposited organic matter and the consequent increase in oxygen consumption by decomposers near the bottom.

Anoxia forces the fish to move higher in the water column, where the warmer water is suboptimal. This places them in greater danger from predation, as they move out from their normal hiding places. In some instances, where the surface waters are too hot, yet the lower water oxygen content is too low, fish kills will occur, particularly of bottom living species such as the chequered pufferfish and catfish species. Fish also become more susceptible to pollution, including from trace metals that can be mobilized by very low DO concentrations.

Excess nutrients from watershed pollution (such as agro-chemicals) will cause eutrophication – an over-stimulation of algal growth. This also accelerates the rate of oxygen depletion and reduces the level of available oxygen in the water. When these factors are particularly strong, or combined, the result may be fish kills.

As fish kills are related to increased temperatures reducing oxygen availability, they can therefore be expected to be more frequent in the wet season, when temperatures are at their highest – particularly near the river mouths. Severely hypoxic conditions have been encountered in the deeper waters at the mouth of the New River, with a mean dissolved oxygen (DO) content as low as 21.0% in places (lower than 4mg/l). There is a steep gradient of DO content from the river mouth into the bay, where DO% is high - 96.4 ± 4.6%.

Seagrass is affected by low DO levels in that extremely high or low DO slows the rate of photosynthesis

Chiwa, snappers and grunts are all tolerant of low DO, though specific tolerance thresholds are difficult to obtain for fish, as their oxygen requirements are directly related to metabolic rates, which are in turn affected by other physical conditions (e.g. increased temperature = increased metabolic rate = increased oxygen requirement).

Water parameters of Corozal Bay Wildlife Sanctuary are affected by three very distinct seasonal weather systems:

- ***Trade Winds*** – the predominant winds, blowing from the east and south-east
- ***Northers*** - high-pressure fronts moving down from the north, occurring between October/November and April
- ***Tropical Storms*** – circulating systems occurring between in the wet season (June to October/ November), originating in the mid-Atlantic, bringing heavy rainfall. Sometimes develop into hurricanes

Water Quality – pH

pH is a measure of the acidity or alkalinity of water, with pH 7 being neutral, pH reading lower than 7 being acidic, and those above 7 being alkaline (or basic). A difference of one pH unit is equivalent to a ten-fold change in acidity or alkalinity pH of an estuary tends to remain constant as the chemical components in seawater resist large changes to pH. Biological activity, however, may significantly lower pH in an estuary, as in cases of eutrophication following nutrient contamination.

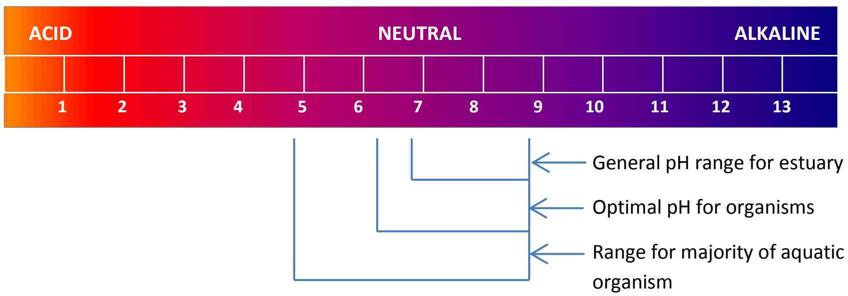


Figure 23: pH Ranges

Why measure pH?

The pH of an estuary is generally between 7 and 9, and not expected to change significantly in the short term, but the baseline developed for long term monitoring is important, particularly with the predicted (and observed) increase in CO_2 concentrations linked to climate change - as carbon dioxide in the ocean increases, ocean pH decreases with the water becoming more acidic. Sudden changes in pH can act as an indicator for agricultural runoff, sewage/grey water discharge, etc.

Why is pH important?

The pH of water determines the solubility (amount of solids that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.).

Most aquatic organisms are adapted to live environments with a pH between 5.0 and 9.0, though prefer a range closer to 6.5 and 8.2.

The pH of Corozal Bay Wildlife Sanctuary

The pH readings throughout the estuary were uniformly alkali, (with the exception of the sink holes). This is not unexpected as the bedrock of northern Belize is limestone, a component of the Yucatan limestone platform. Water being discharged from the rivers is slightly more acidic, with readings around pH 7 (neutral), thought to be attributable to the decomposition of organic matter.

Water Quality – pH

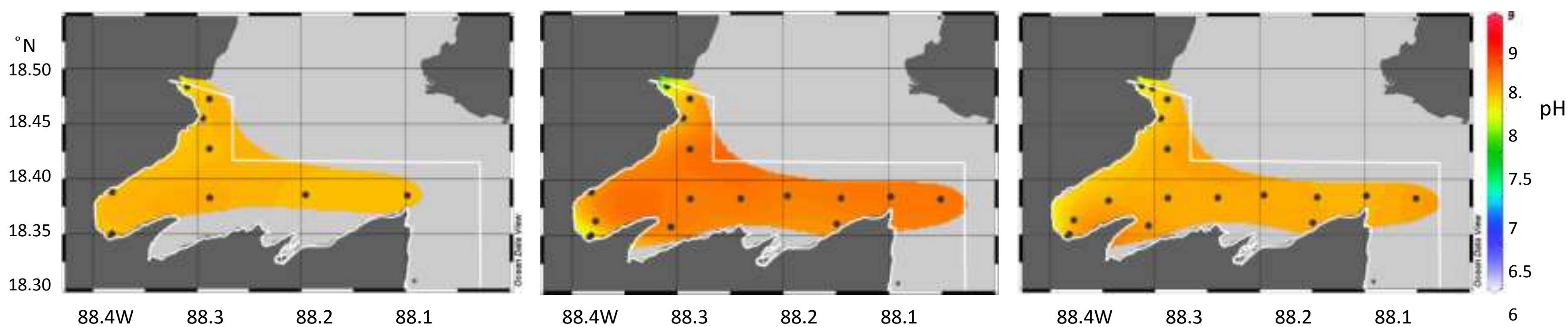
Corozal Bay North - pH	Minimum	Maximum
Dry	7.88	8.19
Wet	7.37	8.39
Norther	7.62	8.23
TS Ernesto	7.26	8.20

There is variation between the seasons, with an annual minimum of 7.37 and maximum of 8.39 in Corozal Bay North. In general surface waters are very slightly more alkaline in the wet season than all other times of year, potentially due to this acidity in the sediment layer.

The lowest pH was recorded after Tropical Storm Ernesto (pH 7.26), which stirred up the bottom sediments of the Bay - the more acidic anaerobic mangrove mud – though readings were still on the alkaline side of neutral. This mud is found in deep banks near the coastal mangroves. It is generally grey to black in colour, and is composed of highly decomposed organic matter. As the mud is so fine, there are few air spaces and little oxygen available leading to the presence of anaerobic bacteria. These decomposers use the oxygen from calcium sulphate, found in the seawater, and produce hydrogen sulphide as a waste product, resulting in the rotten egg smell so typical of the mangrove coastline. One by-product of mangrove mud processes can be sulphuric acid, countering the high alkaline nature of the limestone sediments in areas of high decomposition activity.

The role of the mangrove mud in the physical processes and status of the estuarine system is still considered a knowledge gap that requires further investigation.

The most acidic conditions were encountered in the deepest points of the sinkholes – depressions in the seabed. Sinkhole 1 and Sinkhole 'cave'. Both of these had distinct halo/thermoclines with pH in the 'normal range for the estuary in the water body above the halo/thermoclines, but much lower below (6.85 and 6.89 respectively).



(a) Dry Season **(b) Wet Season** **(c) Norther Season**

Figure 24: Horizontal transect of Corozal Bay North – pH in (a) the Dry Season, (b) the Wet Season and (c) Norther Season (River entry points are to the west).

Water Quality – Turbidity

Turbidity is a measure of how cloudy or clear the water is - as sediments and other suspended solids increase in the water, this increases the turbidity. The lower the amount of light that can pass through the water, the harder it is for plants to photosynthesise. As algae, sediments, or solid wastes increase in the water, so does turbidity.

Turbidity is measured using a secchi disc, with readings being in centimetres below the water surface, and corresponding to the depth at which the secchi disc can no longer be seen from the water's surface.

Why measure Turbidity?

Increased turbidity (i.e. increased suspended sediment) effects include:

- decreased light penetration into the water
- reduction in plant growth and oxygen production
- reduced breeding and survival of fish and other aquatic animals
- increased water temperature, causing lower oxygen levels
- degraded visual clarity of water

Scientists often consider turbidity of the water in connection with other factors to get a better understanding of its causes and consequences. For example, high levels of turbidity can identify problems with shoreline erosion, or sewage processing facilities not functioning properly.

What affects Turbidity?

Turbidity is affected by the depth of the water body, and therefore how easy it is for the bottom sediments to be stirred up by wind action. It is also affected by salinity. Salt settles sediment, so the presence of salt in estuaries has the effect of reducing turbidity.

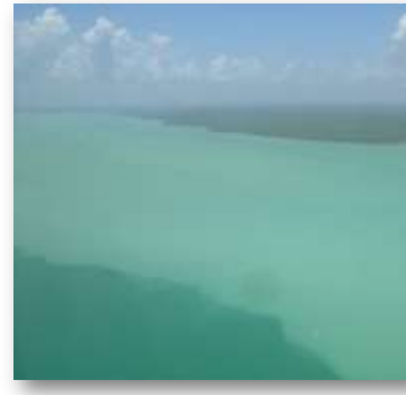
Turbidity affects organisms that are directly dependent on light, like aquatic plants, because it limits their ability to carry out photosynthesis. This, in turn, affects other organisms that depend on these plants for food and oxygen.

Turbidity in Corozal Bay Wildlife Sanctuary

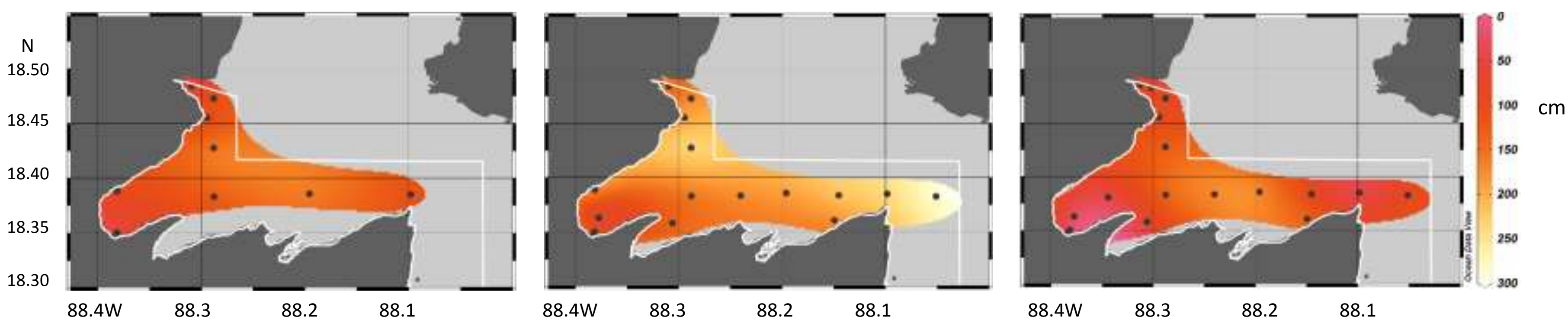
Corozal Bay is a very shallow estuarine area with extemely fine sediment, and generally strong winds either from the north or southeast. This results in water being turbid, with a large sediment load, for much of the year in either the north or east coast. In Corozal Bay North, turbidity is lowest in the dry season, with improved water clarity.

How does this affect biodiversity?

Water clarity is very important for the primary producers of the estuary – the algae and seagrass species that require access to sunlight to photosynthesise. A heavy sediment load will reduce, or even block, the light penetration, restricting the potential for plant growth. If there are areas where turbidity is therefore high and relatively constant throughout the year, these can be expected to have limited or no presence of photosynthesiszing plants or algae.



Freshwater meets salt – turbidity changes in Corozal Bay Wildlife Sanctuary



(a) Dry Season **(b) Wet Season** **(c) Norther Season**

Figure 25: Horizontal transect of Corozal Bay North – Turbidity (cms below water surface level) in (a) the Dry Season, (b) the Wet Season and (c) Norther Season (River entry points are to the west).

Water Quality – Summary - Monitoring Protocols

Parameters monitored	Monitoring protocol used	Type of equipment used	Frequency of monitoring (daily, weekly, monthly, yearly)	Number of sites	General location of sites	Monitoring Started
Current Parameters						
Temperature / water depth (pressure)	SACD WQM protocol - time series data	HOBO Water level data logger saltwater: U20-001-01	Hourly - downloaded quarterly	2	North and south CBWS	October 2012
Salinity	SACD WQM protocol - time series data	HOBO Conductivity Data Logger: U24-002		2		
Temperature	SACD WQM protocol	YSI Proplus Quattro with temperature probe	Seasonally (dry, wet and norther)	50	CBWS North and East transects	April 2012
Salinity	SACD WQM protocol			50		
Dissolved Oxygen	SACD WQM protocol			50		
Turbidity	SACD WQM protocol	Secchi disc		50		
Water Depth	SACD WQM protocol	Depth sounder		50		
Salinity	SACD Manatee protocols	YSI Proplus Quattro with temperature probe	Monthly	3	Manatee resting holes	1 year (but not monthly)
Temperature	SACD Manatee protocols			3		
Water Depth	SACD WQM protocol	Depth Sounder	During Seagrass Mapping	TBD	TBD - throughout	April 2013
Temperature	SACD WQM protocol	YSI Proplus Quattro with salinity probe		TBD		
Salinity	SACD WQM protocol			TBD		
Dissolved Oxygen	SACD WQM protocol			TBD		
Turbidity	SACD WQM protocol	Secchi disc		TBD		
Support Equipment						
Location		Garmin GPS 62	All monitoring	All	All	
Identified Gaps						
Chlorohyll a		Chlorophyll Meter	Seasonally (dry, wet and norther)	50	CBWS North and East transects	Not started
Turbidity / Total Dissolved Solids		Turbidity Meter		50		Not Started
River flow		Flow meter	TBD	TBD	New River, Rio Hondo, Progresso Lagoon system, Shipstern Creek	Not Started
Weather Station		Weather Station	Constant	1	Sarteneja	Not started

Water Quality – Monitoring Protocols

Water Quality Monitoring Equipment

Equipment:

- 1 YSI Proplus Quattro Water Monitoring equipment with three probes (dissolved oxygen, conductivity / temperature and pH).
- 2 HOBO water level data loggers
- 2 HOBO conductivity loggers
- 1 Secchi disc with weights
- 1 Depth Sounder

HOBO Conductivity Logger and Shuttle

HOBO Water Depth Logger

Secchi Disc

Handheld device (for recording and showing data)

Bulkhead with ports and sensors / probes installed

Cable (on cable winding kit) – cable plugs into handheld device and attaches to probe with bulkhead

Oxygen probe (with red caps on covering both electrode end and the port end

Conductivity and temperature probe

pH probe (sensor end is in plastic bottle with pH 4 *buffered* solution)

Water Quality Monitoring

Full YSI Survey (50 fixed survey points)

IMPORTANT:

- ***It is critical that the YSI equipment be fully calibrated the day before the survey***
- ***Ensure all participants have viewed the recording instructions for the Use and Care of the YSI meter***

1. Full surveys are conducted once a season
   - Dry Season (April / May)
   - Wet Season (July / August / September)
   - Norther Season (December / January)

2. Each survey consists of two transects, with a total of 50 survey points
   - North Corozal Bay
   - East Corozal Bay

3. At each point, the following parameters are measured:
   - Temperature (°C)
   - Salinity (ppt)
   - Dissolved Oxygen (% and mg/l)
   - Turbidity (cm)

Permanent Loggers

Four permanent loggers are launched at the start of the year (January), then retrieved and re-launched every three months (April, July and October). The time lag between retrieval, download and re-launch should be minimized.

Associated Materials

Training Presentation : Use and Care of the YSI ProPlus Quattro Water Monitoring Probe (M. Sgambati / Wildtracks, 2012)

HOBOware

YSI Data management software

Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Norther Season			***Dry Season***			***Wet Season (excl. August)***					***Norther***

Water Quality Monitoring – Quality Assurance Plan	
Method	***Seasonal Transect - YSI***
References	Maria Sgambati (2012). Use and Care of the YSI ProPlus Quattro Water Monitoring Probe. Wildtracks, 2012 YSI Professional Plus User Manual. YSI Incorporated Ronald L. Ohrel, Jr. and Kathleen M. Register (2006). Volunteer Estuary Monitoring: A Methods Manual. US Environmental Protection Agency / Ocean Conservancy
Quality Control	All personnel using equipment are fully trained in use and care. One person is designated as responsible for the safety of the YSI equipment during surveys **YSI PROBES ARE FULLY CALIBRATED THE DAY BEFORE USE.** The YSI probe is stored safely when not in use. Where feasible, all transects are completed within a week Fresh batteries are installed before each survey day
Environmental Impact Mitigation	Ensure the outboard engine is functioning well, no oil leaks. Dispose of all lube containers, equipment batteries and garbage appropriately.
Data Storage and Analysis	Storage: Hard copies and Excel file Analysis: Using ODV. Seasonal changes, annual comparisons, climate change baseline
Reporting / Dissemination	Post survey report integrated into quarterly report to Forest / Fisheries Departments Data sharing with Blue Ventures and Ecosur Annual Monitoring Report

Water Quality Monitoring – Quality Assurance Plan	
Method	***Permanent Loggers***
References	HOBO User Manual Conductivity Conversion Excel (James Douglass, 2010)
Quality Control	Equipment is deployed and recovered by experienced personnel. Time out of water is limited to as little as possible (1 day before redeployment is optimum, 1 week before redeployment is maximum). Loggers are handled and downloaded by trained personnel. Batteries are replaced every six months
Environmental Impact Mitigation	Ensure the outboard engine is functioning well, no oil leaks. Dispose of all lube containers, equipment batteries and garbage appropriately. Ensure all cable ties are removed from water.
Data Storage and Analysis	Storage: Research and Monitoring Programme computer hard drive Analysis: Daily, seasonal and annual fluctuations
Reporting / Dissemination	Post survey report integrated into quarterly report to Forest / Fisheries Departments Data sharing with Ecosur

Estuarine Environment: Strategic Actions		Desired Status
Research and Monitoring Programme		
Baseline information on water parameters of Corozal Bay Wildlife Sanctuary	▪ Seasonal monitoring of salinity, temperature, pH, dissolved oxygen, turbidity and chlorophyll a ▪ Permanent in-water loggers for monitoring water depth, temperature and salinity	▪ Accurate baseline water quality monitoring (on-going, 2013/2015) ▪ Increased understanding of physical changes within Corozal Bay Wildlife Sanctuary
Other Research and Monitoring Activities	▪ Measurement of water parameters during seagrass surveys – particularly salinity and depth ▪ Installation of permanent salinity and temperature loggers by fish traps to identify triggers for seasonal fish movements ▪ Identification of seasonal freshwater / saltwater confluence points ▪ Mapping of human impacts along New River and Rio Hondo ▪ Installation of parallel weather station	▪ Increased knowledge of effects of water parameters on conservation targets ▪ Increased knowledge of watershed impacts on water quality – location, type etc. ▪ Increased knowledge of relationship between climate and changes in estuarine water characteristics
Natural Resource Management Programme		
Increase knowledge of identified threats: ▪ Agricultural runoff ▪ Coastal Development	▪ Identification of potential and actual human impact areas during patrols (algal blooms, dredging, increased chlorophyll levels etc.)	▪ Identification and mapping of baseline human-impacted areas affected by dredging and boat traffic
Education and Outreach Programme		
Increase awareness of the estuary, its importance, and the need to maintain and improve the current conditions	▪ Increase stakeholder awareness of activities that can affect water quality, with dissemination of Best Practices	▪ Greater awareness in the key stakeholder communities, resulting in community engagement

2.7 Sharks and Rays

Corozal Bay is reported to have at least four shark species (Bonfil, 1997) within the general area, with bull, blacktip, nurse and bonnethead sharks (*Carcharhinus leucas*, *C. limbatus*, *Ginglymostoma cirratum* and *Sphyrna tiburo*) reported from the Bulkhead Shoals area to the southern end of the Wildlife Sanctuary, southeast of Deer Caye. The channels in this area are thought to be an important nursery area for these Elasmobranchs, and recent surveys have highlighted the presence of the only documented bull shark nursery in Belize (Graham, 2010). The size ranges of the bull sharks captured suggest that the animals were between 2-4 years old based on size birth of 56-81 cm (R. Graham, 2010; Compagno, 1984) and a conservative growth estimate of 16 cm a year during the first two years of life (Bransttetter and Stiles, 1987).

The Wildlife Sanctuary is also important as a pupping area for a number of species of rays (R. Graham, 2010). The presence of a mixture of juvenile and adult longnose stingrays (*Dasyatis guttata*) of both sexes suggests that coastal lagoons such as the Spanish Point site are important for this species at different life stages, particularly as a potential pupping site, and as a site that maturing longnose rays move to, at times when salinity is reduced. Also recorded are southern stingrays (*Dasyatis americana*) and Caribbean whiptail stingray (*Himantura schmardae).*

SACD is collaborating with the Belize Shark Project (WCS) to build greater knowledge of shark and ray use of Corozal Bay Wildlife Sanctuary.

A juvenile bull shark (*Carcharhinus leucas*) captured and tagged with a conventional spaghetti tag placed at the base of the first dorsal fin (Photo: R. Graham).

A longnose stingray (*Dasyatis guttata*). Corozal Bay Wildlife Sanctuary (Photo: H. Salazar)

Sharks and Rays: Strategic Actions		Desired Status
Research and Monitoring Programme		
Baseline information on shark and ray presence in Corozal Bay Wildlife Sanctuary	▪ Inclusion of sharks in aerial surveys ▪ Opportunistic sightings ▪ Reports from fishermen	▪ Increased information on use of CBWS by sharks
Other Research and Monitoring Activities	▪ Collaborate with WCS (R. Graham) in Belize Shark Project ▪ Investigate any reports of sawfish sightings in coastal lagoons and / or CBWS	▪ Increased information on shark and ray population status in Belize
Natural Resource Management Programme		
Increase knowledge of identified threats:	▪ Engage fishermen in shark and ray protection	▪ Improved protection of sharks and rays in Corozal Bay Wildlife Sanctuary
Education and Outreach Programme		
Increase awareness of sharks and rays, their role within the ecosystem, and their conservation status	▪ Increase awareness of sharks and rays in stakeholder community schools ▪ Increase fishermen knowledge of sharks and rays	▪ Greater awareness of sharks and rays in stakeholder communities

The waters of Corozal Bay Wildlife Sanctuary

2.7 Stromatolites

A 1.5km stretch of reef-forming stromatolites occurs in Corozal Bay Wildlife Sanctuary, just south of the mouth of the Rio Hondo and the Mexican border. This stromatolite formation is composed of cyanobactera (primarily of the *Scytonema* genus. Cyanobacteria are very ancient life forms first known from the Precambrian era 3.5 billion years ago, and were the first organisms to build reefs. These bacteria form a living microbial mat on the surface. Underneath this, the subsurface is stratified, representing former surface mats that have solidified to become sedimentary rock - the word “Stromatolite” comes from the Greek for “layered rock”. The Corozal Bay stromatolites are thought to have first become established 2,300 years ago.

Stromatolites

There are very few modern stromatolite reefs known in the world, making Corozal Bay Wildlife Sanctuary globally important in representing protection of these rare reef structures. There is currently no monitoring plan in place – this is scheduled for development in late 2013. The stromatolite reef has been mapped using remote imagery, to be followed by on-site mapping in collaboration with Blue Ventures in 2013. It should be noted, though, that this reef passes in front of a proposed property development that may have a significant impact on the structures.

Modern Stromatolite Reefs Fringing a Brackish Coastline, Chetumal Bay, Belize

- Reef-forming stromatolites have been discovered along the windward shoreline of Chetumal Bay, Belize, just south of the mouth of the Rio Hondo.
- The reefs and surrounding sediment are formed by the precipitation of sub-microcrystalline calcite upon the sheaths of filamentous cyanobacteria, principally *Scytonema*, under a seasonally fluctuating, generally brackish salinity regime (0‰ to 10‰).
- Well-cemented, wave-resistant buttresses of coalesced stromatolite heads form club-shaped reefs up to 42 m long and 1.5 m in relief that are partially emergent during low tide.
- Oncolitic rubble fields are present between well-developed reefs along the 1.5 km trend, which parallels the mangrove coastline 40-100 m offshore.
- The mode of reef growth, as illustrated by surface relief and internal structure, changes with increasing water depth and energy, proximity to bottom sediments, and dominant cyanobacterial taxa.
- Sediment trapping and binding by cyanobacteria are of limited importance to reef growth, and occur only where stromatolite heads or oncolites are in direct contact with the sandy sea floor.
- Radiocarbon-dated mangrove peat at the base of the reef suggests that it began to form about 2300 yr B.P., as shoreline encrustations that were stranded offshore following storm-induced retreat of the mangrove coast.

K. A. Rasmussen, Ian G. Macintyre and Leslie Prufert, Geology March, 1993 v. 21, no. 3

Stromatolite: Strategic Actions		**Desired Status**
Research and Monitoring Programme		
Baseline mapping of stromatolites	▪ Aerial photography ▪ Satellite imagery ▪ In-water mapping (protocol to be developed)	▪ Accurate baseline on extent of stromatolites in Corozal Bay Wildlife Sanctuary
Monitoring of water parameters in stomatolite area	▪ SACD Water quality monitoring protocol - YSI	▪ Increased information on water parameters required by stromatolites
Other Research and Monitoring Activities	▪ Development of protocol for assessing health / status of stromatolites over time	▪ Increased knowledge of the stromatolite reefs of Corozal Bay and the pressures that impact them
Natural Resource Management Programme		
Increase knowledge of identified threats: ▪ Coastal Development	▪ Identification of potential and actual human impact on the stromatolites	▪ Proactive protection of stromatolites
Education and Outreach Programme		
Raise awareness of the presence of stromatolites in Corozal Bay Wildlife Sanctuary	▪ Increase stakeholder awareness of stromatolites in Corozal Bay Wildlife Sanctuary and Belize	▪ Greater awareness in Belize of the role of Corozal Bay Wildlife Sanctuary in protecting stromatolites

3.0 Monitoring for Climate Change

With the current regional and global environment of increasing sea surface temperatures, ocean acidification and tropical storm intensity, planning for climate change has become a fundamental necessity for long term viability of Corozal Bay Wildlife Sanctuary.

The area is in the 'highest risk of tropical storm impact' belt for Belize and this, combined with the increased intensity of storms and increasing sea level, is predicted to result in salination of the aquifer, especially with the generally low elevation (almost all Sarteneja lies less than 2m above sea level).

Annual rainfall has decreased by 25 cm or more in the north over the last 30 years and is predicted to continue decreasing, with lengthened dry seasons and reduced predictability of rainfall. This will further impact productivity of the already shallow soils, restricting options for diversification into traditional agriculture. Local fish stocks are already considered to be significantly reduced when compared with twenty years ago, providing only a minimal income for local fishermen and their families. However, as more fishermen find it challenging to support themselves from the lobster and conch fisheries, there will be increased pressure to access Corozal Bay Wildlife Sanctuary for its finfish resources.

There is, however, limited awareness among community stakeholders of climate change and the significant impacts it is predicted to have on the area.

Monitoring for Climate Change

Monitoring key climate change parameters can help inform on climate change impacts and adaptive management decisions. Corozal Bay Wildlife Sanctuary can also actively play a part in providing mechanisms for community adaptation to climate change:

Mitigation

- ***Store**: Protection of the seagrass and mangroves prevents the loss of carbon that is already present in vegetation and soils*
- ***Capture**: The mangroves and seagrass can help sequester further carbon dioxide from the atmosphere*

Adaptation

- ***Protect**: By maintaining ecosystem integrity, Corozal Bay Wildlife Sanctuary can assist in buffering local climate, and reduce risks and impacts from extreme events such as storms, droughts and sea-level rise, with mangroves stabilizing shorelines and seagrass stabilizing estuarine sediments*
- ***Provide**: By maintaining essential ecosystem services – mangrove and seagrass nursery areas for commercial fish species*

Predicted Impacts on Ecosystem			
Climate Change Impact	**Predicted Changes**	**Seagrass**	**Mangrove**
Sea level rise	▪ Current average increase in sea level rise in the Mesoamerican region is estimated at 3.1mm per year (IPCC, 2007). ▪ Predicted increase of between 0.6m and 1.0m over next 100 years, though could be higher (up to 3.3m), dependent on the rate of melt of ice sheets (Simpson et al., 2009)	Corozal Bay Wildlife Sanctuary is at the limit of seagrass environmental preferences, being shallow and hot, with seasonally low salinity. Increases in water depths above present meadows may be beneficial and reduce heat and turbidity in the water column. Shifts in distribution of seagrass beds. Over the medium term, seagrass should be able to survive in increased water depth and may benefit in this system. May be beneficial for aquatic organisms dependent on seagrass, such as the West Indian manatee, promoting a more stable environment, with increased buffering against high and low temperatures, and extreme salinity shifts.	Inundation of lenticels in the aerial roots can cause the oxygen concentrations in the mangrove to decrease, resulting in death. If migration of mangrove inland cannot occur as sea level rises, then mangroves may disappear – as long as the saline mud flats of the low coastal plain remain undeveloped, migration should occur naturally. Increase in saltwater intrusions may also affect distribution of mangroves. Potential for changes in dispersal patterns for mangrove propagules Projected loss of the cayes to inundation – but new cayes may form. Potential impacts on bird nesting colonies on mangrove cayes, where migration cannot occur.
Sea surface temperature rise	▪ Water temperature has increased by 0.74˚C between 1906 and 2005 ▪ Current levels of increase are estimated at 0.4˚C per decade (Simpson et al., 2009) ▪ Predicted regional increase of temperature by up to 5˚C by 2080, with the greatest warming being experienced in the north-west Caribbean (incl. Belize) (WWF, 2009).	Temperature stress on seagrass may result in distribution shifts, changes in patterns of sexual reproduction, altered seagrass growth rates, metabolism, and changes in their carbon balance. High temperatures may increase epiphytic algal growth, increasing shading and reducing available sunlight. When temperatures reach the upper thermal limit for individual species, the reduced productivity will cause plants to die (above 35˚C for *T. testudinum*). Increased water depth may, however play a role in moderating water temperature in the Wildlife Sanctuary.	

Predicted Impacts on Ecosystem			
Climate Change Impacts	**Predicted Changes**	**Seagrass**	**Mangrove**
Increased frequency and intensity of storms	▪ Increased intensity of storms from 1999 onwards, with annual fluctuations. Stronger storms > Cat 4 / 5	Massive sediment movements that can uproot or bury seagrass, as seen during Hurricane Dean. It may also become harder for seagrasses to become re-established. Would be exacerbated by anthropogenic impacts – primarily dredging and landfill	Large storm impacts result in mass defoliation, mortality, storm inundation and changes in sediment dynamics. Possible increase in nutrients / growth. Projected increase in frequency of high water events, salinity and inundation could affect mangrove health and composition. More frequent storm inundation is also projected to decrease the ability of mangroves to photosynthesize.
Ocean acidification	▪ Atmospheric CO_2 concentration has increased from 280 parts per million (ppm) in 1880 to 385 ppm in 2008 (Simpson et al., 2009). ▪ 48% of all atmospheric CO_2 resulting from burning of fossil fuels has been taken up by the ocean (Hartley, 2010) ▪ Predicted atmospheric CO_2 levels of 450 by 2040 (Simpson et al., 2009) ▪ Predicted 30% decrease in pH ▪ Predicted decrease in calcification rate by 20 - 50% by 2050 ▪ Some experts predict a 35% reduction in coral growth by 2100 (Simpson et al., 2009)	Possible direct positive effect on photosynthesis and growth, as in some situations, seagrass is carbon limited. Higher CO_2 levels may also increase the production and biomass of epiphytic algae on seagrass leaves, adversely impacting seagrass by causing shading. Acidification of seawater could counter the high pH formed by photosynthesis in dense seagrass stands, increasing seagrass photosynthesis and productivity. May affect invertebrates and other organisms of seagrass communities.	Positive increase in growth. May affect invertebrates and other organisms of mangrove root communities.

Predicted Impacts on Ecosystem			
Climate Change Impacts	**Predicted Changes**	**Seagrass**	**Mangrove**
Decreased Precipitation	▪ Mean monthly rainfall over Belize has decreased at an average rate of 3.1mm per decade since 1960 (NCSP/UNDP) ▪ Increased concentration and seasonality of agrochemical delivery / pollution ▪ Predicted decrease in precipitation of 9% by 2099 (IPCC, 2007), with significant fluctuations, attributed to El Niño ▪ Some models predict a decrease of as much as 22% (IPCC 2007)	Seagrass has relatively high adaptation to shifts in salinity. Increasing salinity in the estuarine system would permit an increase in extent and biomass production.	Reduction of freshwater lens, effect on carbon uptake, photosynthesis. Decreased precipitation would result in a decrease in mangrove productivity, growth, and seedling survival, and may change species composition favouring more salt tolerant species.
Increased Air Temperature	▪ Mean annual temperature has increased in Belize by 0.45°C since 1960, an average rate of 0.10°C per decade. ▪ Average number of 'hot' days per year in Belize (days exceeding 10% higher than current average temperature) has increased by 18.3% between 1960 and 2003 (NCSP/UNDP). ▪ Predicted mean annual temperature increase is 3.5° by 2099 (UNDP, 2009).	Indirect – by increasing water surface temperatures If mangroves are lost due to increased air temperatures beyond the acceptable range, this will destabilize the coastline, with increased erosion and water turbidity, negative impacting seagrass and other conservation targets	May alter phenological patterns - timing of flowering and fruiting. At temperatures above 25°C, some species show a declining leaf formation rate. Above 35°C have led to thermal stress affecting mangrove root structures and establishment of mangrove seedlings. At leaf temperatures of 38-40°C, almost no photosynthesis occurs (IUCN, 2006). Possible localized changes in distribution. If mangroves are lost, this will destabilize the coastline, with increased erosion and water turbidity

Basic Monitoring Requirements for Climate Change		
Climate Change Factor	**Monitoring Requirements**	**Equipment**
Sea level rise	Continual monitoring of water level	Two in-water data loggers (HOBO) are currently deployed in CBWS. May need replacing every two to three years. Seasonal YSI transects - 50 sites, three times a year, include depth measurements
Sea surface temperature rise	Continual monitoring of water temperature	Four in-water data loggers (HOBO) are currently deployed in CBWS. May need replacing every two to three years Seasonal YSI transects - 50 sites, three times a year include surface temperature measurements Historical and current remote imaging data on sea surface temperature available on-line
Increased frequency and intensity of storms	Maintain log of tropical storm / hurricane activity and level of impact Post-storm monitoring of erosion	Download historical data from NHC. Conduct post- storm monitoring (one event per year) Maintain log of tropical storm / hurricane activity and level of impact (eg. erosion, flooding)
Ocean acidification	Annual monitoring of pH	Seasonal YSI transects - 50 sites, three times a year, include pH measurements
Decreased Precipitation	Continual monitoring of precipitation	Automated weather station with rain gauge at SACD office, linked to dedicated computer
Increased Air Temperature	Continual monitoring of precipitation	Automated weather station with air temperature / air humidity probe at SACD office, linked to dedicated computer

4.0 Sarteneja Alliance for Conservation and Development

The Sarteneja Alliance for Conservation and Development (SACD) holds co-management responsibility for Corozal Bay Wildlife Sanctuary through a five-year agreement with Forest Department, signed in 2012. SACD has been established since 2007, and is dedicated to improving the management of Corozal Bay Wildlife Sanctuary and the quality of life of the stakeholder communities through conservation, outreach and protected area management activities, and promotion of the sustainable use of the natural resources. It was registered as an NGO on September 2008, under the Non-Governmental Organization Act. It is a community based organization, located in Sarteneja, Corozal District.

SACD provides a mechanism for effective communication, collaboration and networking between local individuals, associations and organizations in Sarteneja. It has a structured Executive Board composed of representatives from the Sarteneja Tour Guide Association, Sarteneja Fishermen Association, local fishing, education and tourism/business sectors, and local NGOs which, together, form the Alliance.

Vision: *SACD is an effective alliance of organizations, focused on community development and the sustainable resource use of the Corozal Bay Wildlife Sanctuary, for the benefit of the present and future generations of Sartenejeños.*

Mission Statement: *The Sarteneja Alliance for Conservation and Development is a community-orientated, non-profit organization dedicated to improving the quality of life of Sartenejeños through strengthening mechanisms for collaboration, support and community engagement; and through the promotion of the sustainable use of the Corozal Bay Wildlife Sanctuary.*


Carolie Verde
President, SACD

Annex: Standards

Geo-referencing			
Target	**Monitoring Activity**	**Coordinate System**	**Data Storage / Analysis**
West Indian Manatee	Aerial Survey	UTM UPS NAD27 Central	Excel / GIS / ODV4
	Resting Hole	UTM UPS NAD27 Central	Excel / GIS / ODV4
	Opportunistic Sightings	UTM UPS NAD27 Central	Excel / GIS
Commercial Fish Species	Beach trap locations	UTM UPS NAD27 Central	Excel / GIS
Mangroves / Coastal Ecosystems	Coastal monitoring	UTM UPS NAD27 Central	Access / GIS
Bird Nesting Colonies	Caye locations	UTM UPS NAD27 Central	Excel / GIS
Seagrass	Quadrat locations	UTM UPS NAD27 Central	Excel / GIS / ODV4
Water Quality	Point locations	WGS1984 spheroid	Excel / ODV4
Sharks and Rays	Aerial Survey	UTM UPS NAD27 Central	Excel / GIS
Stromatolites	Mapping	UTM UPS NAD27 Central	Excel / GIS

Measurement	
Length / depth	Centimetres / Metres / Kilometres
Time	24 hour (eg. 14:30)
Temperature	°C

Acronyms

GIS Global Information System
ODV Ocean Data View

Annex: Water Quality Monitoring Points

YSI Transects		
Site	Longitude (WGS84, Decimal Degrees)	Latitude (WGS84, Decimal Degrees)
WQ 17	-88.1495600	18.3606500
WQ 2	-88.1959000	18.3856200
WQ 2B	-88.2400200	18.3835600
WQ 3	-88.2878200	18.3830800
WQ 4	-88.2882300	18.4276900
WQ 9	-88.2945800	18.4553900
WQ 5	-88.2881300	18.4726600
WQ5B	-88.3022000	18.4826300
WQ6	-88.3124500	18.4851100
WQ 7	-88.3183400	18.4883100
WQ 8	-88.3281500	18.4899600
WQ RIO HONDO	-88.3367500	18.4873700
WQRIO HONDO2	-88.3460100	18.4859300
WQ 3B	-88.3441770	18.3808730
WQ NEW RIVER	-88.4028700	18.3421200
WQ 12	-88.3908900	18.3412400
WQ11B	-88.3836000	18.3437900
WQ 11	-87.8391000	18.1863800
WQ 13	-88.3816600	18.3503800
WQ 13B	-88.3772400	18.3631400
WQ 18	-88.3060600	18.3581600
WQ 1B	-88.1454000	18.3839300
WQ 1	-88.0982900	18.3850500
WQ 0	-88.0511500	18.3826810
EDWQ0	-88.0496540	18.3356606
EDWQ1	-88.0512659	18.2923007
EDWQ1	-88.0512659	18.2923007
EDWQ1B	-88.0464646	18.2489035
EDWQ2	-88.0449819	18.1858950
EDWQ2	-88.0449819	18.1858950
EDWQ2B	-88.0419108	18.1399572

YSI Transects (continued)		
Site	Longitude (WGS84, Decimal Degrees)	Latitude (WGS84, Decimal Degrees)
EDWQ3	-88.0396153	18.0985606
EDWQ4	-88.0391546	18.0540089
EDWQ5	-88.0369026	18.0195614
ESWQ8	-88.0865300	17.9703900
ESWQ8B	-88.0897900	17.9681600
ESWQ7	-88.1427400	17.9706346
ESWQ6	-88.1355708	18.0042951
ESWQ5B	-88.0851966	18.0144346
ESWQ5	-88.1149225	18.0520503
ESWQ4B	-88.0847690	18.0510109
ESWQ4	-88.0868644	18.0983001
EDWQ2B	-88.0848759	18.1390872
ESWQ3	-88.0829985	18.1856844
ESWQ2	-88.0844866	18.2504089
ESWQ1	-88.0846909	18.2939484
ESWQ0	-88.0850590	18.3348027

Permanent HOBO Loggers		
Site	Longitude (WGS84, Decimal Degrees)	Latitude (WGS84, Decimal Degrees)
ESWQ8	-88.0865300	17.9703900
ESWQ8B	-88.0897900	17.9681600
ESWQ7	-88.1427400	17.9706346
ESWQ6	-88.1355708	18.0042951
ESWQ5B	-88.0851966	18.0144346
ESWQ5	-88.1149225	18.0520503
ESWQ4B	-88.0847690	18.0510109
ESWQ4	-88.0868644	18.0983001
EDWQ2B	-88.0848759	18.1390872
ESWQ3	-88.0829985	18.1856844
ESWQ2	-88.0844866	18.2504089
ESWQ1	-88.0846909	18.2939484
ESWQ0	-88.0850590	18.3348027

Top: Manatees – Aerial Survey
Bottom: Water Quality – Collaboration with

Mangroves – Site Assessment
Colony Nesting Birds – Monitoring Cayo Falso

Coastal Mapping – Training in GPS Use
Water Quality – Conducting YSI transects

SACD…bringing people together to promote conservation and sustainable development.

Wildtracks