JUMBY BAY SILT REMOVAL

Benthic Marine Assessment Report

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Executive Summary

Jumby Bay Island LTD is proposing the dredging of areas adjacent to the beach on the western portion of long island with the aim to replace the dredged area with suitable sand. As per the Department of Environment requirements, marine ecological surveys were conducted to better understand the environmental conditions of the area, and the possible impacts of the proposed dredging activities. Seagrass surveys indicated that the area is a seagrass bed ecosystem which is dominated by native seagrass species such as Turtle Grass and Manatee grass, along with the presence of the invasive Broad-leaf seagrass. This seagrass bed ecosystem is providing ecosystem services such as biodiversity support, nursery habitat for Queen conch, and aiding in the reduction of turbidity from the water column which improves water quality. Downstream from the proposed sites, there is evidence of coral recovery, with some areas exhibiting >45% live coral cover. Dredging activities are likely to result in a greater expansion of the invasive broadleaf seagrass to the affected areas, reduce the ecosystem services being provided by the seagrass beds, and increase turbidity which may smother downstream coral reef areas. If unavoidable, dredging activities should be reduced, and paired with ecosystem restoration activities, to mitigate its negative impacts on the marine environment.

Introduction

Map 1: Area of Interest. Map provided by Blue Ocean

The Jumby Island LTD has submitted a proposal for the removal of silt from the bay on the western side of Long Island, and to replace this area with suitable sand. The area of removal is said to be 800ft (243.8m) long (North to South) by 40ft (12.2m) wide (West to East), covering a total of 32000 sq ft (2972.9m^2) or approximately 0.73 acres. The depth of the excavation is to be 16in (0.4m), and the proposal is to replace the silt with suitable sand from offshore.

The project site is located directly West of Long Island. The Area of Interest is located within the North East Marine Management Area (NEMMA), which is home to a variety of marine ecosystems, inclusive of mangrove wetlands, seagrass beds and coral reefs ecosystems (Map 1). In an effort to understand the possible implications of the project, a benthic marine assessment was commissioned.

Background and Literature Review

The Long Island, on which Jumby Bay Ltd is located is one of several offshore islands belonging to the island of Antigua and Barbuda and is located in the North East Marine Management Area (NEMMA). NEMMA was designated as a Marine Managed Area (MMA) in 2005 under the 1983 Antigua and Barbuda Fisheries Act, Cap 173. It encompasses an area of 30 sq-miles (77.7km^2) at the North-Eastern side of the mainland and is the largest MMA in Antigua & Barbuda. A management plan was created for the NEMMA region in 2008 which detailed the objectives and the scope of the area [1]. NEMMA is recognized as a globally "*globally significant research and conservation site as a refuge for endemic, rare and globally important wildlife including the critically endangered Antigua Racer Snake (Alsophis antiguae), the Hawksbill Turtle (Eretmochelys imbricata) and the vulnerable West Indian Whistling Duck*

(Dendrocygna arborea) [1]. This management plan is however in need of review to better address the needs of the area.

The primary marine assets found with the NEMMA region are coral reefs, mangrove wetlands and seagrass beds, all of which support a wide variety of marine life. Mangrove wetlands cover over 240 hectares within the NEMMA [2] and consists of 4 species: Red Mangrove (*Rhizophora mangle*), Black Mangrove (*Avicennia germinans*), White Mangrove (*Laguncularia racemosa*) and Buttonwood Mangrove (*Conocarpus erectus*). In total, eighteen (18) individual mangrove wetland sites have been recorded in the NEMMA region [1].

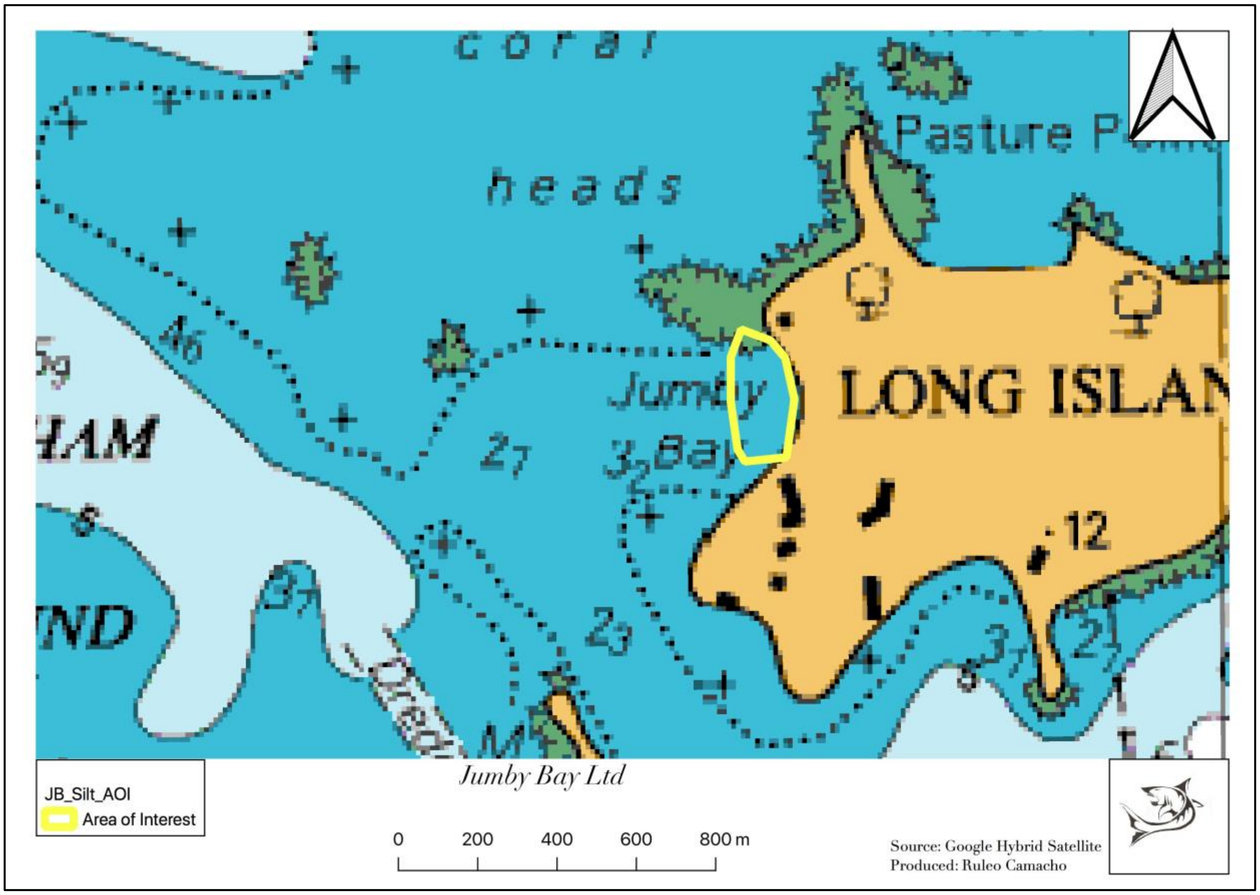
Significant coral reef structures have been recorded in the NEMMA region, particularly in the outer regions of the area which has been identified as having some of the most extensive coral reef systems of the mainland Antigua [3]. Coral reefs in these areas were reported to have the highest live coral cover, 13% Live Coral Cover, in surveys conducted in 2017, with reef types being primarily patchy and fringing reefs dominated by branching corals including the Acroporid species, including the critically endangered *Acropora palmata*[4]. Coral structures have been subjected to a variety of pressures over the years, which include hurricanes, anchors, fishing gear, sedimentation, eutrophication, pollution and diseases [2]. Coral reefs in the area have been found to provide habitat for a variety of marine species, including the commercially important fish like Grouper (Serranidae) and Snapper (Lutjanidae), as well as Caribbean Spiny Lobster (*Panulirus argus*) [2].

Seagrass beds are reported common within the NEMMA, primarily within the shallow lagoons. Dominant seagrass species observed included the Turtle Grass (*Thalassia testudinum*), while other species such as Manatee grass (*Syringodium filiforme*) and Shoal grass (*Halodule wrightii*) have also been observed [2]. Algal overgrowth by the brown algae *Dictyota sp.* have been observed in some areas, particularly where there has been anchor scarring. These seagrass beds are also known to provide habitat for marine turtles, including the Green Sea Turtle (*Chelonia mydas*) and the Hawksbill Turtle (*Eretmochelys imbricata*).

Beaches are distributed throughout the NEMMA region and are important for recreation along with providing nesting habitats for marine turtles. Beach monitoring does occur within the NEMMA region to assess impacts of erosion. Extensive turtle monitoring has occurred on the Long Island for over 30 years, with over 200 nesting females tagged since the start of the program [1].

Site Description

The proposed development area is a sheltered bay on the Western end of Long Island. It is enclosed within a swim line and is used primarily for recreational activity by the guest of Jumby Bay Resorts. There is a swim platform midway in the bay, on the inner part of the swim line, where individuals were regularly observed during the survey period. The bay is shallow, with marine nautical charts indicating a depth range less than 10ft (1.2 – 3.2m) (Map 2), and depths during the survey ranging from 3-6ft (1-2m).



Map 2*: Benthic nautical chart showing the AOI.*

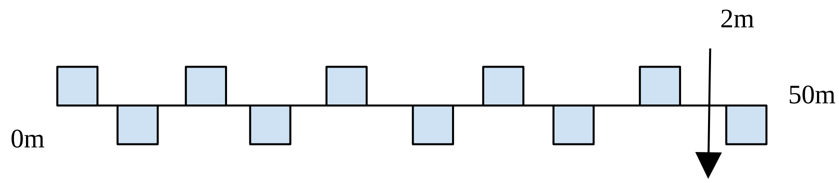
Methodology

Seagrass Surveys

Based on the desktop research, the primary benthic habitat for the area was identified as seagrass, and the seagrass protocol developed by Ruleo Camacho and previously used in the assessment of seagrass beds in the Nelson Dockyard National Park [5] was utilized. Seagrass surveys were conducted via scuba-diving, and was focused on the area of interest as specified in Map 3. The protocol is as follows:

- Lay out a 50m transect along the seagrass bed parallel to the shore if possible. While laying the transect, record the following within a 1m belt on either side of the transect:
    - # of conch (adult and juvenile)
    - # of urchins (differentiate by species)
    - # of sea cucumbers
    - # of other fauna (upside down jellyfish, starfish, etc.)
- Approximately every 5 m (starting at 0m) at alternating sides along the transect tape using a 1-meter squared quadrant, measure the following:
    - % cover of: Seagrass, live coral, sand, other (specify if possible). Ignore living fauna but indicate what is beneath if possible. If invasive species of seagrass is present, measure % cover of invasive species as well as % cover of other species of seagrass.
    - Abundance and species richness of Seagrass within the quadrant

  - Average canopy height of Seagrass to the nearest mm.
- Repeat to obtain at least 3 transects per survey site, at progressively shallow depths (e.g. 7m, 5m, 3m)
- Transcribe data from under-water data sheet to Microsoft Excel and analysed.



Coral Surveys

In an effort to understand the ecological condition of the coral reef areas within proximity of the project, coral reef surveys were carried out. These surveys were conducted using in-situ assessment of coral reef sites to the west of the study sites using the photo-transect methodology.

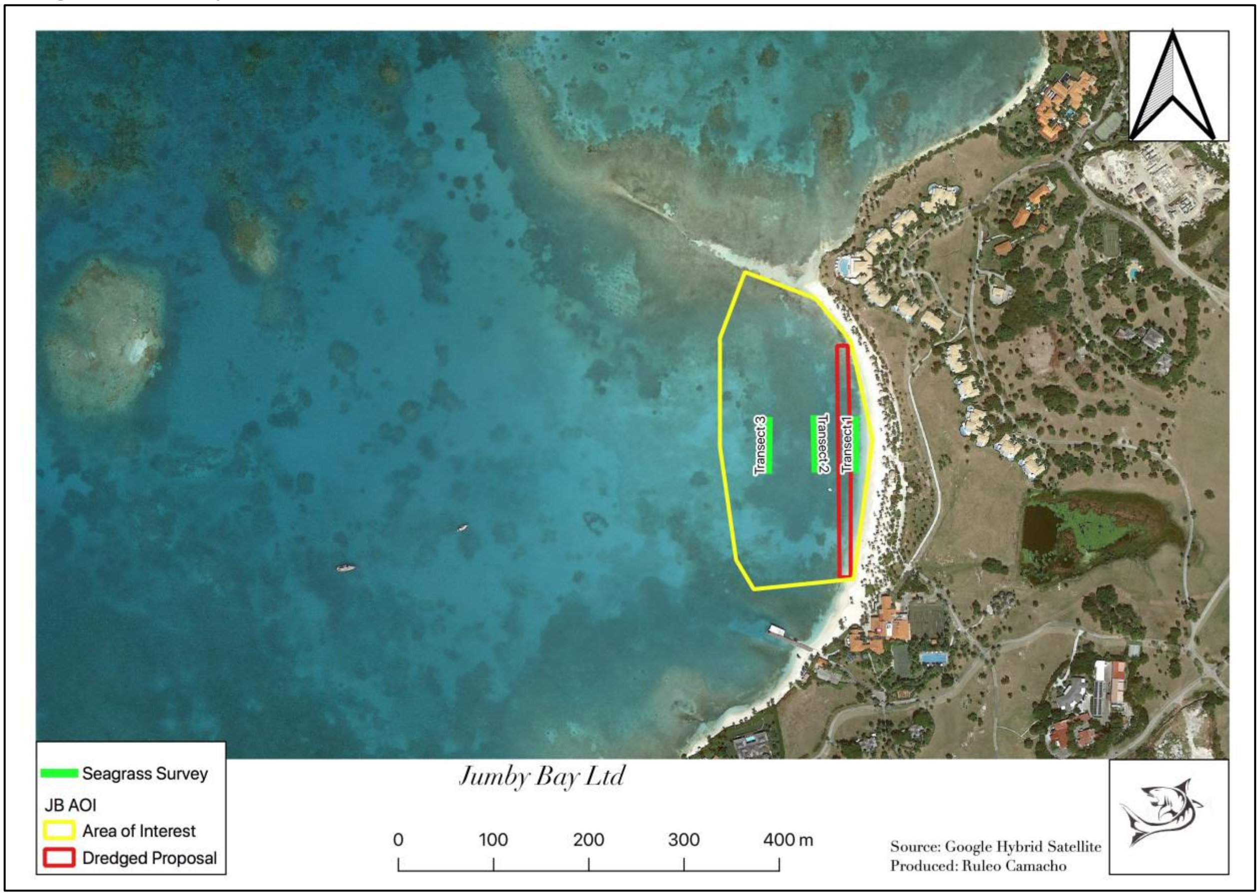
- Lay out a 10m transect along the reef area. Where possible, use a lead line to reduce the possible swaying and damage to the coral reef environment.
- Using a measuring tape and a tripod pole, set a distance from the substrate where a width of 50cm is visible in the camera frame.
  - The camera used in these surveys was an Olympus TG-6
- Take sequential pictures along the left side of the 10m line, ensuring that there is minimal overlap between pictures.
  - Proceed around along the right side of the transect line to conduct a photo-transect survey covering $10m^2$.
- Process pictures using the Coral Point Count Program with excel extensions[6].
  - Ten (10) points were randomly assigned to each picture. The substrate type under each point was identified using a substrate code, then submitted for processing.
  - Final analysis and creation of graphs was conducted using Microsoft suite.

Other Marine Checks

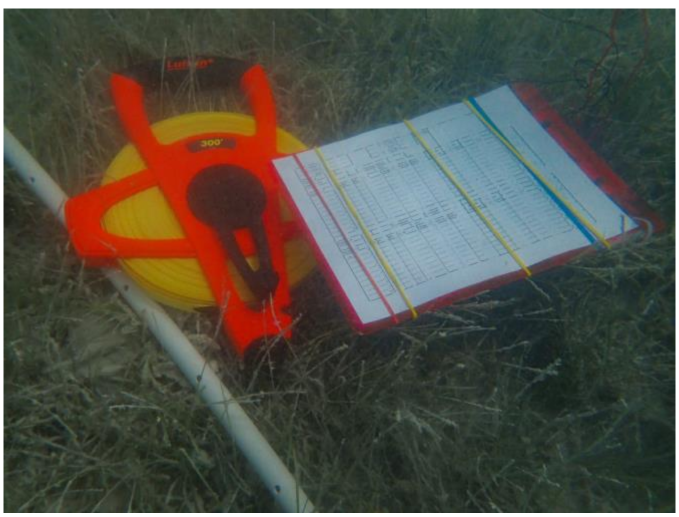
To better understand the marine environment of the surrounding area, additional “spot-checks” were conducted around the site using snorkeling. Dominant benthic characteristics were recorded, and observations were made along with GPS recordings.

Findings/Results

Seagrass Surveys



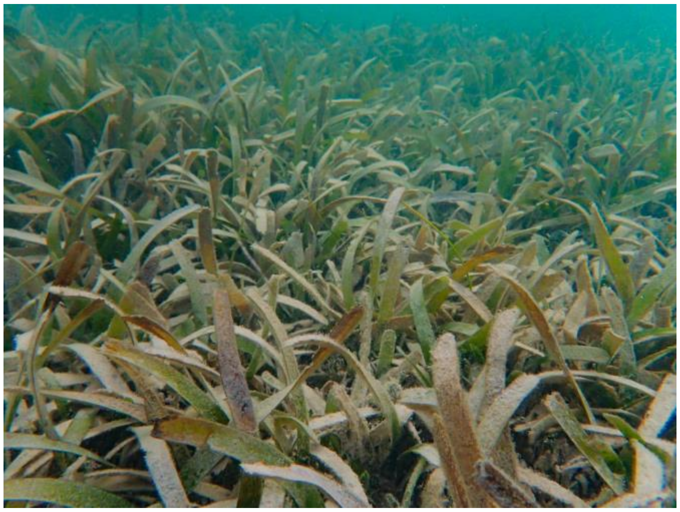
***Map 3**: Seagrass Surveys.*



***Picture 1**: Seagrass Survey Equipment.*

Three Seagrass survey transects were executed using the above-described methodology (Map 3, Picture 1). Each transect was separated by 130-150ft (39-46m), in an effort to capture the ecological characteristics of the area of interest specified in Map 3. Transect 1 was conducted nearest to the shore, in an average depth of 3.5ft (1m). Transect 2 was conducted adjacent to the swim platform in the swim area, and depth was 6ft (1.8m). Transect 3 was executed beneath the swim line, and the depth average was 5.5ft (1.7m).

The benthic substrate was dominated by the native species of seagrass, i.e., Turtle Grass



***Picture 2**: Turtle Grass*

(*Thalassia testudinum) (Picture 2),* Manatee Grass (*Syringodium filiforme*) *(Picture 3)* and *Halimeda sp*.. The invasive Broad-leaf Seagrass (*Halophilia stipulacea*) (Picture 4) was also noted in the transects, with the dominant benthic substrate being a mud/silt material. In Transect 1, native seagrass species accounted for 85% of benthic cover, while the invasive broadleaf species accounts for 3.5% and the remaining 11.5% made up by mud/silt. Transect 2 consisted of 58.5% of the benthic cover, with the invasive broadleaf species accounting for 11% and the remaining 30.5% mud/silt. Transect 3 had 54.5% native seagrass cover, 22% invasive seagrass cover and 23.5% silt/mud (Figure 1). Overall, native seagrass species accounted for 66% of the benthic coverage in the area of interest, followed by mud/silt (21.83%) and invasive seagrass (12.17%). In all transects, seagrass blades, particularly the native species, were heavily inundated by sediment (Picture 5).

***Picture 3**: Quadrant dominated by Manatee Grass*

***Picture 4**: Broad-Leaf Seagrass showing sedimentation on leaves*

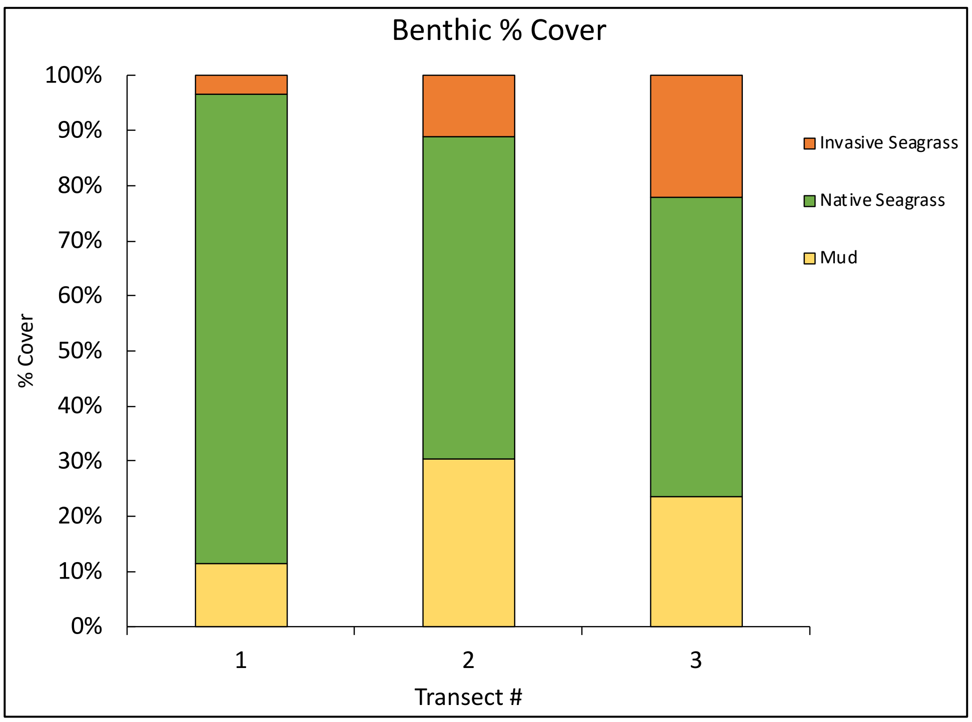


***Figure 1**: Benthic Substrate percentage (%) coverage*

***Picture 5**: Turtle Grass with sedimentation on leaves*

Floral Canopy height showed variation between transects, with transects having a higher proportion of the invasive broadleaf species showing a reduction in canopy height (Figure 2). Transect 1 and Transect 2 were similar, measuring 164mm and 160mm respectively. This dropped to 141.5mm in Transect 3, where the coverage of the invasive broadleaf species increased to 22%. Average canopy height throughout the area of interest is 155.17mm. Floral species richness varied, with Transect 1 measuring 4.5 species/m^2, while Transect 2 and Transect 3 both measured 3.5 species/m^2. Overall average species richness in 3.7 species/m^2.

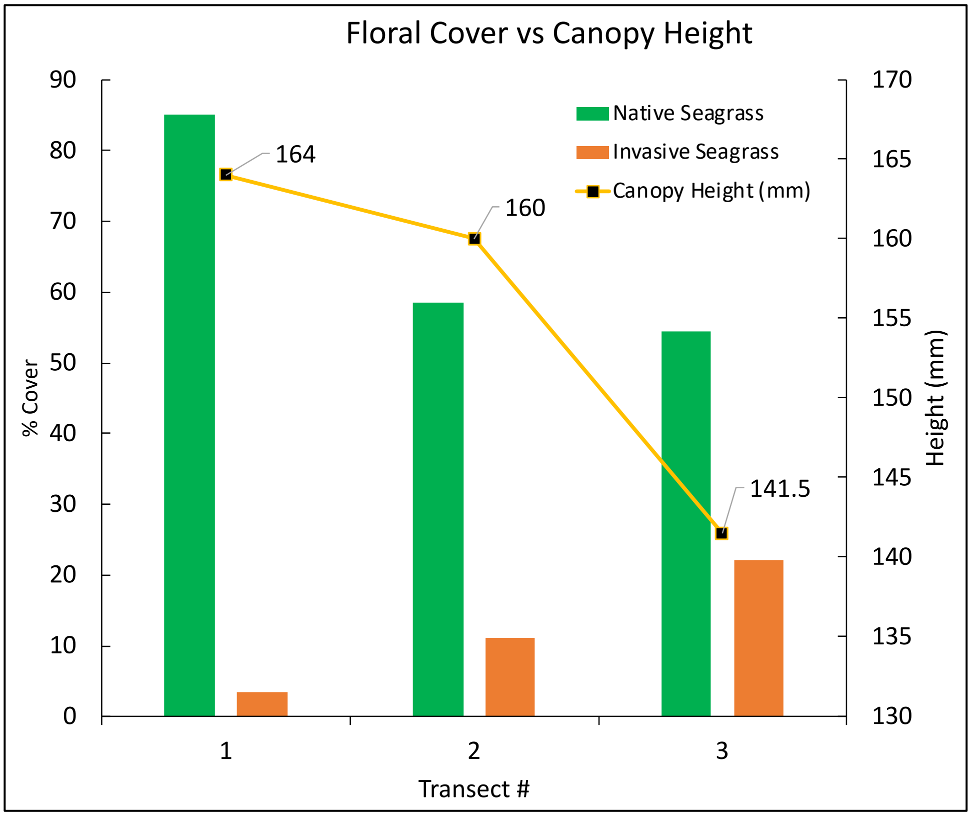


***Figure 2**: Seagrass percentage cover (%) and canopy height (mm).*

Macro-invertebrates varied across transects, with the Upside-down jellyfish (*Cassiopea frondosa* and *Cassiopea xamachana*) *(Picture 6)*, being the most dominant but only seen in Transect 2 (26/100m^2) and Transect 3 (5/100m^2). A single Queen Conch (*Aliger gigas*) *(Picture 7)* was seen in Transect 2, while 6 Cushion Sea Star (*Oreaster reticulatus*) *(Picture 8)* were observed in Transect 6. No Macro-invertebrates were observed in Transect 1 (Figure 3).

***Picture 6**: Upside-down Jellyfish in seagrass*

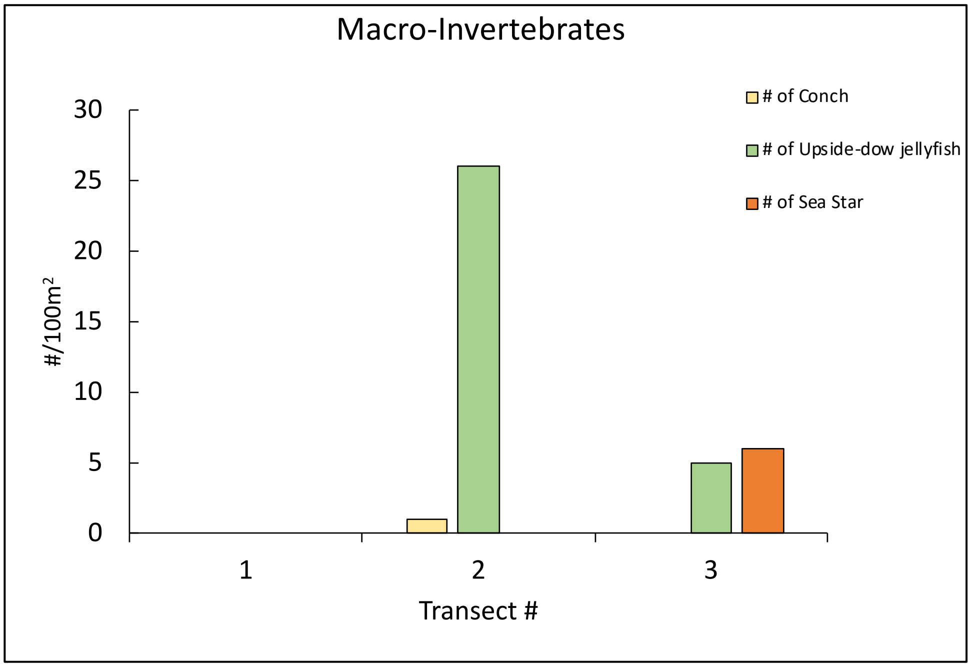
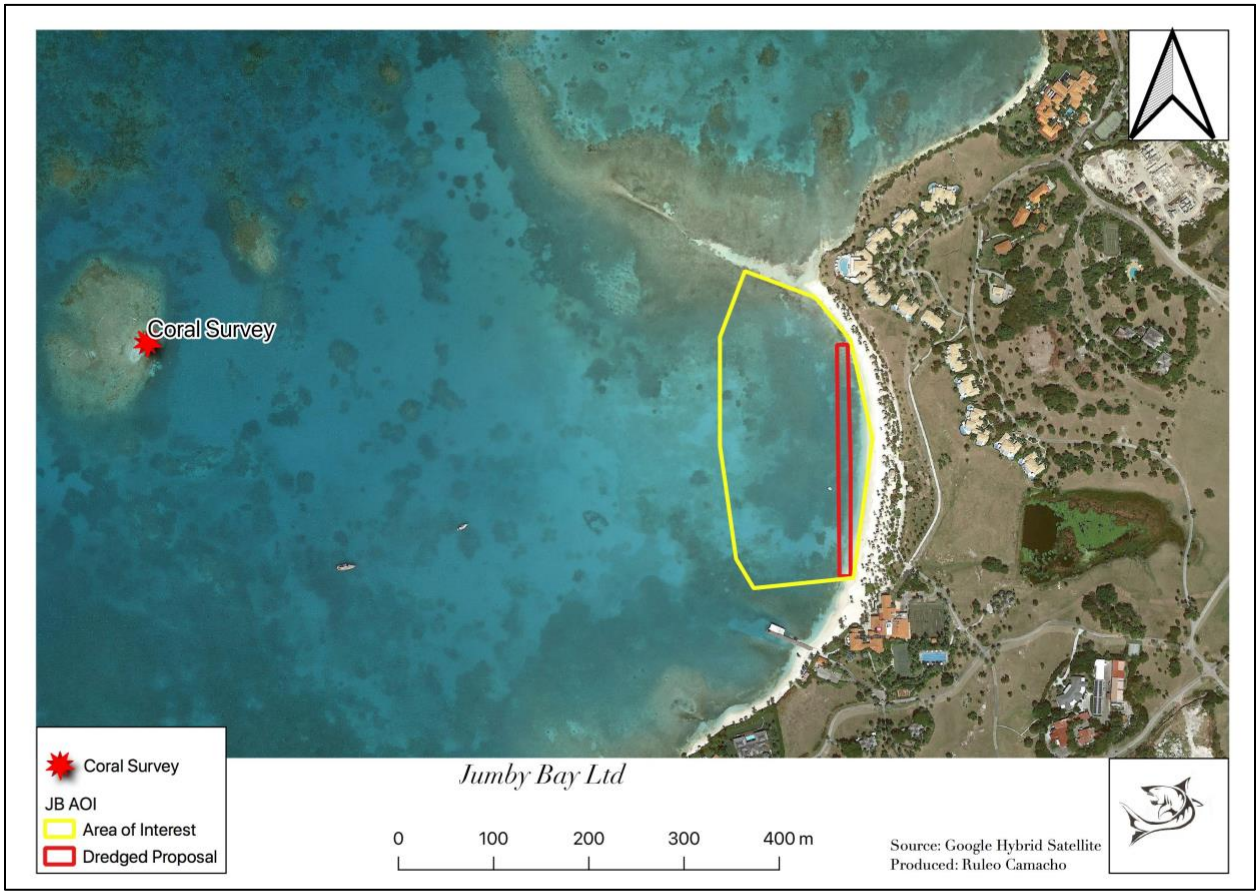


Figure 3*: Macro-invertebrates per 100m^2.*

Picture 7*: Queen Conch in seagrass*

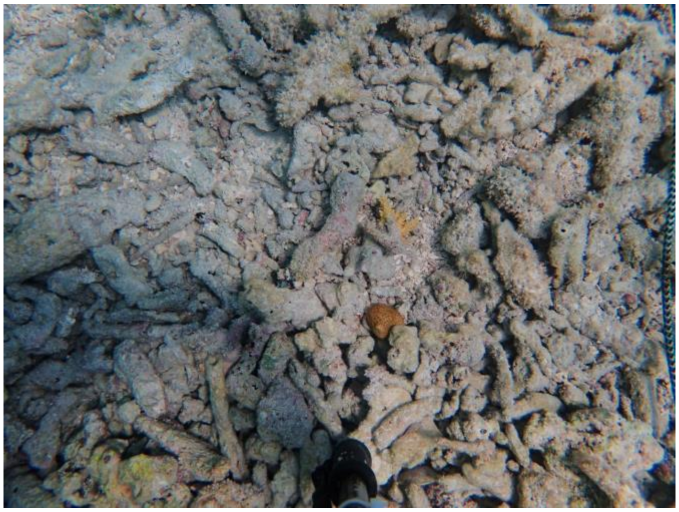
Picture 8*: Cushion Sea Star in seagrass*

Coral Reef Surveys



Map 4*: Coral Survey Site*

Coral surveys were carried out at the point specified "Coral Survey" in Map 4. This would ascertain the baseline ecological conditions of this coral reef site. T1 was carried out on the southern part of the point. The area here is algal dominated *(Picture 9)*, with Dead Coral with algae (49.24%) and Macroalgae (28.90%) accounting for the majority of the benthic cover. Live coral accounted for 0.38% (Figure 4).



Picture 9*: T1 Coral Transect picture*

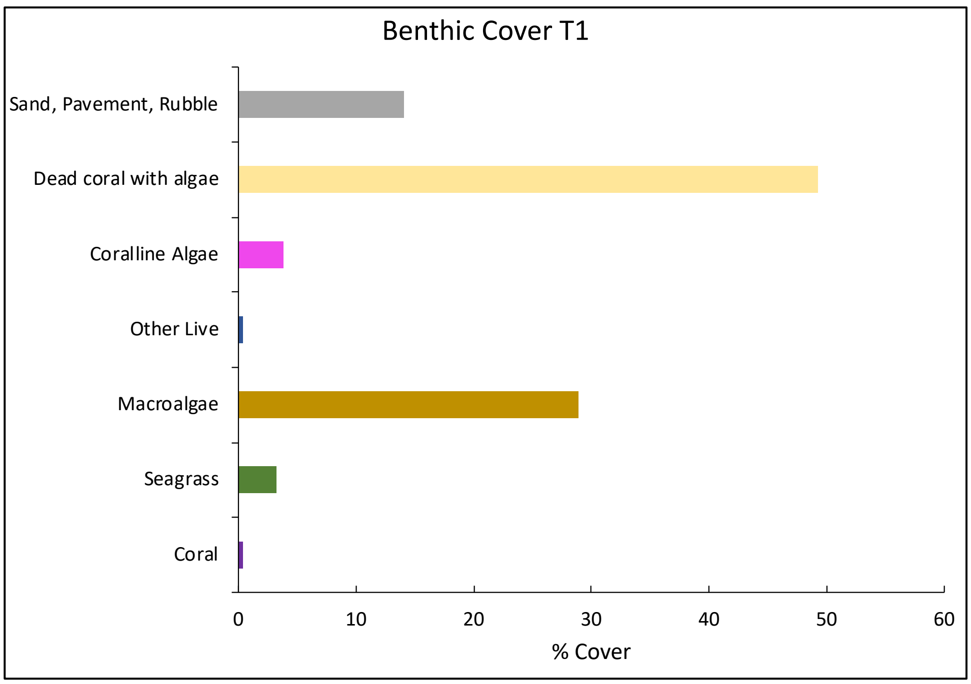


Figure 4*: Coral Transect 1 - Benthic Cover*

T2 was carried out to the northern part of the "Coral Survey" point. The dominant substrate here was live coral, accounting for 47.36% of the benthic cover (Picture 10). Dead coral with algae accounted for 28.41% while macroalgae and seagrass each accounted for 8.15% (Figure 5).

***Picture 10**: T2 Coral Transect picture*

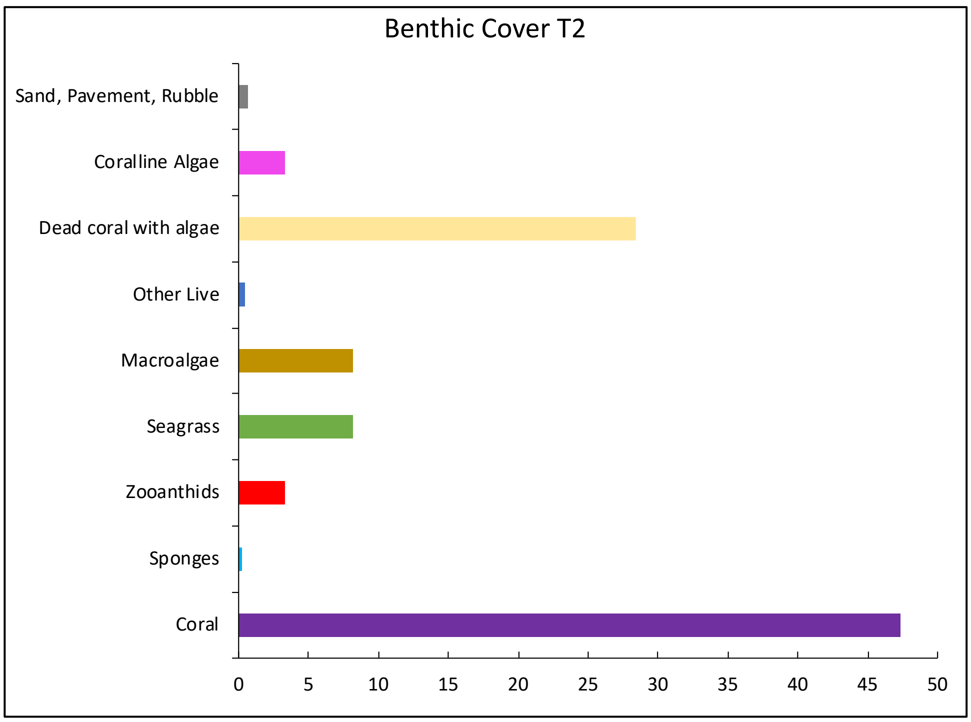
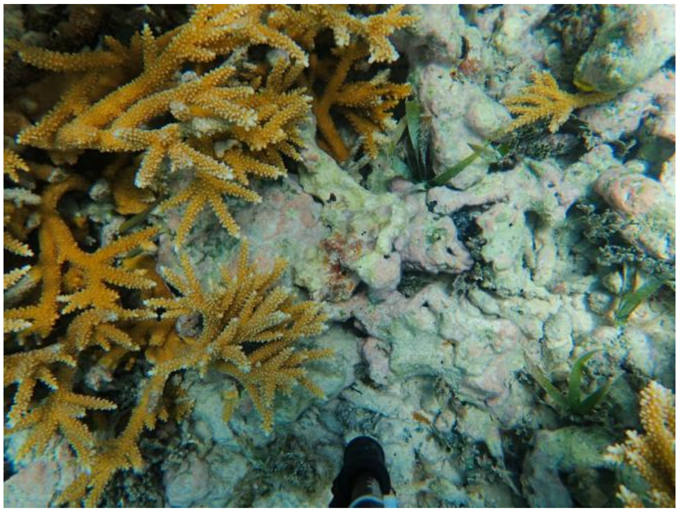


***Figure 5**: Coral Transect 2 - Benthic Cover*

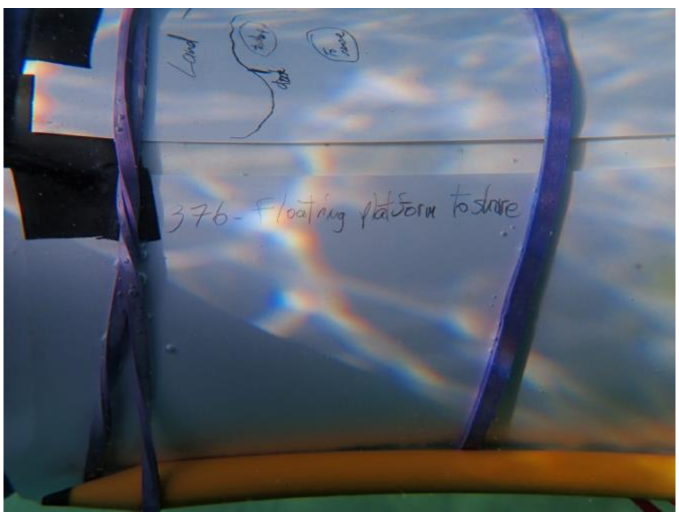
Averaged together, Live Coral accounted for 23.87% cover, Dead Coral with algae 38.83% and macroalgae accounted for 18.53% (Picture 11).



***Picture 11**: Coral Reef area*

While not explicitly surveyed, a variety of fish species were noted at the coral reef sites, and family names are given in Table 2.

Other Marine Checks



***Picture 12**: Data collection during Spot Checks*

Several spot-checks were carried out to better understand the distribution of benthic marine ecosystem *(Picture 12 – data recording)*. The areas are displayed in Map 5 and the data are summarized in the Table 1 & 2 below:

***Table 1**: Spot Check Observations*

Location Number	Location Notes	Observations	Faunal Observations	Depth (ft)
373		Seagrass: TG, MG, HA, BL		
374		Seagrass area: TG, MG, BL		
375		Seagrass/Sand: BL, TG	Sea Star	
376	Floating swim platform within swim line adjacent to beach	Seagrass area: TG, MG, BL, CYAN. Floral coverage 80%. Average canopy height 17cm. Sedimentation on blades		6ft

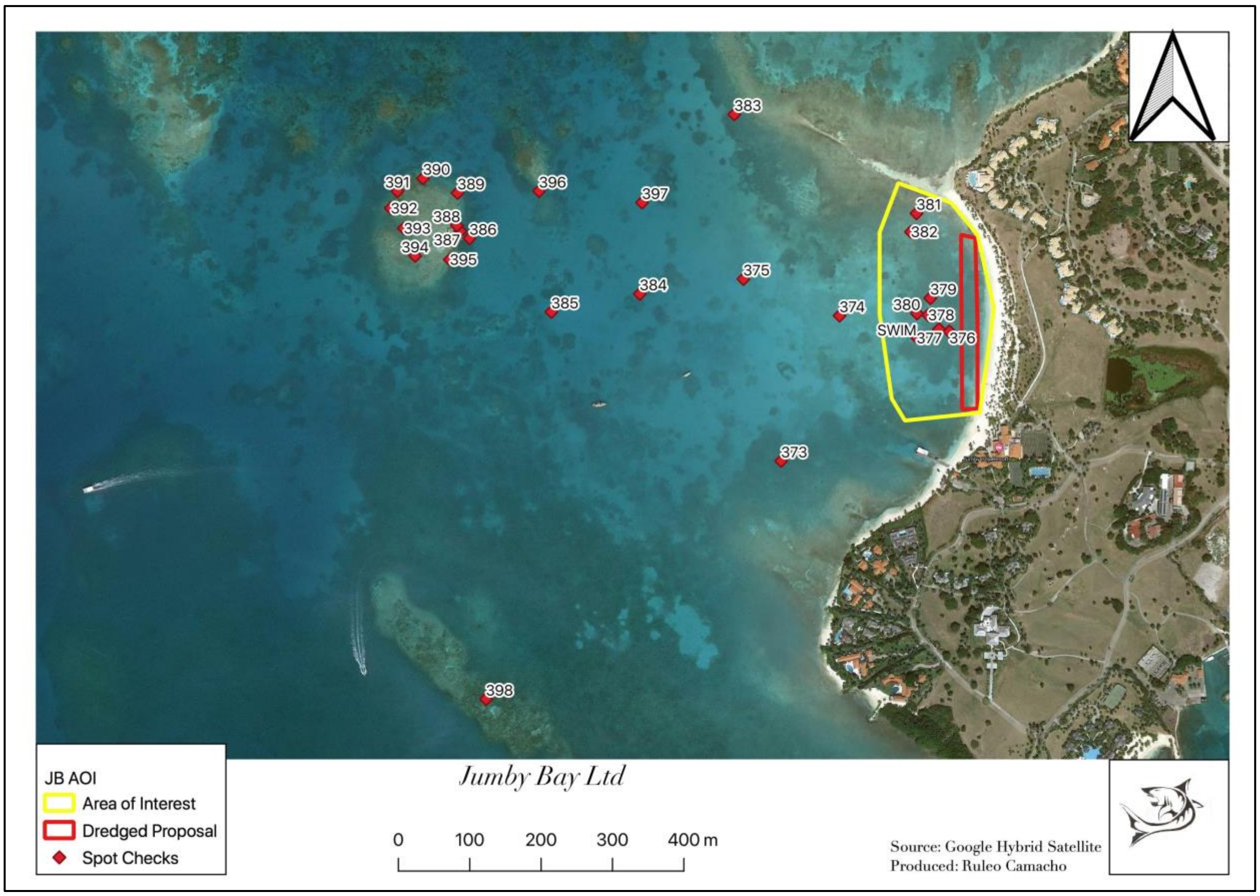
376-a	Inward 30ft from 376	Seagrass area: TG, MG, HA, BL, CYAN. Floral coverage 70%. Canopy height is 17cm. Sedimentation on blades	Sea Star, Juvenile Nassau Grouper	6ft
376-b	Inward 30ft from 376-a	Seagrass area: TG, MG, HA. Floral coverage 90%. Canopy height 19cm. Sedimentation on blades		5ft
376-c	Inward 30ft from 376-b	Seagrass area: MG, HA, TG, BL. Floral Coverage 70%. Canopy Height 16cm. Sedimentation on blades	Sea Star, Juvenile Parrotfish	4ft
376-d	Inward 30ft from 376-c. Transition from seagrass to sandy area.	Seagrass area: MG, HA, TG. Floral coverage 80%. Canopy height of 12cm. Sedimentation on blades		4ft
377		Seagrass area: TG, MG, HA, CYAN, BL. Floral coverage 80%. Floral canopy height 16cm. Sedimentation on blades	Sea Star, Juvenile Snapper, Juvenile Grunt	6ft
SWIM	Swim Lane	Seagrass area: TG, HA, MG, CYAN. Floral coverage 70%. Canopy Height 17cm. Sedimentation on blades		6ft
378		Seagrass Area: MG, TG, BL, HA. Floral Coverage 65%. Canopy Height 17cm. Sedimentation on blades		6ft
379		Seagrass Area: TG, HA, MG, BL. Floral Coverage 80%. Canopy Height 19cm. Sedimentation on blades		6ft.
380		Seagrass area: BL, MG, TG, HA. Floral coverage 80%. Canopy height 12cm.		6ft
381	Approaching and along seagrass bank.	Seagrass Area: TG, HA. Canopy Height 19cm. Isolated PAST in seagrass	Juvenile Queen Conch	<3ft
382		Seagrass area: MG, BL, HA. Floral coverage 95%. Canopy Height 14cm.		4ft
383		Mixed substrate area. Seagrass: TG, GORG, HA. Scruffy Bottom: APRO, MILL, PDIV, PPOR, PPOR Skeleton, DIAD, Red Urchin, OANN, MAUR.	Juvenile snappers & grunts, squirrel fish, jacks	3-6ft
384		Seagrass Area: CYAN, TG, TG, HA, BL. Floral coverage 80%. Canopy Height 10c		13ft
385		Sand and BL. Canopy Height 7cm		14ft
386	Seagrass area which transitions to reef bank	Seagrass dominated by TG. Reef bank is PPOR and APAL skeleton. Southern side of reef bank dead. Northern side: APRO, MILL, PPOR, OANN, PCLI, DLAB, PSTR, PAST	Parrotfish, Grunt, Snapper, Doctorfish,	10ft – 2 ft
387	Transect was conducted here	Seagrass (TG), few coral (APRO, MILL)	Juvenile Fish	7ft

388	Transect was conducted here	Coral thicket (more defined point than 386)	Juvenile fish (Snappers, grunts, squirrel fish, Doctorfish, et al)	7ft
389		Reduction in coral density. Isolated colonies of APRO, OANN, PPOR.		
390		Mixed reef (increased diversity of corals) with large fish biomass. APRO, OANN, SSID, PAST, PPOR, DLAB, PSTR, PCLI, MILL,	Large schools of grunts, parrotfish, doctorfish	
391		APRO Thicket		
392		Greater dead zone, heavy macroalgae		
393		Sea Grass (TG), APRO, PDIV, PFUR		
394		APAL(?)		
395		Seagrass (TG) and isolated HC (APRO, MILL, PFUR,		
396		High Coral diversity (APRO, PAST, SSID, PPOR, OANN	Juvenile fish, DIAD	
397		BL, TG, CYAN, SAND		
398		TG, MG, HA, PDIV, PFUR	Conch	

***Table 2**: Abbreviations and species list*

Abbreviation	Common Name	Species Name	Notes
TG	Turtle Grass	*Thalassia testudinum*	
MG	Manatee Grass	*Syringodium filiforme*	
BL	Broad-Leaf	*Halophila stipulacea*	Invasive seagrass
HA	Halimeda	*Halimeda sp.*	Group of seagrass species which contribute towards sand making
CYAN	Cyanobacteria		Can be an indicator of high nutrient levels in the marine environment
	Upside-down Jellyfish	*Cassiopea xamachana*	
PAST	Mustard Hill Coral	*Porites Astreoides*	
APRO	Fused Staghorn	*Acropora prolifera*	
PDIV	Thin Finger Coral	*Porites divarcata*	
MILL	Fire Coral	*Millepora sp.*	

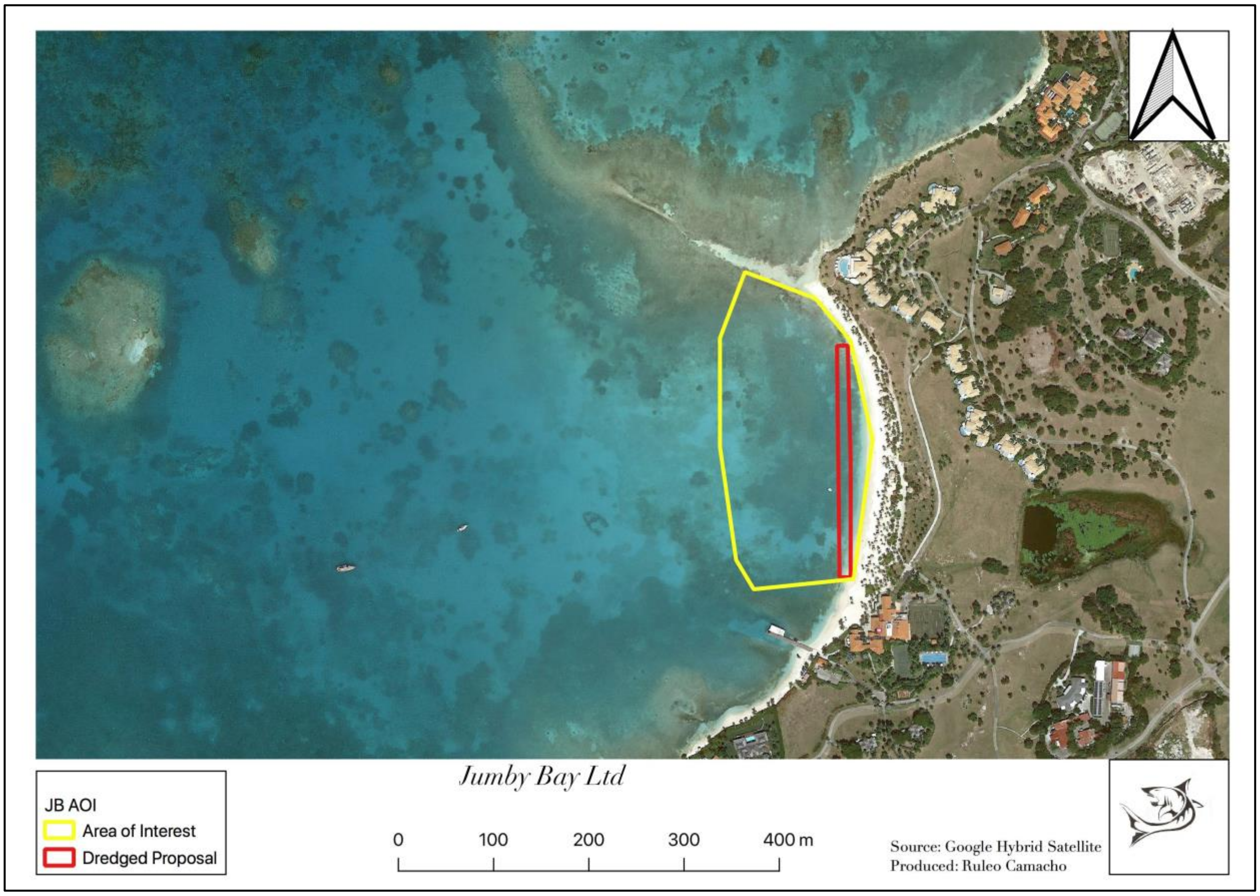
PPOR	Finger Coral	*Porites porites*	
DIAD	Black Sea Urchin	*Diadema antillarum*	
OANN	Lobed Star Coral	*Orbicella annularis*	
DCLI	Knobby Brain Coral	*Diploria clivosa*	
PFUR	Branched Finger Coral	*Porites furcata*	
	Groupers	*Serranidae*	
	Snappers	*Lutjanidae*	
	Grunts	*Haemulidae*	
	Parrotfish	*Scaridae*	
	Jacks	*Carangidae*	



Map 5: *Spot Checks*

Discussion

The proposed activity to remove silt and replace with sand is to take place on the western portion of Long Island in the JumbyBay Bay area (Map 1). Map 6 highlights the proposed 800ft (243.8m) long by 40ft (12.2m) wide section that is proposed to be dredged (Map 6 – Red rectangle). The process of dredging raises environmental concerns, particularly as it can result in the removal of seagrass material as highlighted in the Department of Environment's Review (REF #D.o.E 9/6 F6). There is also concern about the potential impact of the dredging on the surrounding marine environment, given its location within the North East Marine Management Area (NEMMA), an area known to be rich in marine biodiversity and recognized as a globally significant area for endangered and endemic species [1]. As such the benthic assessments highlighted in this report were carried out to address these concerns.



***Map 6**: Area of interest, and proposed site to be dredged.*

Seagrass beds are known havens for biodiversity, providing nursery areas for a variety of marine species[7], and serving as a crucial linkage between coral reefs and mangrove wetlands[8]. Additionally, they provide a variety of ecosystem services including habitat stabilization[9], carbon sequestration[10] and improving water quality[11]. Seagrass surveys indicated that the Area of Interest (Map 6) is a seagrass bed ecosystem dominated by native seagrass species including: Turtle Grass (*Thalassia testudinum),* Manatee Grass (*Syringodium filiforme*) and *Halimeda sp*.. It was also noted that there exists the presence of the Invasive Broad-leaf seagrass (*Halophilia stipulacea)*. The three transects executed all noted the dominance of the native seagrass species (Figure 1). However, the percentage cover of the invasive broadleaf seagrass species increased as transects moved away from shore, with transect 3 more than doubling the quantities seen in the previous two transects. There is some concern here, as the area closest to shore (Transect 1, Map 3) had the least coverage of invasive seagrass species, but it is the area likely to be most affected by dredging activities.

Broad-leaf seagrass is native to the Red Sea and Indian Ocean, was first observed in Grenada in 2004, and has since spread throughout the Caribbean region [12]. Broad-leaf seagrass has been observed to re-colonize disturbed areas faster than native seagrass species [5], which could result in reduced sedimentation from construction activities. However, consideration must be made to reduce the benthic disturbance, as it has been shown to survive in the water column for several days and can actively displace native species in 10-12 weeks [13]. This can be a concern for native species, as the invasive can out-colonize the local species, reducing the functionality of the native seagrass within the ecosystem. However, the broad-leaf seagrass has some positive effects on the ecosystem, as it has been observed to support larger fish species [13].

***Picture 13**: Turtle Grass with high sedimentation*

Seagrass beds play a crucial role in the reduction of turbidity and stabilization of the surrounding habitat[14]. The seagrass blades observed had large quantities of sedimentation and epiphytes associated with them (Picture 13), suggesting that the ecosystem services of improving water quality is heavy at work within the Area of Interest. Possible disturbance of the seagrass beds from dredging activities is likely to increase turbidity within the area of interest. Additionally, the presence of the invasive Broad Leaf seagrass among the seagrass beds could result in a faster colonization of the dredged area by this species. As seen in Figure 2, canopy height decreases as the proportion of invasive seagrass species increases[5]. The smaller leaves of the invasive broad-leaf seagrass are likely to have a lessened effect on reduction of turbidity within the bay. The high levels of epiphyte cover could lower the productivity of the seagrass beds by reducing the availability of sunlight to these species [15]. It has been theorized that epiphyte cover can be used as an indicator for nutrient load, but no positive correlation has been found between the two [16]. Cyanobacteria were observed in the spot checks (Table 1) and during the seagrass surveys. Cyanobacteria (Picture 14) can often be a result raised nutrient levels in the marine system and could be an indication of anthropogenic pollution[17]. Water quality test were not conducted during these surveys.

***Picture 14**: Cyanobacteria in seagrass beds*

***Picture 15**: Juvenile Nassau Grouper among seagrass beds*

Several species of fish were observed during the seagrass surveys, including Jacks (Carangidae), Snappers (Lutjanidae), Parrotfish (Scaridae), Groupers (Serranidae) (Picture 15) and Grunts (Haemulidae). Additionally, several macro-invertebrates were observed (Figure 3), including Sea Stars, Queen Conch and Upside-down jellyfish. Although not observed, the seagrass beds also likely provide a foraging area for reptiles like the Green Turtle (*Chelonia mydas*) and predators like the Spotted Eagle Ray (*Aetobatus narinari)*.

Coral Surveys and Spot checks were carried out around the area of interest (AOI) (Map 4 & 5). These surveys were done to help to improve the understanding of the surrounding ecosystems and determine possible impacts from the proposed activities. As seen in Table 2, the areas immediately around the AOI were predominantly seagrass beds, consisting of native and invasive seagrass species (Table 2). The area to the immediate North of the AOI had large numbers of juvenile queen conch (Picture 16, Map 5-381) associated with its seagrass beds. Queen conch are very important for the local fisheries economy and food security, and the presence of the juveniles is an indication of the nursery support being provided by the

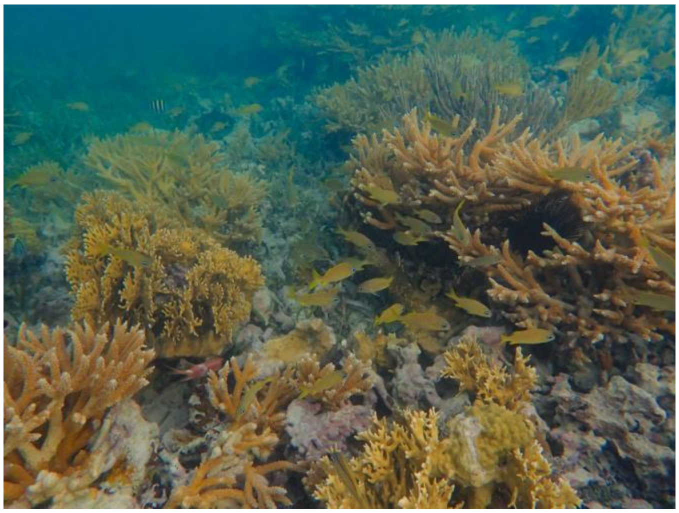
***Picture 16**: Juvenile conch in seagrass beds*

seagrass beds[18]. Further offshore, the presence of coral reef colonies was observed (Table 1). Included among these species was the Fused Staghorn (*Acropora prolifera*) (Picture 17), a hybrid of the Critically endangered *Acropora palmata* and *Acropora cervicornis* corals. This correlates with earlier observations where areas of recovery of coral reefs, aided by this Fused Staghorn coral had been observed[19]. It was also observed that areas further offshore (Table 1-375, 385; Map 5) where you would have expected to find open sand/mud habitats were being colonized by the invasive Broad-leaf seagrass (Picture 18). This can provide an indication of the likely impact of dredging on the nearshore areas, where the invasive is likely to colonize and dominate the native species.

***Picture 17**: Fused Staghorn Coral*

***Picture 18**: Broad Leaf Seagrass colonizing open areas*

Coral Reef surveys were undertaken at one of the reef sites (Map 4) in an effort to understand the ecological conditions of the coral reef ecosystem. The entire reef ecosystem appeared to be making a slow recovery in a northern to southern direction, as areas to the north had greater health than areas to the south. This was exhibited in the results, as the transect executed to the North of the site T2 (Figure 5) had a healthier reef characteristic, with Coral cover accounting for 47.36% and algae (Dead coral with algae and macroalgae) accounting for 36.56%. This contrasted with the southern transect, T1 (Figure 4), where coral cover only accounted for 0.38%, while algae (Dead coral with algae and macroalgae) accounting for 78.14%. Overall, the reef condition was comparable to what has been observed in surveys in the NEMMA regions[4], with coral cover averaging 23.87% and algae (Dead coral with algae and macroalgae) accounting for 57.36%. The recovery of these coral reef ecosystems, particularly as conditions similar to T2 were observed at reef sites to the north (Table 1), should be prioritized and encouraged. A variety of fish species were also observed using these coral reef areas, highlighting the habitat and biodiversity support being provided by these ecosystems (Picture 19).



Picture 19*: Healthy Coral Reef Areas*

Recommendations

The proposed dredging is likely to have a significant impact on the seagrass bed ecology and the ecosystem services being provided by them. Dredging activities are likely to create an opportunity for the already present invasive seagrass species to colonize and dominate the dredged areas, as has been observed in previous areas. The proposed area for dredging is the areas currently least affected by the invasive broad-leaf seagrass species, although it is already colonizing areas further offshore. Dredging in this area will likely enhance the spread of the invasive species in this area and result in the reduction of the benthic coverage of the native seagrass species. Dredging may also result in a reduction in the turbidity of the nearshore waters, as the ability of the invasive species to capture and reduce water sedimentation is reduced when compared to the native species. Increased sedimentation and turbidity from the dredging activities can have detrimental effects on the down-stream coral reef areas, by smothering and reducing the sunlight available to these ecosystems. This is of concern, as these areas are showing significant recovery, and area averaging higher coral cover than is seen throughout the rest of the island.

Climate Change, and its associated effects, such as increased frequency and intensity of tropical storm systems, is an ever-present threat for Antigua and Barbuda. While the NEMMA region is protected externally by coral reefs, and the coastlines are protected wetlands, the impacts of these storm systems are still felt, with previous assessments showing damage to marine ecosystems [2]. This proposed development will need to take into consideration the effect of such storm systems, particularly in the consideration to the movement of sediments, and possible impacts on the surrounding marine environment.

The preferred option would be greater emphasis on the ecological importance of seagrass beds, the role that they play in the fight against climate change, and the loss of ecosystem services which can result from its removal. The seagrass beds in the bay are playing a crucial ecological role to the surrounding environment as a nursery and support for the coral reefs and is of tremendous ecological benefit to Long Island and its associated properties. It is providing ecosystem services via reduction of turbidity/sedimentation, carbon sequestration and stabilization of the habitat. Dredging of the area may result in loss of native biodiversity and increased sedimentation in the bay area, which could result not only in a deteriorating ecological condition, but also a less attractive beach for recreational uses.

If dredging is totally unavoidable, then emphasis should be placed on reducing the environmental footprint as much as possible. Thus, the proposed dredged area (800ft by 40ft – Map 6) should be reduced if possible but should not be exceeded under any circumstance. Greater emphasis should be placed on the protection of the surrounding ecosystems: seagrass beds, coral reefs and mangroves (if applicable[1a]). Where possible, habitat restoration, including the replanting of mangroves and coral reefs should be prioritized in an effort to mitigate against the impacts of the proposed activities. These is little data to suggest ways in which to control the spread of the invasive broad-leaf seagrass, but protection to the seagrass beds by reducing any possible physical degradation activities (e.g. use of moorings) should be encouraged. While natural coral reef recovery is being observed at some sites (Figure 5), some areas are still struggling (Figure 4), and even recovering areas are not yet at the classically defined healthy coral reef levels[20]. By providing coral restoration activities, such as setting up a coral nursery and outplanting coral fragments in areas struggling to recover, and providing greater protection to these areas, the health of the marine environment can be enhanced. Anecdotal reports indicate that areas of the Long Island coastline were once dominated by mangrove flora. Increasing the coverage of mangrove flora will not only assist ecologically, but also aid in the protection of the island and the quality of the marine environment which surrounds it[21]. Additional emphasis should be placed on ensuring recreational users of the area understand the ecological and economic importance of these ecosystem, and the benefits they are providing.

A breakdown of suggested risk and mitigation measures is provided in Table 2.

Table 3*: Impact, Description, Risk and Mitigation measures.*

Impact	Description	Risk	Mitigation
Hurricanes	Intense hurricanes, like Hurricane Irma 2017, can result in increased sedimentation, movement of sediment, and damage to surrounding ecosystems	High	Ensure healthy seagrass beds will aid to stabilize sediment, the leaves will help to capture sedimentation and reduce turbidity in the water column. Healthy reefs have a greater chance of recovering following large scale physical degradation
Habitat Displacement	Dredging will displace ecological habitats.	High	If dredging cannot be avoided, then the footprint should be reduced as

[1a] Mangrove Wetland checks were not carried out as part of these marine surveys

			much as possible. Monitoring of the surrounding seagrass beds needs to be carried out to ascertain any damages. Long term monitoring of coral reefs to see changes. No anchoring should be allowed on the seagrass beds to reduce further physical degradation to the ecosystem. Boats should be maintained on mooring systems only. Coral reef restoration can be carried out to aid the restorations of the surrounding coral reef areas.

Monitoring Guidelines for Development

The primary concern for the proposed development, from a marine ecological perspective, is the impact of the proposed dredging activities on the surrounding marine ecosystems, including the seagrass beds and coral reefs. Ecological monitoring will be needed to document the impact on the marine environment, and the benthic ecological information highlighted in this report provides a baseline for that monitoring.

Pre-Construction

Water Quality

Water quality conditions should be observed for the bay prior to any activities. From an environmental perspective, emphasis should be place on turbidity and nutrient measurements. From a human safety perspective, bacterial checks (Enterococci, etc.) should also be executed.

Construction Phase

During dredging phase, careful consideration should be made to effectively reduce the dredging footprint where possible. The use of sediment traps would be encouraged to reduce the negative impact on the surrounding environment.

All fauna, i.e., Cushion Sea Star, Queen conch, etc., should be removed from the proposed area prior to the commencement of any activities.

Post-Construction

Seagrass Surveys

Seagrass surveys should be conducted to assess the impact of the dredging on the surrounding marine ecosystem. This should be conducted on an annual basis.

Coral Reefs

The coral reefs areas around the bay should be monitored for any possible changes. The surveys should be conducted on an annual basis and should be paired with ecosystem restoration activities such as coral re-planting activities.

List of Figures, Maps, Pictures, Tables

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