An Environmental Review of CMC's 2017 Coral Transplant Report

&

Assessment of the Coral Transplants in 2023

ENVIRONMENTAL SYSTEMS LTD.

November 2023

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List of Acronyms

BVI	British Virgin Islands
CMC	Coastal Management Consulting
ESL	Environmental Systems Ltd.
RDT	Roving Diver Technique

1 INTRODUCTION

1.1 BACKGROUND

The British Virgin Islands (BVI) situated at 18˚30'N and 64˚ 30'W, is an archipelago of roughly 60 islands, cays, islets, and rocks on the edge of the Caribbean Plate, called the Virgin Islands. The Territory is situated between the Caribbean Sea in the south and the North Atlantic Ocean in the north. All of the islands except for Anegada and Sandy spit are of volcanic origin as they have been formed from the uplifting of the seafloor.

In October 2014, Econcerns Ltd. completed an environmental management and monitoring plan (EMMP) for Nanny Cay for the Nanny Cay Expansion Project, which included the construction of an outer marina and a 6.5-acre peninsula. As part of the environmental mitigative measures, specifically for coral disturbance, it was recommended that Nanny Cay move rare and endangered corals, if healthy, beyond the project footprint. Nanny Cay complied with the recommendation of transplanting corals outside of the project footprint prior to the start of dredging and reclamation works for the outer marina (*see* **Figure 1**).

Figure 1. The **YELLOW** rectangle encompasses the outer marina and 6.5-acre peninsular created between 2016 and 2017 by Nanny Cay as part of their Nanny Cay Expansion Works [Map Source: Google®]

Coastal Management Consulting (CMC), Husky Salvage, and Guavaberry Farms were contracted by Nanny Cay to execute coral relocation in accordance with the EMMP. The findings in this review consists of:

- a review of the April 2017 report entitled "***The Nanny Cay Coral Relocation Project – Final Report***" completed by CMC; and
- an analysis of coral transplants at five sites near Nanny Cay.

1.2 2017 Coral Transplant Report - Overview and Key Findings

CMC removed and physically attached a total of 505 corals over 19 work days to one of six locations depicted in **Figure *2* (A)** and **(B)**. Key points outlined in the "***The Nanny Cay Coral Relocation Project – Final Report"*** completed by CMC include the following:

- Upon completion of works in April 2016, monthly monitoring of the transplanted coral was executed over a 12-months period.
- CMC's analysis concluded that there was an "***overall success of the relocation project, that resulted in a 79% success rate***".
- Photos were taken of randomly selected corals (n = 77), that is, 15% of a total of 505 corals, and these photos were provided in the monthly reports to Nanny Cay and catalogued for future reference.
- Fish counts to family level only, were completed on the north-eastern periphery of the development at Site 1 (Northern Marina), Site 2 (Rock Armouring), and Site 3 (Coral Spur) using the roving diver technique (RDT) developed by REEF(www.reef.org).
    - The RDT is a fish survey technique where divers and snorkelers swim freely throughout a site and record every observed fish species that can be positively identified.
- Fish count data included fish family and size classes.
- The **only** site where *Diadema* counts were completed was at Site 3 (Coral Spur) and the data were included in monthly reports.
- The **only** site where the growth rate (i.e., the horizontal spreading) of seagrass was monitored occurred at Site 5 (Hannah Reef), and the species monitored was the invasive seagrass *Halophila stipulacea* (Fern seagrass).
- Changes on the reef, unique characteristics, impacts, and disease were photographed and included in each monthly report.

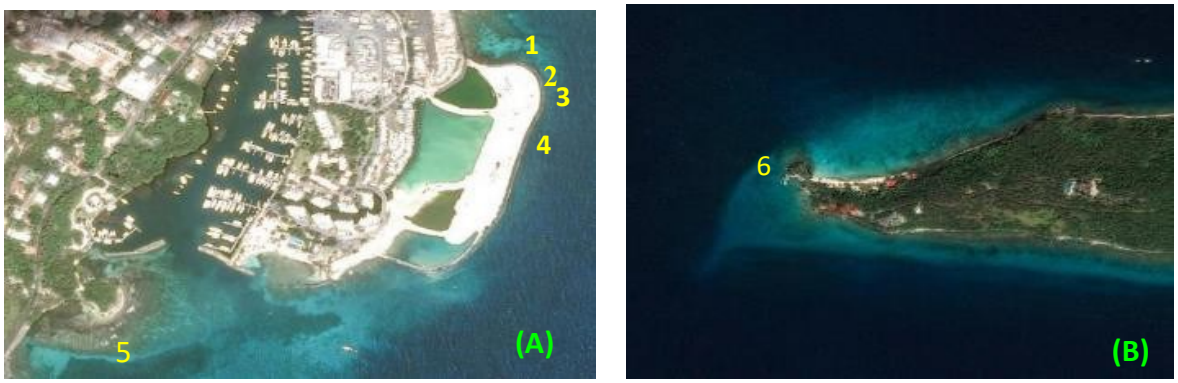

Figure 2. Aerial photographs of coral transplant sites used by CMC in 2016. **(A)** Are sites within the Hannah's Watershed where: 1 = Northern Marina; 2 = Phase 1 – Rock Armouring; 3 = Coral Spur; 4 = Sand Channel; and 5 = Hannah Reef; and **(B)** is Site 6, Little Thatch Island Nursery [*Source:* CMC, 2017].

1.2.1 Coral Transplant Results

The results section of the report completed by CMC included 51 photos of the same corals in 2016 and 2017 and a data table (**Table 1**) that has been adapted by Environmental Systems Ltd. (ESL). Of the 505 corals transplanted, only 77 (i.e., 15.2%) of those corals were monitored over the 12-month period. From this data, CMC concluded that there was an overall 79% success rate overall for the transplanted corals, which is misleading at best considering only 77 coral specimens or 15% of the total transplanted specimens were monitored for survival rate and loss of tissue per site (see ***Table 1***). In addition, based on the number of sites that CMC reported that they monitored, ESL calculated the percentage of specimens monitored for each of the individual sites, and this ranged from only 14.5 to 16.7% of the samples transplanted. Hence, based on the results as outlined in the report, CMC did not monitor even 25% of the total transplanted corals.

Based on the data provided in the original report by CMC, it would be more accurate to report that of the roughly 15% of corals transplanted and monitored for survival over a 12-month period, the survival rate of the coral transplants ranged from 25% to 92% depending on location (**Table 1**). Moreover, available data suggests that the highest survival rate occurred at: Phase 1 – Rock Armouring (92%) > Coral Spur (84%) > Sand Channel (83%) > Northern Marina (66%) > Hannah Reef (61%) > Little Thatch Island Nursery (25%).

Of the coral species documented by photographs in the April 2017 Report, ESL compiled a coral species list, and assessed their conservation status (***Table 2***) as per their designation according to the International Union for Conservation of Nature (IUCN). IUCN classifies the conservation status of species globally in one of seven (7) categories: extinct (EX), extinct in the wild (EW), critically endangered (CR), endangered (EN), vulnerable (VU), near threatened (NT), and least concern (LC).

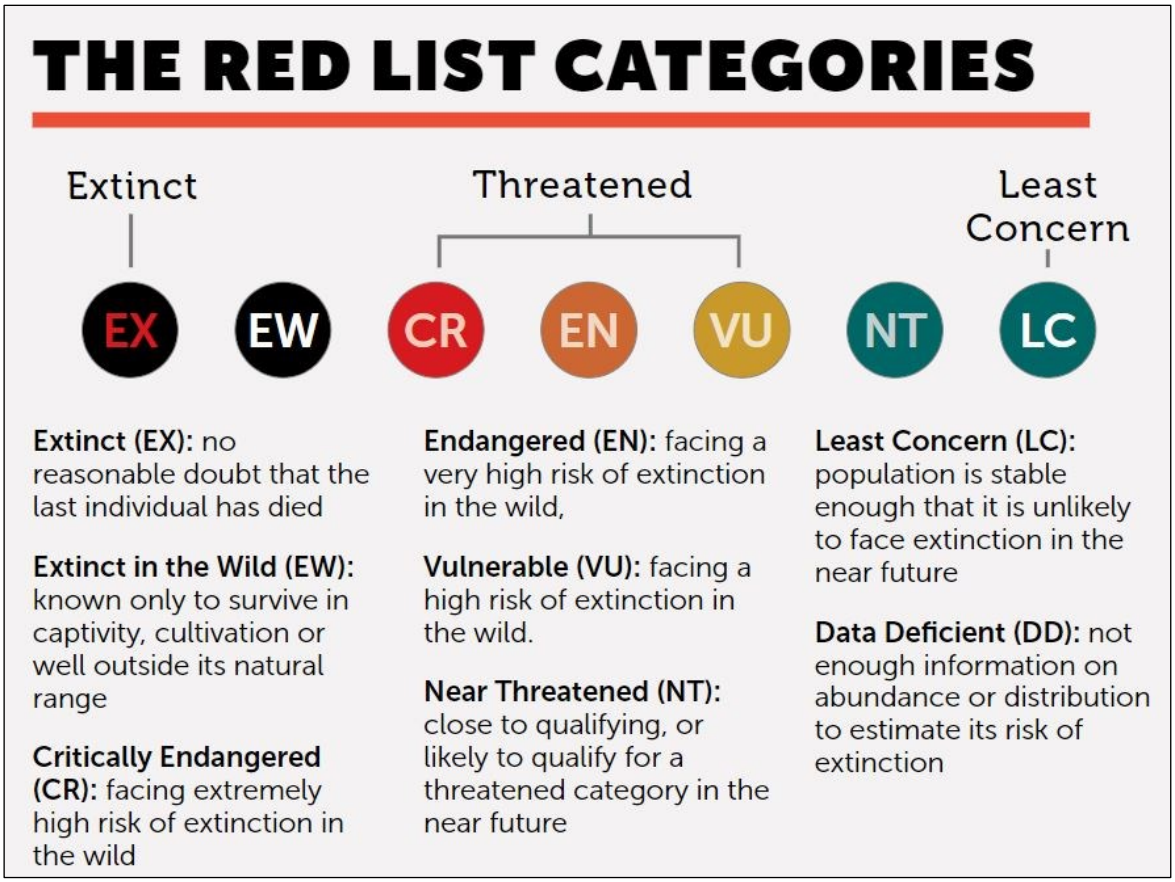

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Table 1. Raw data from the April 2017 Coastal Management Consulting Report entitled "*The Nanny Cay Coral Relocation Project – Final Report (April 2017)*". Data table has been modified as Environmental Systems has included a data column "*Percent of Corals Monitored per Site (%),*" and ESL has not included the total for Survival Rate (%) originally included in the report.

Site No.	Site Name	Total No. of Corals Relocated	Total No. of Corals Monitored	Percentage of Corals Monitored Per Site (%)	Total Loss of Live Tissue Per Site	Survival Rate (%)
1	Northern Marina	30	5	16.7	1.70	66
2	Phase 1 – Rock Armouring	125	19	15.2	1.50	92
3	Coral Spur	200	29	14.5	4.75	84
4	Sand Channel	75	12	16.0	2.08	83
5	Hannah Reef	50	8	16.0	3.15	61
6	Little Thatch Island - Nursery	25	4	16.0	3.00	25
Totals		**505**	**77**		**16.18**	**68.5**
		CMC's Reported Success Rate Overall				79.0
		ESL's Calculated Success Rate Based the Mean Success Rate (%) [i.e., 411/6]				**68.5%**

Table 2. Coral Species list and location of each species transplant based on the photographs included in the April 2017 Coastal Management Consulting Report entitled *"The Nanny Cay Coral Relocation Project – Final Report (April 2017)".* The conservation status each species of transplanted coral was assessed using IUCN's website (https://www.iucnredlist.org/).

Common Name	Scientific Name	Location(s) Documented in CMC's 2017 Report	IUCN Conservation Status	No. of Times Pictured
Maze Coral	*Meandrina meandrites*	● Phase 1 – Rock Armouring ● Coral Spur ● Sand Channel	Critically Endangered	3
Mustard Hill Coral	*Porites astreoides*	● Phase 1 – Rock Armouring	Least Concern	1
Symmetrical Brain Coral	*Pseudodiploria strigosa*	● Phase 1 – Rock Armouring ● Coral Spur	Critically Endangered	15
Lobed Star Coral	*Orbicella annularis*	● Phase 1 – Rock Armouring ● Coral Spur ● Sand Channel	Endangered	3
Grooved Brain Coral	*Diploria labyrinthiformis*	● Phase 1 – Rock Armouring ● Coral Spur	Critically Endangered	4
Boulder Star Coral	*Orbicella franksi*	● Phase 1 – Rock Armouring ● Sand Channel	Endangered	3
Boulder Brain Coral	*Colpophyllia natans*	● Phase 1 – Rock Armouring ● Coral Spur ● Sand Channel	Vulnerable	6
Massive Starlet Coral	*Siderastrea siderea*	● Coral Spur	Critically Endangered	2
Pillar Coral	*Dendrogyra cylindricus*	● Sand Channel	Critically Endangered	2
Mountainous Star Coral	*Orbicella faveolata*	● Sand Channel	Endangered	2
Staghorn Coral	*Acropora cervicornis*	● Sand Channel	Critically Endangered	3
Elkhorn Coral	*Acropora palmata*	● Sand Channel ● Little Tatch Island Nursery	Critically Endangered	6
		Total No. of Photographs		**50**

1.2.2 Diadema Results

According to CMC (2017), *Diadema* counts for the "***The Nanny Cay Coral Relocation Project – Final Report (April 2017***)" was only assessed at Site 3 (Coral Spur), which is roughly 875 m^2. Data were collected from April 2016 to April 2017 (**Figure 4**). There were two (2) months when data were not collected, April 2016 and August 2016. CMC concluded that the average number of sea urchins throughout the year per square meter was 4.7.

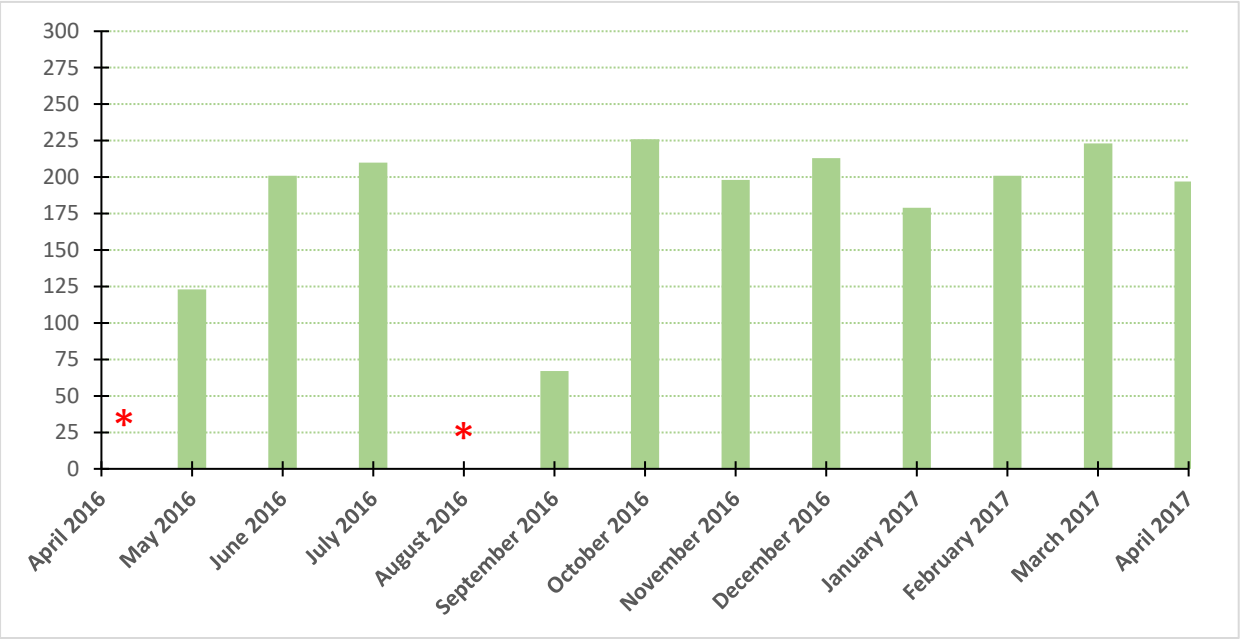


Figure 4. Number of *Diadema* observed at Site 3 (Coral Spur) from April 2016 to April 2017. The **RED** asterisk (*) indicates that data were not collected [*Data Source:* CMC, 2017].

Table 3. Raw *Diadema* data from the April 2017 Coastal Management Consulting Report entitled "*The Nanny Cay Coral Relocation Project – Final Report (April 2017)*".

Date	Total Number of *Diadema* Observed
April 2016	No *Diadema* counts
May 2016	123
June 2016	201
July 2016	210
August 2016	No *Diadema* counts
September 2016	67
October 2016	226
November 2016	198
December 2016	213
January 2017	179
February 2017	201
March 2017	223
April 2017	197
Total no. of *Diadema*	2,038
Average number of *Diadema*	185
Average number of *Diadema* per year per square meter	4.7

1.2.3 Fish Count Data

According to CMC (2017), reef fish surveys were completed just off the Rock Armouring area (Site 2), and Coral Spur (Site 3). This method entailed that of a rover diver counting the number of fish seen within a 20-minute time frame, and categorizing the fish by size class: i.e., (a) 0 to 10 cm; (b) 10 to 30 cm; (c) 30 to 50 cm; and (d) > 50 cm. The overall fish counts and size classes are depicted in **Figure 5**. Based on the data provided by CMC in **Figure *5***, the fish counts were dominated by: parrot fishes > surgeon fishes/tangs > snappers > butterfly fishes > damsel fishes. Further, of the dominant fishes observed, the feeding type (i.e., herbivore, carnivore, omnivore) of those dominant fishes was assessed by ESL (***Table 4***).

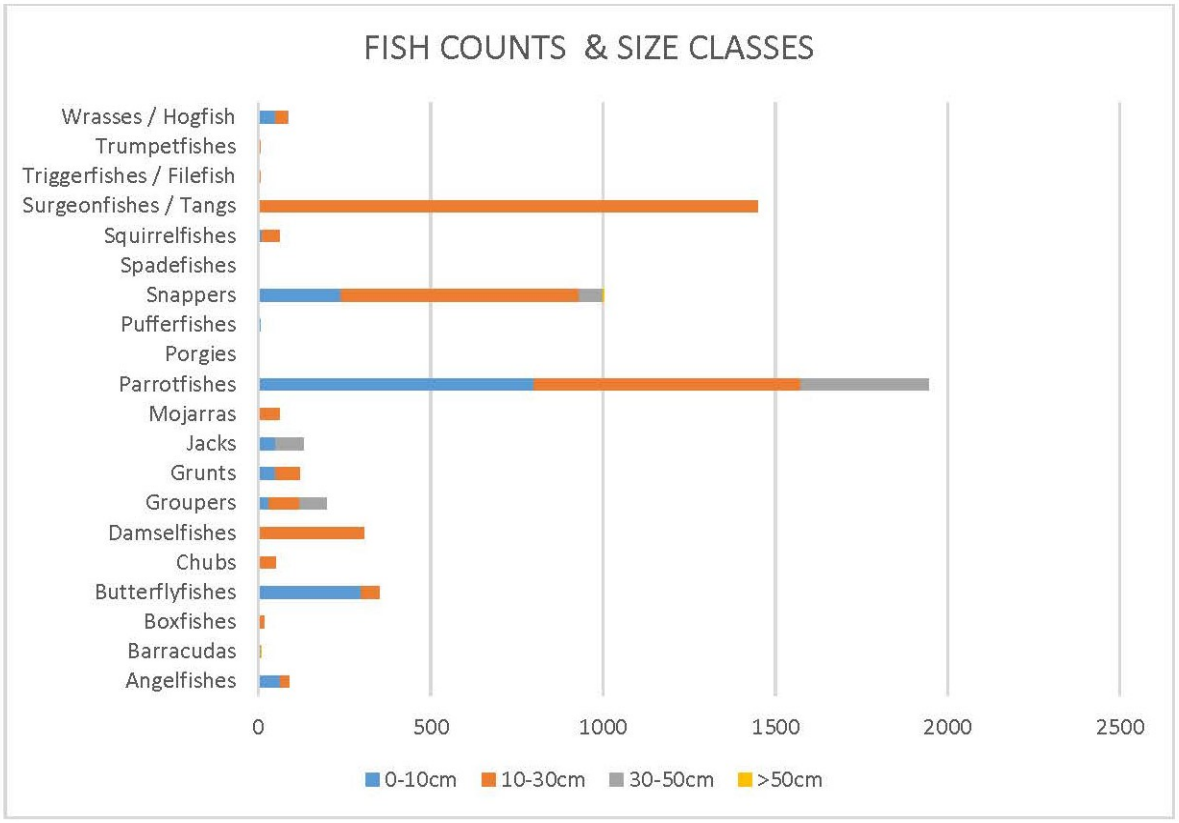


Figure 5. Reef fish count and size classes observed by Coastal Management Consulting at the Rock Armouring and Coral Spur and included in "*The Nanny Cay Coral Relocation Project – Final Report (April 2017)*." [*Data Source:* CMC, 2017].

Table 4. The dominant fish types documented by Coastal Management Consulting at the Rock Armouring and Coral Spur and assessed by ESL for feeding type.

Dominant Fish	Feeding Type	Feeds on…
Butterfly Fish	Omnivore	Algae, seaweed, worms, crustaceans, coral (soft & stony)
Damsel Fish	Herbivore	Algae (that they cultivate)
Parrot Fish	Herbivore	Algae
Snapper	Carnivore	Crustaceans and other fish
Surgeon Fishes/Tangs	Herbivore	Algae

Based on the dominant fishes outlined in CMC (2017), feeding type was dominated by: herbivores > carnivores ≥ omnivores. All feeding types are needed to keep the coral reef ecosystem in balance. For example, parrotfish and other herbivores feed on algae keeping it algae growth in check so that they do not smother and overgrow the reef all the while creating sand for the white sandy beaches that humans enjoy. On the other hand, carnivores are needed to keep the population of crustaceans and fish in check.

1.2.4 Invasive Seagrass (Halophilia stipulacea)

In "***The Nanny Cay Coral Relocation Project Final Report (April 2017)***" CMC noted the presence of the invasive fern seagrass, *H. stipulacea*, on the southern periphery of Nanny Cay. Further, it was noted that the horizontal growth rate was colonizing the barren spots in the sand channel at about 0.2 m^2 per month.

One of the benefits of the invasive seagrass spreading is that it would minimize turbidity as the roots of the seagrass would hold the exposed sand in place. However, as this is an invasive species and its ecology not well understood, the impacts on the marine ecosystem can include, but is not limited to:

(a) the possibility that *H. stipulacea*'s can outcompete native species such as turtle grass, *Thalassia testidum*, a preferred food source for the green turtle;

(b) the presence of *H. stipulacea* can result in changes at population, community, and ecosystem levels in dramatic ways over a relatively short period of time; and

(c) the spread of *H. stipulacea* can result in the loss of biodiversity.

2 ENVIRONMENTAL SYSTEMS LTD. REVIEW OF CSC'S REPORT

2.1 REVIEW OF CSC'S CORAL RELOCATION EFFORTS

An analysis of the available data included in CMC's report entitled, "***The Nanny Cay Coral Relocation Project Final Report (April 2017),"*** and the contents contained therein is as follows:

1) The corals transplanted by CMC in 2016 were not tagged so there is no definitive way to confirm the transplanted corals by ESL roughly 5 years later.

2) CMC has indicated an overall 79% success rate under its tenure. However, based on the raw data in the report, it is ESL's professional opinion that the statement is erroneous and very misleading for the following reasons:

a. CMC documented that they relocated/transplanted a total of 505 corals, but monitored only 77 or 15% of those corals.

b. The percentage of transplanted corals was not consistent across the six (6) sites, as it ranged between 14.5% to 16.7%.

c. The site with the highest number of transplants (n = 200), that is, Site 3 – Coral Spur, had the lowest number (n = 29) or percentage (14.5%) of corals monitored.

3) ESL completed a review of the raw data included in CMC's report. A more accurate narrative of the coral transplants monitored by CMC is as follows:

- **a.** During CMC's tenure, Nanny Cay transplanted 505 corals and monitored 15% (n = 77) of those corals at six (6) different sites over a one-year period.
- **b.** The percent survival rate of the transplanted corals varied across sites ranging from 25% to 92%.
- **c.** The mean percentage survival rate across the six sites for the 77 transplanted corals was 68.5%.

4) Of the 50 transplanted corals photographed in CMC's report, they were twelve (12) species across sites.

5) When the 12 species were assessed for their conservation status, the following conclusions were made:

- **a.** according to IUCN's website, 7 of the transplanted corals were classified as critically endangered, 3 as endangered, 1 as vulnerable, and 1 was of least concern;
- **b.** the 7 critically endangered species included: the Symmetrical Brain Coral > Elkhorn Coral > Grooved Brain Coral > Staghorn Coral ≥ Maze Coral > Massive Starlet Coral ≥ Pillar Coral; and
- **c.** the 3 endangered species included: Lobed Star Coral ≥ Boulder Star Coral > Mountain Star Coral.

6) The average number of observed sea urchins throughout the year per square meter at Site 3 (Coral Spur) was 4.7. Based on the Jackson *et al*.'s assessment of coral reefs in the region, Coral Spur is a reef that is borderline overfished.

7) Based on the fish types identified by CMC and illustrated in **Figure 5**, the dominant fish types at Coral Spur were: Parrotfishes > Surgeon fishes/Tangs > Snappers > Butterfly fishes > Damsel fishes.

8) Based on the dominant fish types stated in **7)** above and illustrated in **Figure 5**, the dominant feeding types were: herbivores > Carnivores ≥ Omnivores.

2.2 Review of CSC's Fish Count Results

Two (2) common approaches routinely used by marine biologists for counting fishes in nearshore marine monitoring projects include: (a) belt transects; and (b) the roving diver technique (RDT). RDT fish counts are where fish are counted in an area within a specific time. According to CSC (2017), the fish counts used in their report was RDT.

A technique for counting fish, RDT is potentially very useful because it combines the advantage of a simple timed count to rapidly sample a large area, and it has the potential to calculate area-specific density of fish and their relative abundance. Rassweiler *et. al.,* (2020), compared fish count data using the belt transect method and RDT. Based on their assessment, they concluded that if one is examining fish taxa, RDT would likely under-sample the target area. However, both techniques produce similar estimates of average diversity regionally and temporally. Further, data from RDT is satisfactory for basic research and management decisions.

2.3 REVIEW OF CSC'S DIADEMA RESULTS

The presence of sea urchins at optimal numbers on a coral reef is indicative of a healthy coral reef ecosystem as sea urchins like other herbivores (e.g., parrot fishes) keep algae cover abundance low. Too many sea urchins on a reef can result in scraping and damaging large spans of the reef, while too little of them allows the algae to overgrow and smother coral. Jackson *et al.,* (2014) published, "***Status and Trends of Caribbean Coral Reefs: 1970 – 2012***", and in their report, they investigated the impacts of overfishing as part of their analysis by determining the number of Diadema per m^2. Based on their review of available data from various locations in the Caribbean, Jackson *et al.*, (2014) concluded that prior to the 1983/1984 *Diadema* die-off event, different Diadema densities could be classified as follows:

- A Coral Reef that is Less Fished: *Diadema* densities range between 0.5 to 3.8 m^2.
- An Overfished Coral Reef: *Diaema densities* range from 6.9 to 12.4 per m^2.

As the *Diadema* density per m^2 at Site 3 (Coral Spur) was calculated at 4.7, that location could be classified as a reef that is fished, but not overfished based on the *Diadema* densities documented in Jackson *et al.,* (2014).

3 ENVIRONMENTAL SYSTEMS LTD. 2023 ASSESSMENT

3.1 OVERVIEW

The Environmental Systems Ltd. Team snorkelled Sites 1 to 4 on September 16th, 2023 (**Figure *2* (A)**), to determine the existing environmental conditions (e.g., depth, wave strength), as the report completed by CMC in 2017 did not include this data. Further, the report by CMC (2017) did not include the following:

1) the GPS location of each of the five (5) transplant sites depicted in **Figure *2* (A)** and **(B)**; or
2) photo evidence of tags or other identifiable means (e.g., flagged rebar) to identify the immediate area(s) of the transplanted corals.

Field investigations by the ESL Team were executed using SCUBA and/or snorkelling on September 15th, 16th, 29th, and 30th, 2023, and October 7th, 2023. The goal of the field visits was to ascertain the health of the coral transplants at the sites around Nanny Cay (i.e., Sites 1, 2, 3, 4, and 5). Even though the transplanted corals were not tagged, ESL was able to reliably confirm 51 specimens of the transplanted corals as those specimens were strategically placed on the boulders that were used to construct the revetment that was installed for the extended marina.

ESL divers assessed as many of the corals at the various locations based on the recommendations outlined in Frias-Torres *et al.*, (2018), "***Coral Reef Restoration Toolkit: A Field-Oriented Guide Developed in the Seychelles Islands***." In addition, ESL went a bit further, and did an analysis of the percent (%) live tissue and percent (%) dead tissue and this raw data will be outlined in **Table 5**. Other additional data to be included in this report will be related to coral recruits. Below is a list of data to be included in this report by ESL are as follows:

- Species observed
- Live/Dying/Dead
- Coral Bleached (Yes *or* No)
- *Additional data:*
    - Presence of coral recruits (Yes *or* No)
    - Identify recruit species
    - Presence of coral disease (Yes *or* No), If yes, identify coral species affected.

3.2 METHODS

Based on the contents of CMC's (2017) report, field investigations were completed by the ESL Team on September 15th, 16th, 29th, and 30th, 2023, and on October 7th, 2023, based on the following assumptions:

- All four (4) sites adjacent to the peninsular and used for coral transplantation in 2016/2017, were lumped as one site since the GPS location for none of the individual sites were provided in the final report.
- Site 5 was surveyed, but no data were collected because the visibility of the water was low during the days attempted. The water column and benthos were murky from decomposing *Sargassum* seaweed. However, ESL personnel did take photographs of the area and the reef was in a very degraded condition as it is overgrown with macroalgae, zooanthids, and a few head of Mustard Hill Coral only.
- If any of the coral transplants were transplanted to the scattered nearby coral reefs, these were not included in the 2023 analysis. They were not included because they were not marked, and ESL divers could not confirm if the coral was a transplant or not.
- Coral transplants larger than 50 mm that were conspicuously ***observed only on the armour rocks*** that were used for the construction of the peninsular were assessed since large corals on the rock revetment could not have grown to that size in the 5/6 years when the corals would have been transplanted.
- The presence of coral recruits (i.e., those coral < 50 mm) on the seaward side of the marina revetment were identified to species level, as the rocks would not have had anything growing on them when they came from the quarry.
- A species list of the corals observed at Sites 1 to 5 will be one of the outputs this report.
- Raw data from ESL's field investigations are outlined in **Table 5**.

3.3 HEALTH OF TRANSPLANTED CORALS

ESL divers were able to locate roughly 10% (n = 51) of the 505 transplanted corals that CMC reported transplanting in 2016 (**Table 5**). Of those 51 corals documented by ESL in **Table 5**, pictorial evidence indicates that 51% (n = 26) were alive > 47% (n = 24) were dead > 2% (n = 1) was dying. There were five (5) species of transplanted coral transplant that were identifiable to the species level and they accounted for 65% (n = 33; **Figure 6**). On the other hand, the remaining 35% (n = 18) of transplanted species were classified as "Brain Corals" (**Figure 6**) because of the "dome shape" and striations known to be characteristic of brain corals in general. The transplanted corals identified to species level by the ESL Team were as follows:

- Boulder Coral (*Colpophyilia natans*): n = 16;
- Symmetrical Brain Coral (*Psedodiploria strigosa*): n = 9;
- Mustard Hill Coral (*Porites aestroides*): n = 2;
- Finger Coral (*Porites porites*): n = 5; and
- Massive Starlet Coral (*Siderastrea siderea*): n = 1.

For the 51 transplanted corals (i.e., corals identifiable to species level and those categorized as "Brain Corals") assessed in this report, they were further assessed as: (i) alive, dying, or dead (*see* **Table 5** and **Figure 7**); and (ii) the percentage of live and dead tissue (**Table 5**). The percentage of live and dead tissue by species and for those corals grouped as "Brain Corals" are as follows:

- Boulder Coral (*Colpophyilia natans*)
  - % Live tissue range: 15 to 98.
  - % Dead tissue range: 2 to 100.

Table 5. Corals transplanted by Coastal Management Consulting in 2015/2016 and observed by Environmental Systems Ltd. personnel in September and October 20223 to species level, where all samples were assessed for: (a) coral health, i.e., Alive, Dying or Dead; (b) for percent (%) live tissue; and (c) and percent (%) dead tissue [***Source***: Environmental Systems Ltd.].

Coral Number	Common Name	Coral Scientific Name	Coral Health	Percent (%) Live Tissue	Percent (%) Dead Tissue	Pictorial Evidence and Notes
1	Boulder Brain Coral	*Colpophyillia natans*	**Alive**	96	4	
2	Boulder Brain Coral	*Colpophyillia natans*	**Dead**	0	100	
3	Boulder Brain Coral	*Colpophyillia natans*	**Alive**	98	2	

Coral Number	Common Name	Coral Scientific Name	Coral Health	Percent (%) Live Tissue	Percent (%) Dead Tissue	Pictorial Evidence and Notes
4	Brain Coral	Unverified	**Dead**	0	100	
5	Boulder Brain Coral	*Colpophyillia natans*	**Alive**	95	5	
6	Boulder Brain Coral	*Colpophyillia natans*	**Dying**	15	85	

Coral Number	Common Name	Coral Scientific Name	Coral Health	Percent (%) Live Tissue	Percent (%) Dead Tissue	Pictorial Evidence and Notes
7	Boulder Brain Coral	*Colpophyillia natans*	**Alive**	98	2	
8	Boulder Brain Coral	*Colpophyillia natans*	**Alive**	90	10	
9	Boulder Brain Coral	*Colpophyillia natans*	**Dead**	0	100	

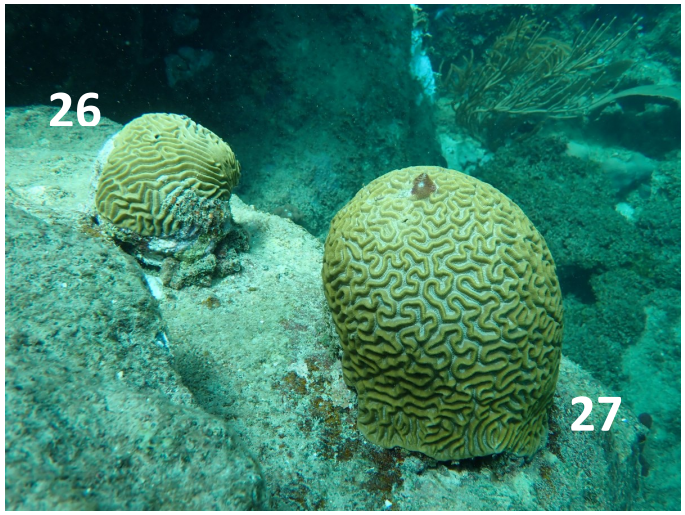
Coral Number	Common Name	Coral Scientific Name	Coral Health	Percent (%) Live Tissue	Percent (%) Dead Tissue	Pictorial Evidence and Notes
10	Brain Coral	Unverified	**Dead**	0	100	
11	Boulder Brain Coral	*Colpophyillia natans*	**Alive**	98	2	
12	Boulder Brain Coral	*Colpophyillia natans*	**Dead**	0	100	

Coral Number	Common Name	Coral Scientific Name	Coral Health	Percent (%) Live Tissue	Percent (%) Dead Tissue	Pictorial Evidence and Notes
13	Brain Coral	Unverified	**Dead**	0	100	
14	Brain Coral	Unverified	**Dead**	0	100	
15	Brain Coral	Unverified	**Dead**	0	100	

Coral Number	Common Name	Coral Scientific Name	Coral Health	Percent (%) Live Tissue	Percent (%) Dead Tissue	Pictorial Evidence and Notes
16	Symmetrical Brain Coral	*Psedodiploria strigosa*	**Alive**	98	2	 Focal tissue loss
17	Brain Coral	Unverified	**Dead**	0	100	
18	Brain Coral	Unverified	**Dead**	0	100	

Coral Number	Common Name	Coral Scientific Name	Coral Health	Percent (%) Live Tissue	Percent (%) Dead Tissue	Pictorial Evidence and Notes
19	Mustard Hill Coral	*Porites aestroides*	**Dead**	0	100	 Bleached
20	Brain Coral	Unverified	**Dead**	0	100	
21	Brain Coral	Unverified	**Dead**	0	100	

Coral Number	Common Name	Coral Scientific Name	Coral Health	Percent (%) Live Tissue	Percent (%) Dead Tissue	Pictorial Evidence and Notes
22	Boulder Brain Coral	*Colpophyillia natans*	**Alive**	100	0	
23	Boulder Brain Coral	*Colpophyillia natans*	**Alive**	85	15	
24	Symmetrical Brain Coral	*Psedodiploria strigosa*	**Alive**	90	10	

Coral Number	Common Name	Coral Scientific Name	Coral Health	Percent (%) Live Tissue	Percent (%) Dead Tissue	Pictorial Evidence and Notes
25	Symmetrical Brain Coral	*Psedodiploria strigosa*	**Alive**	95	5	
26	Symmetrical Brain Coral	*Psedodiploria strigosa*	**Alive**	88	12	 Christmas Tree Worm (*Spirobranchus giganteus*) growing on top of #27.
27	Symmetrical Brain Coral	*Psedodiploria strigosa*	**Alive**	100	0	

Coral Number	Common Name	Coral Scientific Name	Coral Health	Percent (%) Live Tissue	Percent (%) Dead Tissue	Pictorial Evidence and Notes
28	Boulder Brain Coral	*Colpophyillia natans*	**Alive**	20	80	
29	Boulder Brain Coral	*Colpophyillia natans*	**Alive**	80	20	
30	Finger Coral	*Porites porites*	**Alive**	100	0	

Coral Number	Common Name	Coral Scientific Name	Coral Health	Percent (%) Live Tissue	Percent (%) Dead Tissue	Pictorial Evidence and Notes
31	Finger Coral	*Porites porites*	**Alive**	98	2	
32	Brain Coral	Unverified	**Dead**	0	100	
33	Brain Coral	Unverified	**Dead**	0	100	 Covered with algae.

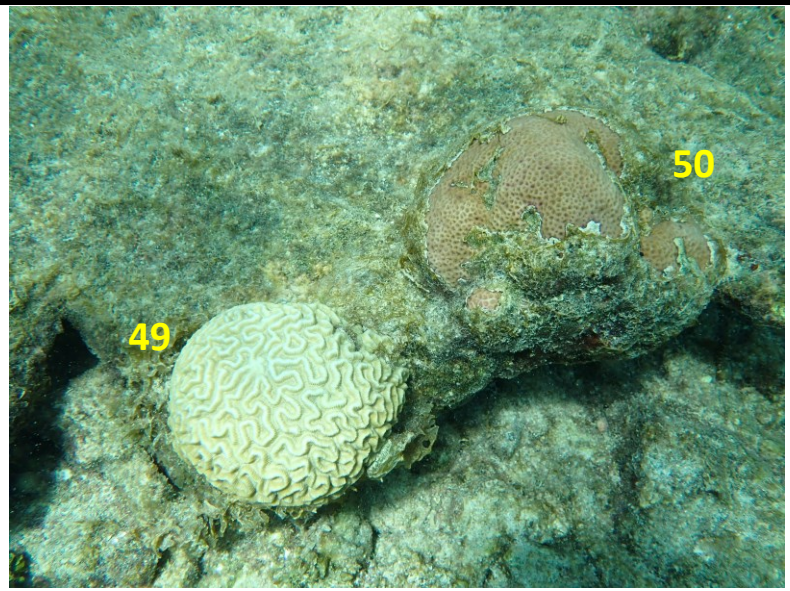
Coral Number	Common Name	Coral Scientific Name	Coral Health	Percent (%) Live Tissue	Percent (%) Dead Tissue	Pictorial Evidence and Notes
34	Brain Coral	Unverified	**Dead**	0	100	
35	Symmetrical Brain Coral	*Psedodiploria strigosa*	**Alive**	98	2	 With snail predation
36	Brain Coral	Unverified	**Dead**	0	100	

Coral Number	Common Name	Coral Scientific Name	Coral Health	Percent (%) Live Tissue	Percent (%) Dead Tissue	Pictorial Evidence and Notes
37	Symmetrical Brain Coral	*Psedodiploria strigosa*	**Alive**	60	40	 Algae growth at base of coral
38	Brain Coral	Unverified	**Dead**	0	100	
39	Mustard Hill Coral	*Porites aestroides*	**Dead**	5	95	

Coral Number	Common Name	Coral Scientific Name	Coral Health	Percent (%) Live Tissue	Percent (%) Dead Tissue	Pictorial Evidence and Notes
40	Symmetrical Brain Coral	*Psedodiploria strigosa*	**Alive**	70	30	 Algae growth at base of coral
41	Boulder Brain Coral	*Colpophyillia natans*	**Dead**	0	100	 Bleached
42	Brain Coral	Unverified	**Dead**	0	100	

Coral Number	Common Name	Coral Scientific Name	Coral Health	Percent (%) Live Tissue	Percent (%) Dead Tissue	Pictorial Evidence and Notes
43	Finger Coral	*Porites porties*	**Alive**	100	0	
44	Finger Coral	*Porites porties*	**Alive**	100	0	
45	Finger Coral	*Porites porites*	**Alive**	100	0	

Coral Number	Common Name	Coral Scientific Name	Coral Health	Percent (%) Live Tissue	Percent (%) Dead Tissue	Pictorial Evidence and Notes
46	Brain Coral	Unverified	**Dead**	0	100	
47	Brain Coral	Unverified	**Dead**	0	100	
48	Brain Coral	Unverified	**Dead**	0	100	

Coral Number	Common Name	Coral Scientific Name	Coral Health	Percent (%) Live Tissue	Percent (%) Dead Tissue	Pictorial Evidence and Notes
49	Boulder Brain Coral	*Colpophyillia natans*	**Alive**	Could not determine		 Brain Coral is paling
50	Massive Starlet Coral	*Siderastrea siderea*	**Alive**	60	40	
51	Symmetrical Brain Coral	*Psedodiploria strigosa*	**Alive**	100	0	 "Strange" growth Anomaly

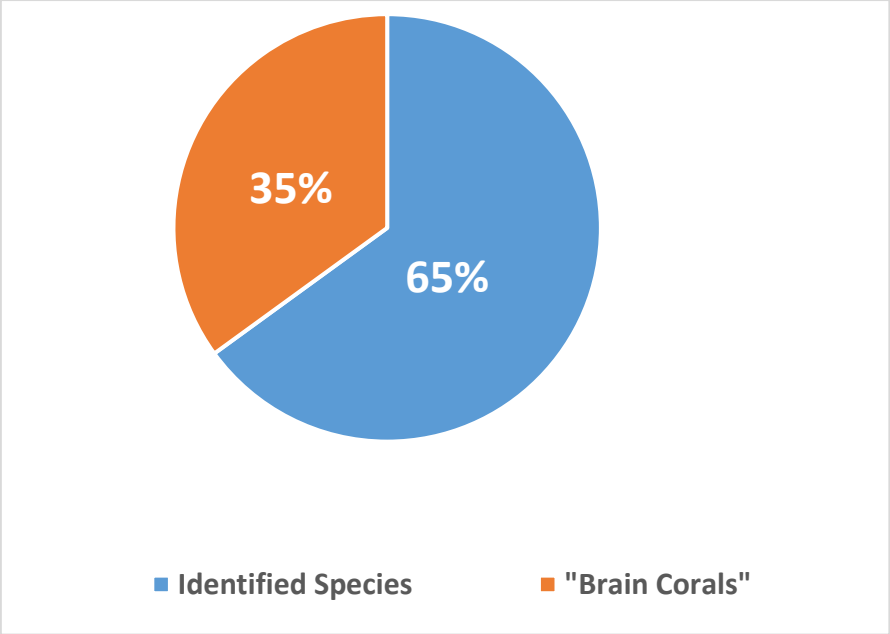


Figure 6. Percentage of transplanted corals identified to the species level and those classified as "Brain Corals [*Data Source:* Environmental Systems Ltd., 2023].

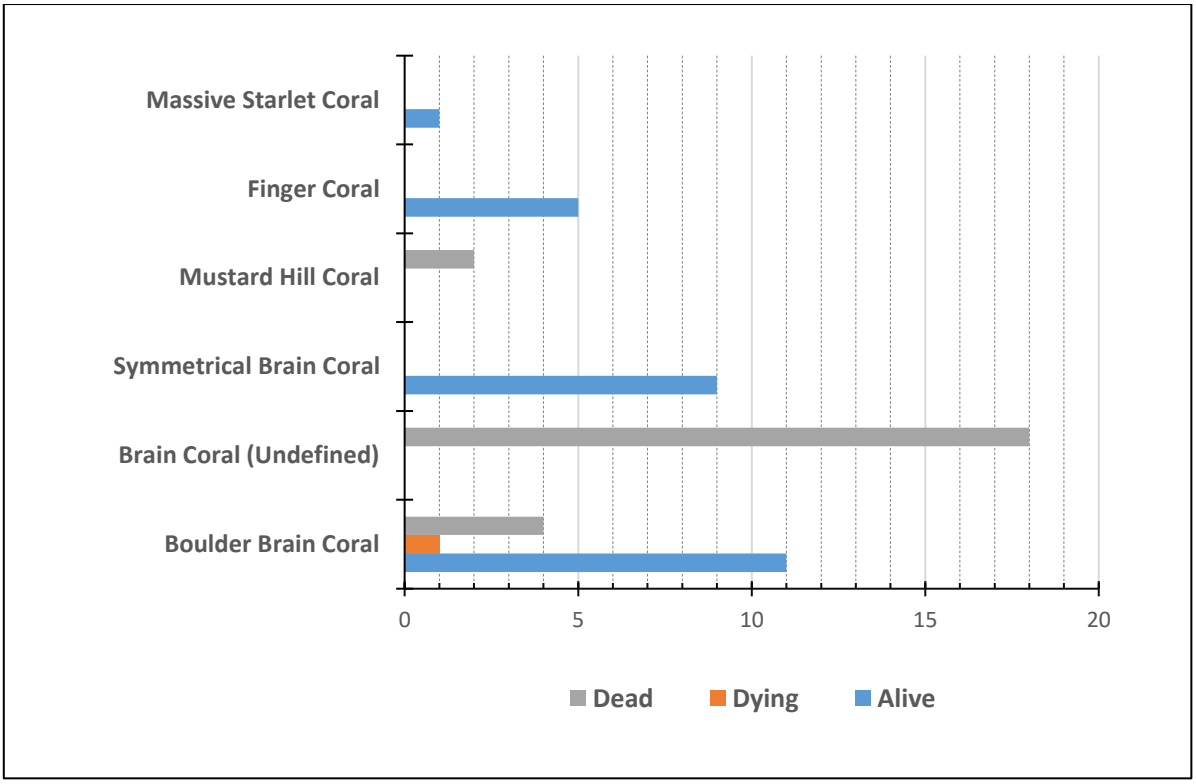


Figure 7. Transplanted corals classified as dead, dying, and alive by ESL Team based on field observations and pictorial evidence [***Data Source***: Environmental System, 2023].

- "Brain Corals" (Unverified): n =18
    - % Live tissue range: None
    - % Dead tissue range: 100

- Symmetrical Brain Coral (*Psedodiploria strigosa*): n = 9
    - % Live tissue range: 88 to 100
    - % Dead tissue range: 2 to 12

- Mustard Hill Coral (*Porites aestroides*): n = 2
    - % Live tissue range: 0 to 5
    - % Dead tissue range: 95 to 100

- Finger Coral (*Porites porites*): n = 5
    - % Live tissue range: 100
    - % Dead tissue range: None

- Massive Starlet Coral (Siderastrea siderea): n = 1
    - % Live tissue range: 60
    - % Dead tissue range: 40

For the 51 transplanted corals assessed in this report, roughly seven (7) years after they were transplanted, the data suggests that the Symmetrical Brain Coral (*P. strigosa*) and Finger Coral (*P. porites*) coped the best under the environmental conditions from 2016 to 2023 as all the specimens observed were alive and the % live tissue ranged from 88 to 100% and 100%, for *P. strigosa* and *P. pories*, respectively (**Table 5**).

It should be noted that for the summer months of 2023 (i.e., June to September), seawater temperatures were significantly higher than normal, and extremely hotter in shallower areas. Moreover, from 2020 to the time of completion for this report, various species of stony corals across the BVI have been impacted by stony coral tissue disease (SCTLD). It is well established that SCTLD destroys the soft tissue in roughly twenty-two (22) species of reef-building corals, killing them within weeks or months of becoming infected.

Of the 12 species documented in CMC's 2017 report, six (6) species were identifiable by ESL divers in 2023 ***based on the survey of the rock revetment only***, and bearing in mind that none of the transplanted corals or areas described by CMC were tagged or identifiable. The six species that were not observed by ESL in this 2023 assessment and their conservation status according to IUCN is as follows:

- Maze Coral (*Meandrina meandrites*): **Endangered**
- Lobed Star Coral (*Orbicella annularis*): **Endangered**
- Grooved Brain Coral (*Diplora labyrinthiformis*): **Critically Endangered** ***
- Boulder Star Coral *(Orbicella franksi):* **Vulnerable** ***
- Pillar Star Coral (Dendrogyra cylindricus): **Critically Endangered**
- Mountainous Star Coral (*Orbicella faveolata*): **Endangered**
- Staghorn Coral (*Acropora cervicornis*): **Critically Endangered**
- Elkhorn Coral (*Acropora palmata*): **Critically Endangered**

It should be reiterated that the "original" coral transplant list generated by ESL for this review was done solely based on the species pictured in CMC's 2017 report as an original species list was not included in that report. On the other hand, there were 18 corals classified as "Brain Corals" during ESL's field visits in September and October 223, but they could not be identified to species level. Hence, it is possible that for any of those 18 coral specimens classified as "Brain Corals" in this report, they could be identified as one of the following:

- Groove Brain Coral (*D. labyrinthiformis*);
- Boulder Brain Coral (*C. natans*); or
- Symmetrical Brain Cor al (*P. strigosa*).

Conversely, there was one (1) species of coral, the Finger Coral (*Porites porites*), that was not pictured in CMC's 2017 report, but listed as a species in the September/October 2023 based on their size and how they were positioned on the rock revetment for the extended marina. IUCN's conservation status for finger coral is **Least Concern**.

3.4 Other Coral Observations at Nanny Cay

ESL was also tasked to perform an environmental inventory and assessment of three (3) other areas at Nanny Cay, ESL will describe in this section some of the threats affecting corals in the area. The 3 areas that ESL were tasked to assessed are as follows:

1) the proposed location for the extension of the boat yard;
2) the marina environment; and
3) the proposed location for the extension of the marina to furnish mega yachts.

In some instances, there were two transplanted corals on the same boulder for the rock revetment, where one coral was alive and the other one was dead (**Figure 8**). In other areas, some of the corals were showing signs of paling due to the abnormally hotter water temperatures (**Figure 9**). Lastly, on the rock revetment completed in 2016, there are signs of coral recruitment/juveniles (**Figure 10** and **Figure 11**).

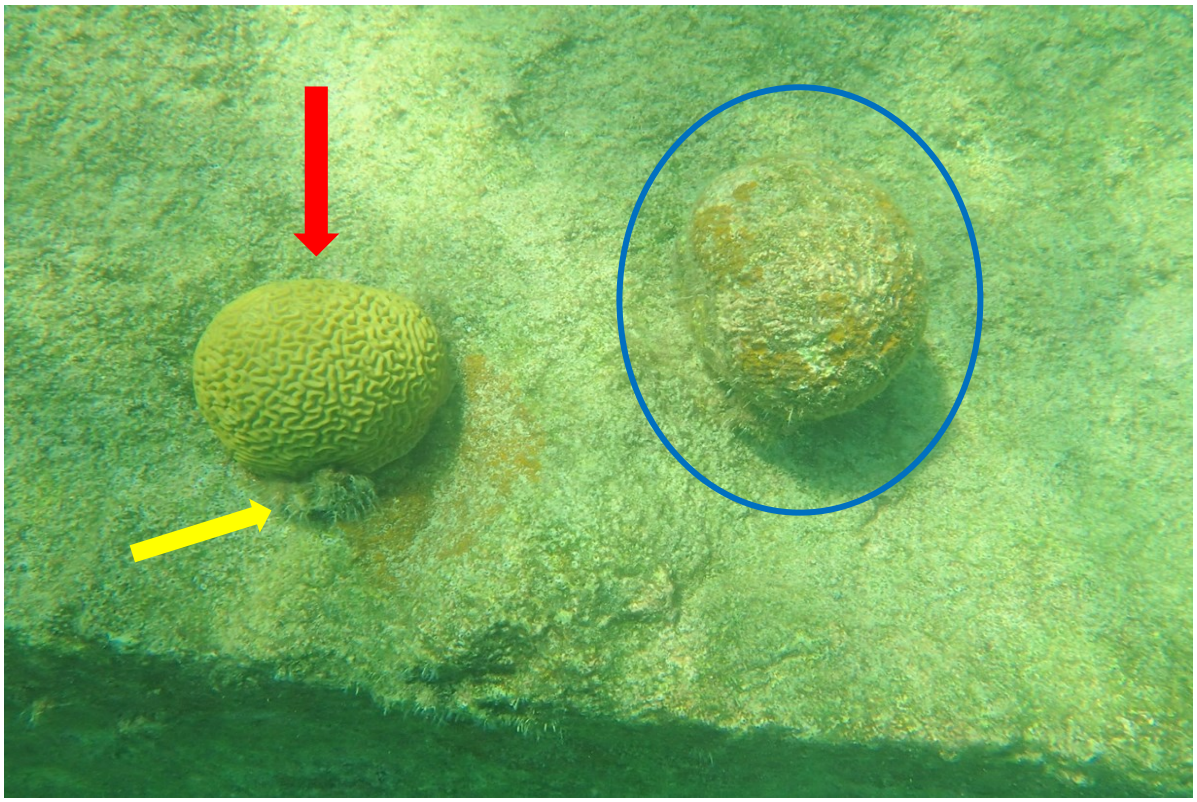


Figure 8. Images of Brain Corals that were transplanted in 2016 where the coral to the LEFT (**RED** arrow) is alive and is showing signs of being healthy, while the coral on the RIGHT (**BLUE** circle) is dead and is showing signs of 100% mortality. The **YELLOW** arrow next to the healthy coral is showing signs of algal growth at the base. Marine algae grows and settles on dead, available substrate through the process of succession over a period of time. If the coral has a weak immune system or starts showing signs of disease, the algae will quickly outcompete the colony, and ultimately kill the coral by smothering it [***Source***: Environmental System, 2023].

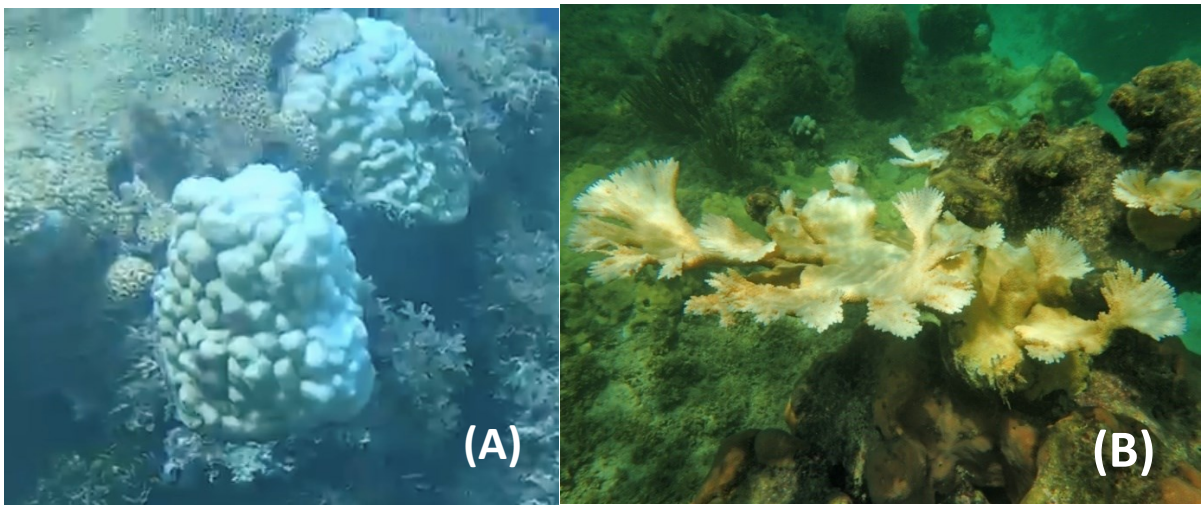


Figure 9. Images of coral specimens that were not transplanted where there is signs of paling due to abnormally warm water temperatures at Nanny Cay, where (A) are Mustard Hill Corals, *Porties aestroides*, and (B) is the critically endangered Elkhorn Coral, *Acropora palmata* [***Source***: Environmental System, 2023].

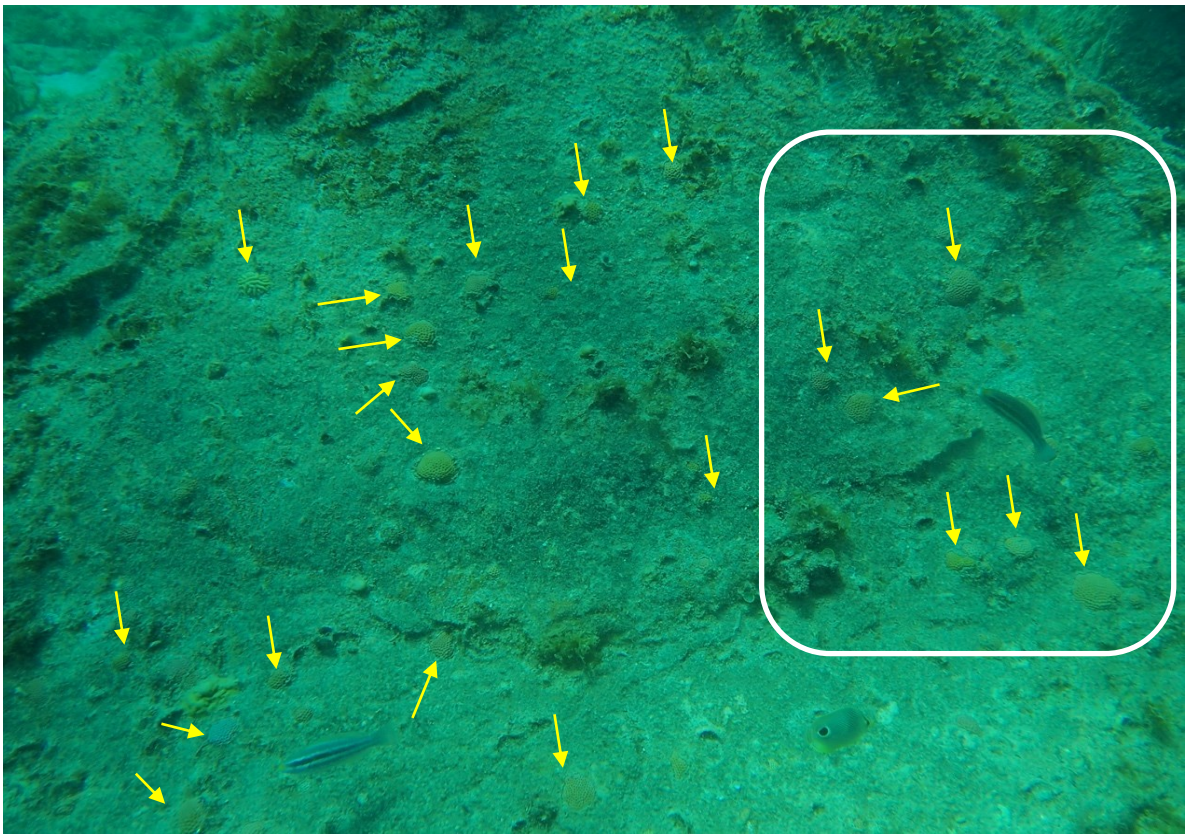


Figure 10. This image is a picture of one of the boulders used to construct the revetment of the marina completed in 2016. Each of the **YELLOW** arrows points towards a coral recruit/juvenile that has started to grow since 2016. The area enclosed in the **WHITE** rectangle is enlarged in the ***Figure 11*** in close-up [***Source***: Environmental System, 2023].

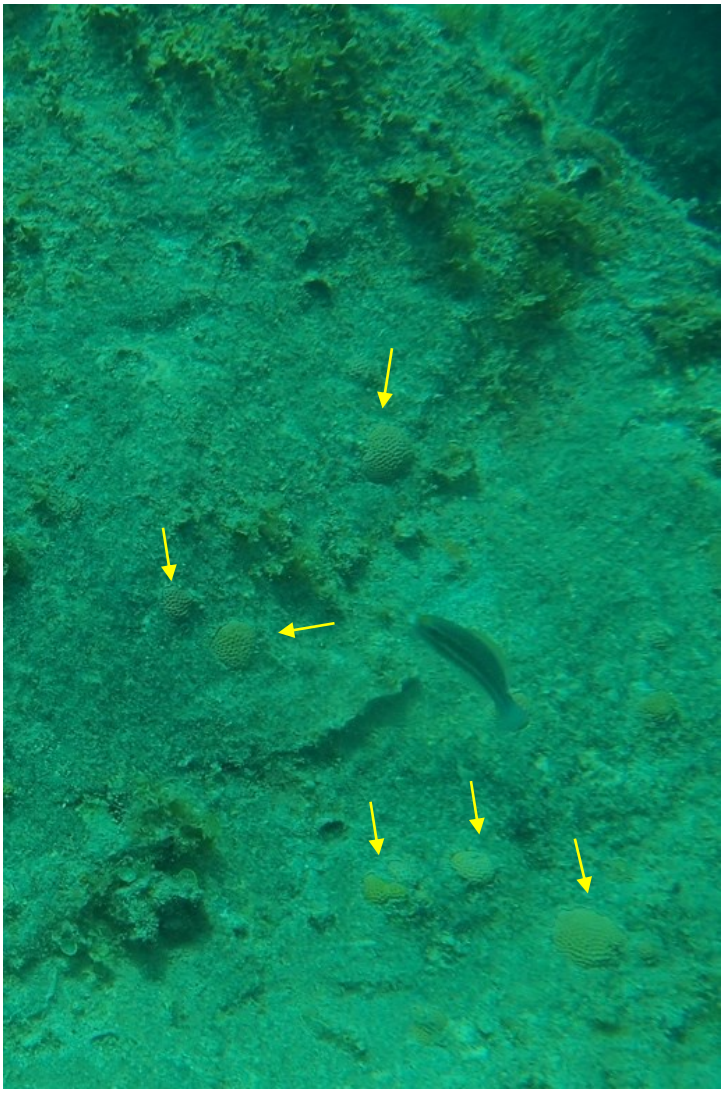


Figure 11. This image is a picture of one of the boulders used to construct the revetment of the marina completed in 2016. Each of the **YELLOW** arrows points towards a coral recruits/juveniles that started to grow since 2016 and is an enlargement of a section of ***Figure 10*** [***Source***: Environmental System, 2023].

3.5 *Fish Survey*

ESL did not complete a fish count like that completed by CMC in their 2017 report. Instead, ESL created a fish list of the various species observed hovering and/or swimming over the revetment, or hiding in the many crevices and overhangs created by the revetment (**Table 6**). At the rock revetment, there were 24 Families, and 65 species represented. There was one invasive species observed, the Lion Fish (*Pterois volitans*).

Table 6. Fish species by Phyla and Family observed hovering, swimming, or hiding along among the rocks and complex overhangs of the rock revetment used to construct the marina at Nanny Cay in 2016. Please note: *** delineates the presence of an invasive species [***Source***: Environmental Systems Ltd.].

Classification (Phyla)	Family Classification	Common Name	Scientific Name
Acanthuridae	Surgeonfish	Ocean Surgeon Fish	*Acanthurus bahianus*
		Blue Tang	*Acanthurus coeruleus*
		Doctor Fish	*Acanthurus chirurgus*
Aulostomidae	Trumpetfishes	Atlantic Trumpetfish	*Aulostomus maculatus*
Caranigidae	Jacks	Palometa	*Trachinotus goodei*
		Bar Jack	*Caranx ruber*
Chaetodontidae	Butterflyfishes	Banded Butterflyfish	*Chaetodon striatus*
		Foureye Butterfly fish	*Chaetodon capistratus*
Diodontidae	Burrfishes	Spotfin Blurrfish	*Chilomycterus reticulatus*
		Porcupine Fish	*Diodon holocanthus*
Bobiidae	Gobies	Cleaning Goby	*Elacatinus genie*
Grammatidae	Basslets	Fairy Basslet	*Gramma loreto*
Haemulidae	Grunts	French Grunt	*Haemulon flavolineatum*
		Porkfish	*Anisotremus virginicus*
		Tomtate	*Haemulon aurolineatum*
		Bluestriped Grunt	*Haemulon Sciurus*
Hemiramphidae	Needlefishes	Ballyhoo	*Hamiramphus balao*
Holocentridae	Squirrelfishes	Squirrelfish	*Holocentrus adscensionis*
		Longspine Squirrelfish	*Holocentrus rufus*
Labridae	Razorfishes or Wrasses	Slippery Dick	*Halichoeres bivittatus*
		Blueahead	*Thalassoma bifasciatum*
		Yellowhead Wrasse	*Halichoeres garnoti*
		Clown Wrasse	*Halichoeres maculipinna*
Labrisomidae	Scaly Blennies	Hairy Blenny Complex	*Labrisomus cricota*
		Saddled Benny	*Malacoctenus triangulatus*
		Redlip Blenny	*Ophioblennius macclurei*
Lutjanidae	Snappers	Mutton Snapper	*Lutjanus analis*
		Schoolmaster snapper	*Lutjanus apodus*
		Yellowtail Snapper	*Ocyurus chrysurus*
		Gray Snapper	*Lutjanus griseus*
		Dog Snapper	*Lutjanus jocu*
		Mangrove Snapper	*Lutjanus griseus*
Monacanthidae	Filefishes	Orange spotted Filefish	*Cantherhines pullus*
Mullidae	Goatfishes	Spotted Goatfish	*Pseudupeneus maculatus*
Ostraciidae	Boxfishes	Smooth Trunkfish	*Lactophrys triqueter*
Pomacanthidae	Angelfishes	Flame Back Angelfish	*Centropyge aurantonotus*
		Queen Angelfish	*Holocanthus ciliaris*
		Gray Angelfish	*Pomacanthus arcuatus*
Pomacentridae	Damselfishes or Chromis	Brown Chromis	*Chromis multineata*
		Seargant Major	*Abudefduf saxatilis*
		Yellowtail Damselfish	*Microspathodon chrysurus*
		Dusky Damselfish	*Stegastes adustus*
		Longfin Damselfish	*Stegastes diencaeus*
		Beaugregory	*Stegastes leucostictus*
		Threespotted Damselfish	*Stegastes planifrons*
		Cocoa Damselfish	*Stegastes xanthurus*

Classification (Phyla)	Family Classification	Common Name	Scientific Name
Pleuronectiformes	Founders, Soles or Tonguefishes	Peacock Flounder	*Bothus lunatus*
Serranidae	Groupers or Sea-Basses	Indigo Hamlet	*Hypoplectrus indigo*
		Barred Hamlet	*Hypoplectrus puella*
		Butter Hamlet	*Hypoplectrus unicolor*
		Harlequin Bass	*Serranus tigrinus*
		Sand Perch	*Diplectrum formosum*
Scaridae	Parrotfishes	Blue lip Parrotfish	*Cryptotomus roseus*
		Rainbow Parrotfish	*Scarus guacamaia*
		Striped Parrotfish	*Scarus iserti*
		Princess Parrotfish	*Scarus taeniopterus*
		Redband Parrotfish	*Sparisoma aurofrenatum*
		Yellowtail Parrotfish	*Sparisoma rubripinne*
		Stoplight Parrotfish	*Sparisoma viride*
Sciaenidae	Drums or Croakers	Spotted Drumfish	*Equetus punctatus*
Spyraenidae	Barracudas	Great Barracuda	*Sphyraena barracuda*
Synodontidae	Lizardfishes	Inshore Lizardsfish	*Synodus foetens*
		Sand Diver	*Synodus intermedius*
Scorpaenidae	Scorpionfishes	Mushroom scorpionfish	*Scorpaena inermis*
		Lionfish ***	***Pterois volitans******

4 CONCLUSIONS

The following conclusions are drawn by ESL based on a field survey of the revetment ***only*** as the following were not included in CMC's 2017 report: (a) the GPS location of each of the five (5) specific transplant sites depicted in **Figure *2* (A)** and **(B)** in CMC's 2017 report; (b) there was no photo evidence of tags or other identifiable means (e.g., flagged rebar) to identify the immediate area(s) of the transplanted corals (CMC, 2017); and (c) there were no identifiable tags found on any corals during the time of field surveys completed by ESL staff in September and October, 2023 .

- There were thirteen (13) species that ESL can confirm as coral transplanted by CMC in 2016 on behalf of Nanny Cay. The 13 species are as follows:
    1) Boulder Coral (*Colpophyilia natans*): **Endangered**
    2) Symmetrical Brain Coral (*Psedodiploria strigosa*): **Critically Endangered**
    3) Mustard Hill Coral (*Porites aestroides*): **Least Concern**
    4) Finger Coral (*Porites porites*): **Least Concern**
    5) Massive Starlet Coral (*Siderastrea siderea*): **Critically Endangered**
    6) Maze Coral (*Meandrina meandrites*): **Endangered**
    7) Lobed Star Coral (*Orbicella annularis*): **Endangered**
    8) Grooved Brain Coral (*Diplora labyrinthiformis*): **Critically Endangered*****
    9) Boulder Star Coral *(Orbicella franksi):* **Vulnerable**
    10) Pillar Star Coral (Dendrogyra cylindricus): **Critically Endangered**

11) Mountainous Star Coral (*Orbicella faveolata*): **Endangered**
12) Staghorn Coral (*Acropora cervicornis*): **Critically Endangered**
13) Elkhorn Coral (*Acropora palmata*): **Critically Endangered**

- From the 13 species outlined above, species 1) to 5) are species confirmed by ESL as: (a) none of the coral transplants or coral transplanted areas were tagged and/or delineated; and (b) the size and placement of the corals on the rock revetment are considerably larger than coral recruits observed during field surveys completed by ESL personnel in 2023.

- It should be noted that the IUCN status of the corals transplanted back in 2016 by CMC was not included in the 2017 report. ESL included the current conservation status as the environmental landscape of the Territory has changed drastically with the floods and hurricanes of 2017, the introduction of SCTLD, and the compounded efforts of warmer seawater temperatures. The current status of the corals as classified by IUCN underscores the importance of coral transplantation in development projects in the BVI.

- Data suggests that the two (2) species of corals transplanted to the rock revetment of the marina that was completed in 2016 fared best in the face of warmer water temperatures and an outbreak of SCTLD in the Territory. The species that coped best from 2016 to date included: (a) the Symmetrical Brain Coral (*P. strigosa*) and (b) Finger Corals (*P. porites*).

- Of the 51 specimens of transplanted corals assessed by ESL, pictorial evidence indicates that:

  i. 51% (n = 26) of those corals were still alive;
  ii. 47% (n = 24) were dead as there was 100% live tissue; and
  iii. 2% (n = 1) was dying, as the % live tissue and % dead tissue were 15% and 85%, respectively.

- As the Territory continues to grapple with the effects of climate change, especially warmer sea temperatures, and an increasing number of tropical storms, the coral transplantation activities by Nanny Cay is commendable as 100% of those coral would have been lost if they were not transplanted. The transplantation efforts versus losing them totally to development will ensure that:

  a. these corals are alive and can continue to reproduce and see other surrounding areas and/or areas downstream of Nanny Cay; and
  b. the various ecosystem services that corals provide (e.g., coastal buffering, habitat for fish) are not lost.

- While 51% of the corals were still alive despite the hot water temperatures and in the face of SCTLD, which kills stony corals, there is another threat to coral survival that should be noted, and this is the release of sewage from the Slaney Outfall upstream of the study area. All things considered, the corals, inclusive of the transplants did exceptionally well.

- There were 65 different species of reef fishes observed in September 2023, by ESL personnel swimming, hovering, or hiding in crevices or complex overhangs created by the rock revetment used to construct the marina in 2016. The rock revetment is and will currently to serve as an artificial reef.

5 RECOMMENDATIONS

1) For any future coral transplant efforts, it is strongly recommended that Nanny Cay consider:

a. Tagging all corals transplanted to make ongoing and/or future monitoring easier;

b. If tagging all transplant corals is not possible for all specimens, placement of flagged rebar or similar should be used to delineate the area(s) being used for coral transplants.

c. Monitoring all the transplants for a minimum of one (1) year as outlined in ***Section 3.1 - Overview*** of this report, and then three (3) to five (5) years follow-up, as environmental and natural conditions can change from season to season and from year to year.

d. As closely as possible, utilize the recommendations for coral transplantation described in Frias-Torres *et al*., (2018).

e. Corals should be transplanted in the cooler months (i.e., November to about March/April) to minimize stress on corals during the transplant process.

f. Routine algae cleaning for a minimum of 1 to 2 years of areas where corals are transplanted and where new coral recruits/juveniles are found to ensure that the algae does not smother or overgrow them.

g. Count, assess and monitor the presence of *Diadema* in the area where the corals are transplanted because:

   i. *Diadema* is an important keystone species on Caribbean reefs that are needed to maintain algae populations from smothering coral.

   ii. Recently, there was a *Diadema* die-off in the Caribbean that occurred in 2022. According to Ramanujan (2023), the 2022 die-off of *Diadema* was caused by a ciliate, *Philaster apodigitiformis*, which is a known parasite in fish.

6 REFERENCES

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