FISH SPAWNING AGGREGATIONS IN CAYMAN CROWN, SAPODILLA CAYES MARINE RESERVE

Monitoring Report for 2020-2022

Prepared for Toledo Institute for Development and Environment (TIDE)

June 2022

Funded by

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LIST OF ACRONYMS

DAFM	Days After the Full Moon
DBFM	Days Before the Full Moon
EDF	Environmental Defense Fund
FSA	Fish Spawning Aggregation
MBRS	Mesoamerican Barrier Reef System
SCMR	Sapodilla Cayes Marine Reserve
SCRFA	Science and Conservation of Reef Fish Aggregations
SI	Statutory Instrument
TIDE	Toledo Institute for Development and Environment

INTRODUCTION

FISH SPAWNING AGGREGATIONS

Fish Spawning Aggregation (FSA) is a term used to refer to large gatherings of fish at the same place and at specific times, to spawn and reproduce, usually along reef promontories. These fish can migrate across hundreds of kilometers and reliably utilize these same locations every year for several days to weeks around the full moon, during their reproductive season. These FSAs are important resources on coral reefs that serve to replenish and maintain productive reef fisheries. A majority of commercially important fish species, belonging to snappers, groupers and jacks, form large transient reef spawning aggregations that constitute the primary means by which these species reproduce and replenish their populations. This highly predictable behaviour makes these species very vulnerable to overfishing and many of the FSAs across the Caribbean and in the Mesoamerican Reef are now inactive and/or threatened, with severely declined numbers. In particular, species such as the Nassau grouper, *Epinephelus striatus*, is now considered critically endangered due to overfishing of their FSAs.

In Belize, the government and its partners worked to establish and manage a network of FSAs, thirteen protected sites, that have either been historically known for spawning aggregations or are currently active aggregation sites. Although these sites have been protected since 1993, further declines in the size of the aggregations and abundance of fish have been noted and there has been no significant recovery, despite almost three decades of protection and management. In 2020, the Cayman Crawn protected area was designated as a part of Conservation Zone IV, with the expansion of the SCMR. This area has been identified as an important biodiversity hotspot with very high coral cover >60%, excellent reef health and reported to include several spawning aggregation sites (Perez Murcia, 2020). The Toledo Institute for Development and Environment, through a research permit from the Belize Fisheries Department, commenced exploratory surveys in the Cayman Crown area during 2020-2022. The primary objectives were to assess the location of potential spawning aggregations and characterize the fish communities observed at these sites, with particular emphasis on commercial species such as snappers, groupers, jacks and grunts.

DESCRIPTION OF STUDY SITE, WITHIN CAYMAN CROWN

Cayman Crown is an offshore reef area located in the Gulf of Honduras, partially within the Sapodilla Cayes Marine Reserve (SCMR). It is approximately 56 km east of Punta Gorda and 16 km south-southwest of Hunting Caye (Figure 1). The Cayman Crown reef is a platform reef with depths to 50 m. The habitats are made up primarily of coral framework, coral framework with algae and individual patch reefs, according to the benthic habitat mapping exercise completed by the Healthy Reefs Initiative for the Southern Belize and Guatemalan Mesoamerican Reef (Purkis, 2021) (Figure 3, inset C).

The Cayman Crown Reef is a large underwater reef spur at depths between 40-50 m, most likely formed on a submarine platform. The major portion is contained within the SCMR (Figure 4) and another portion in the Guatemalan protected area called the "Corona". The northern portion in the Belizean side is characterized by high relief coral formations with some spur and groove to depths of 43 m, and includes a submarine cavern at about 40 m. The northern portion of the spur rises from the depths and forms a ledge at approximately 30 m running the entire length of the northern side, and then levels off into a flattened area. This flattened area was observed to have colonies of *Orbicella, Pseudodiploria* and *Diploria* spp. The spur ascends from the depth on all side where it reaches its shallowest depth of 14 m from the surface. The entire length of the spur is approximately 200 m long by 30 m wide (Belize Fisheries Department, 2022).

Some unpublished studies in 2018 by a US consulting firm, LGL Ecological Research Associations Inc, described observations of spawning aggregations of horse eye and crevalle jack, Atlantic spadefish, mutton snapper and Cubera snapper. Megafauna such as whale sharks, pilot whales, sperm whales and large pelagic fish including marlin, sailfish, wahoo, mahi mahi, kingfish and various tuna were also sighted. The deep-water reefs contain reef geomorphology consisting of spurs that drop nearly vertically from their top at 20 m depth, to over 150m over the steep wall edge, into the Cayman Trench. AGRRA surveys conducted by the Southern Environmental Association and Healthy Reefs Initiative found 60% live coral cover, identifying these reefs as the healthiest in the Caribbean (EDF, 2020).

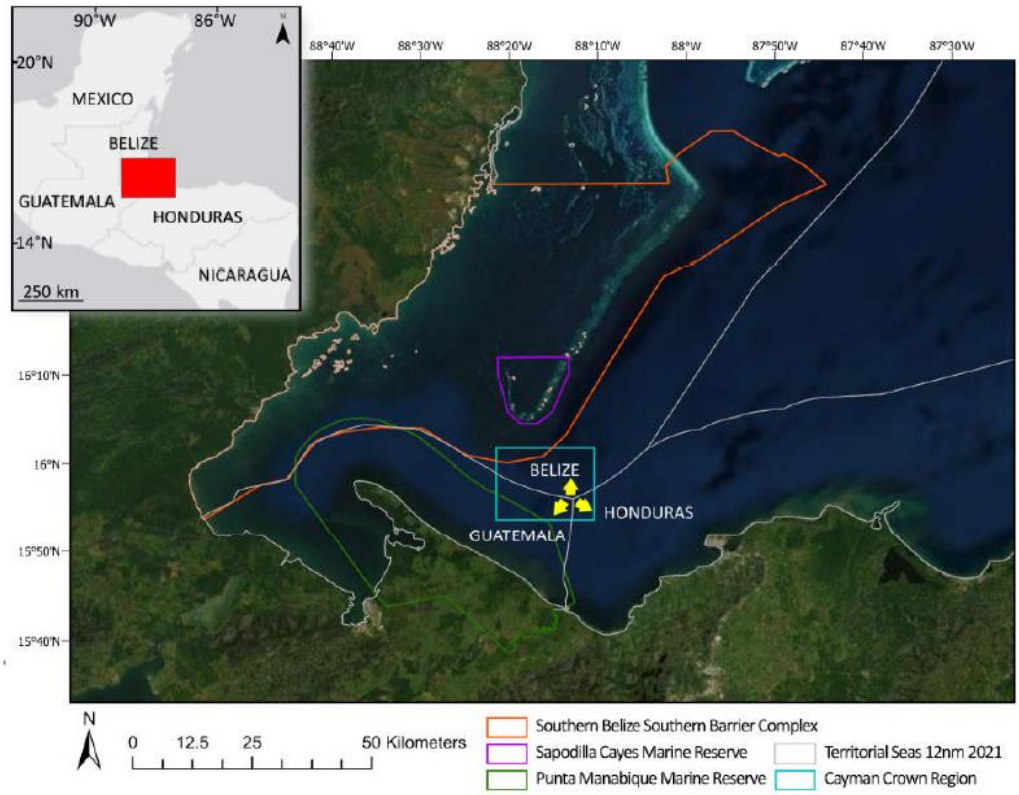


Figure 1a Shows the location of Cayman Crown relative to Belize mainland and the maritime boundaries of Belize, Guatemala and Honduras. The Sapodilla Cayes Marine Reserve 1996 boundary is outlined in purple,

the location of the Cayman Crown corals is in aquamarine and Territorial Seas are outlined in grey. The Southern Barrier Complex of Belize, is outlined in orange (*Source Purkis 2021*).

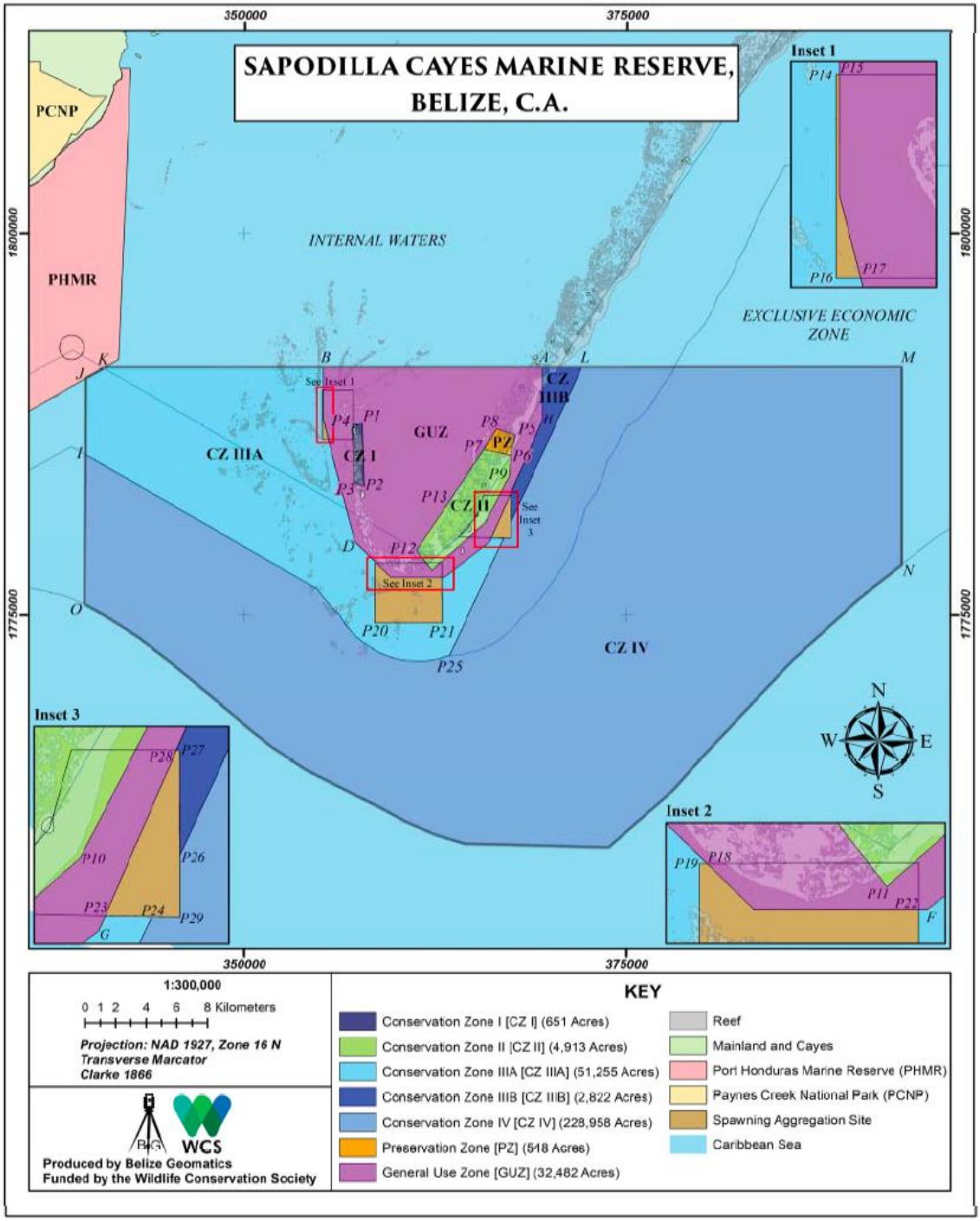


Figure 2 Map of the revised Sapodilla Caye Marine Reserve boundaries including the Cayman Crown Reef located in Conservation Zone IV (*SI No. 107 of 2020*).

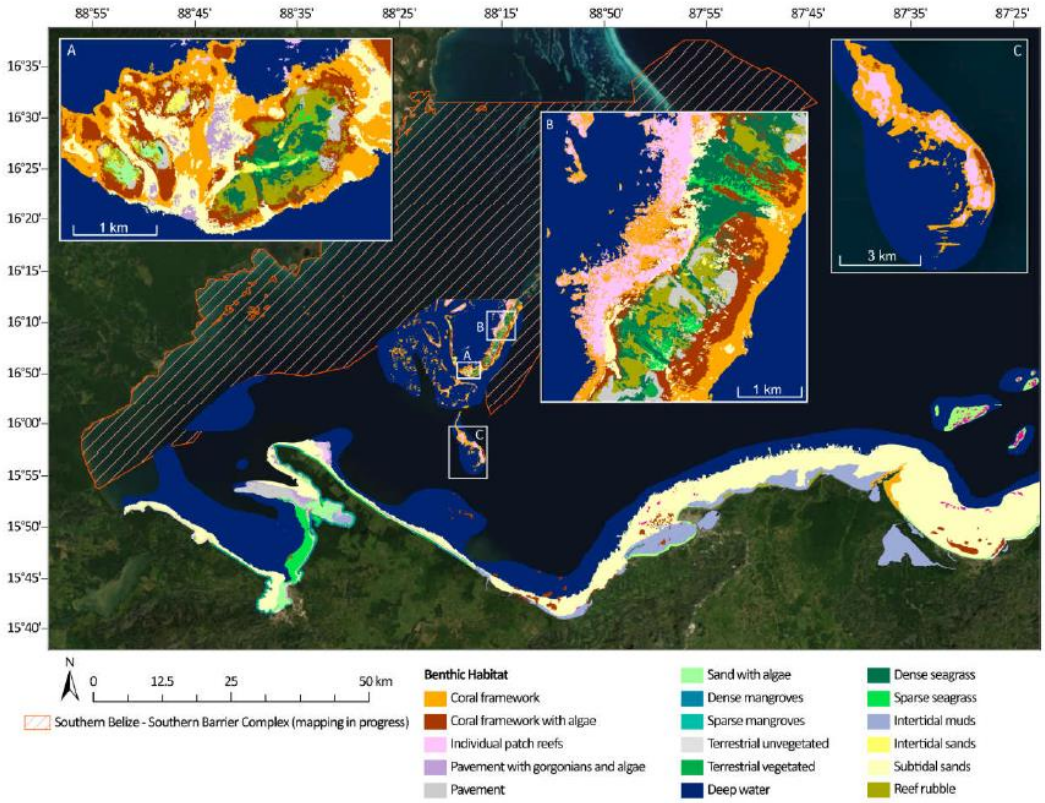


Figure 13: Map of benthic habitats for Area 1 (1,100 sq.km).

Figure 3 Map of the benthic habitats of the Cayman Crown Reef (*Source Purkis 2021*).

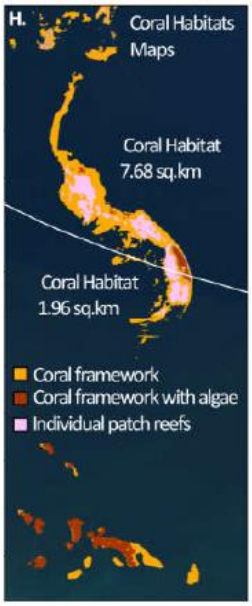


Figure 4 Map of coral reef habitat of the Cayman Crown Reef. White line delineates the Belize-Guatemala boundary, with north of the line in Belize's territory and forms Conservation Zone IV of the Sapodilla Cayes Marine Reserve (*Source, Purkis 2021*).

METHODS

TIDE conducted multiple Fish Spawning Aggregation (FSA) monitoring trips to the Cayman Crown Reef to attempt to identify, characterize and confirm the presence of FSAs within the Cayman Crown area. They also conducted monitoring trips to the known and established FSA sites within the Sapodilla Caye Marine Reserve (SCMR), Rise and Fall and Nicholas (Figure 5a, b). These surveys were conducted during the spawning seasons for groupers and snappers, and other commercial species such as jacks, from 2020 to 2022. In 2020, FSA surveys were conducted during February, June and July at six sites within the Cayman Crown Reef (Table 1a). In 2021, FSA surveys were conducted from February to June and December, at eight sites within the Cayman Crown Reef and seven sites within the SCMR (Table 1b). In 2022, FSA surveys were conducted from January to May at six sites within the Cayman Crown and one site, Nicholas, within the SCMR (Table 1c). The depth at the sites in 2020 ranged from 22 to 42 m. In 2021, depth ranged from 18 to 41 m, with one site in Cayman Crown being only 10-19 m deep. Finally, in 2022 the surveys had depths ranging from 19-35 m (Tables 1a-c). The areas surveyed throughout the years were highly variable based on the site features, time of day, weather conditions and visibility.

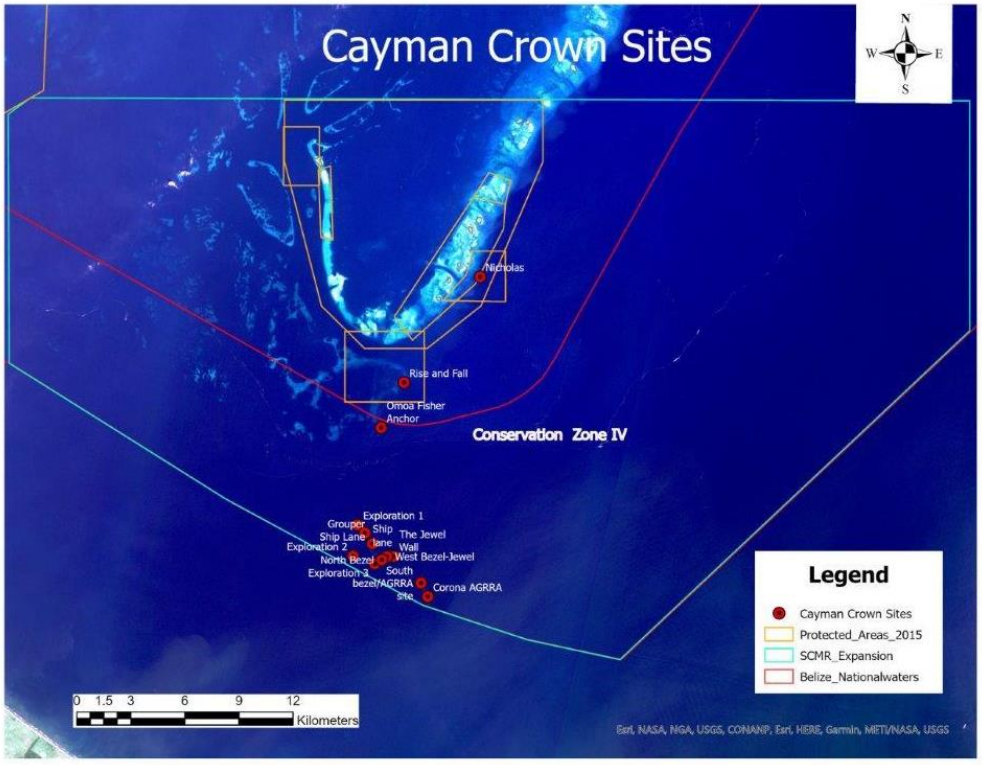


Figure 5a Sites surveyed for fish spawning aggregations within the Sapodilla Cayes Marine Reserve, including known FSAs (Nicholas and Rise and Fall) and potential sites within the Cayman Crown (Source TIDE 2022).

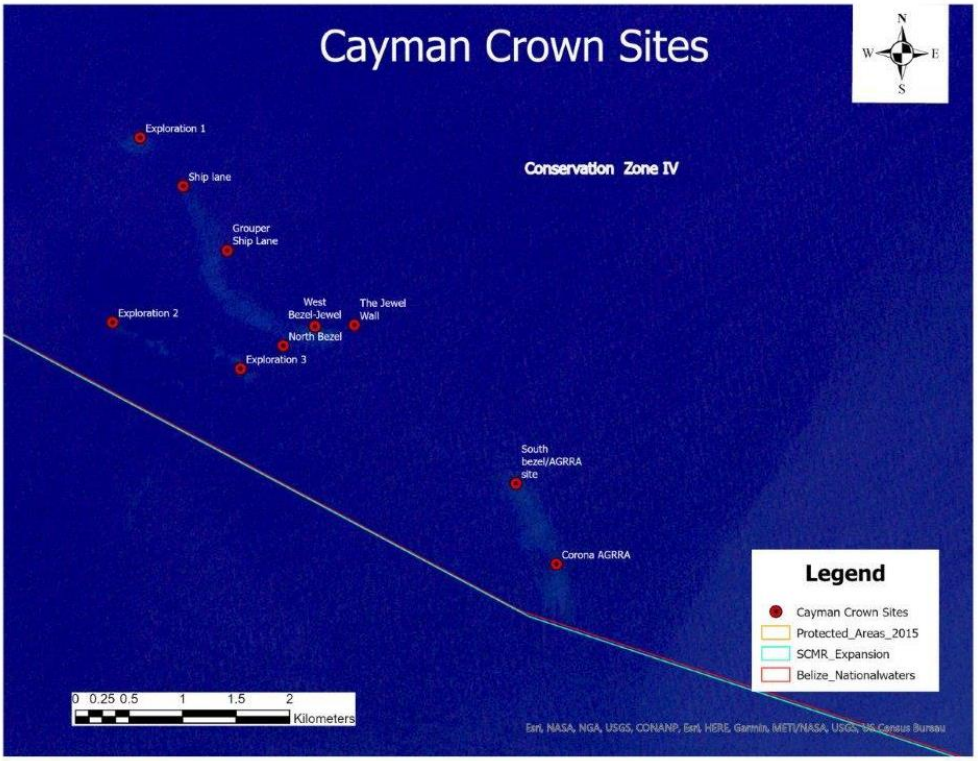


Figure 5b Enlarged view of the Cayman Crown Reef showing the sites surveyed for fish spawning aggregations (Source TIDE 2022).

Tables 1a, b, c. Sites surveyed in 2020, 2021, 2022 with depth and estimated survey area.

Table 1a. 2020 Locations		
Site Name	Depth (m)	Estimated survey area (m2
Corona AGRRA	31-42	650-700
North Bezel	22-30	400-500
Omoa Fisher Anchor	26-32	450-700
South Bezel/AGRRA Site	25	1000
The Jewel Wall	25-42	150-800
West Bezel	27-33	400-500
West Bezel Fisher Marker	28-42	500-750

Table 1b. 2021 Locations		
Site Name	**Depth (m)**	**Estimated survey area (m2)**
The Jewel Wall	24-41	100-885
Omoa Fisher Anchor	18-24	500-933
West Bezel Fisher Marker	19-32	500-770
Exploration 1	10-19	917
Ship Lane	16-22	514-650
Exploration 2	27	965
Exploration 3	28-30	740-885
Rise and Fall	24	901
Grouper Ship Lane	20-24	515
Nicholas	27	200
North Bezel	28	500

Table 1c. 2022 Locations		
Site Names	**Depth (m)**	**Estimated survey area (m2)**
Exploration 1	24-27	350-500
Nicholas	22-35	200-250
Omoa Fisher Anchor	21-31	550-800
Ship lane	19-27	500-550
The Jewel Wall	25-34	100-250
West Bezel	21	350
West Bezel Fisher Anchor	21-33	350-780

SURVEY PERIOD

Surveys were conducted around the full moon of each respective month between 0 to 11 days after the full moon (DAFM). Based on the known literature and field records in the Caribbean and Mesoamerican region from the Science and Conservation of Reef Fish Aggregations (SCRFA) database, spawning usually occurs between a couple days before the full moon (DBFM) up to ten days after the full moon, depending on the particular target species.

Spawning dives were conducted at various times throughout the day in the morning, midday and evenings. In 2020, dives were generally conducted between 6:30-9:30 am, 10:20 am to 12:30 pm and 2:30-4:30 pm. For 2021, dive times spanned across the day between 9:00 am to 12:00 pm, 2:30-4:30 pm and 5:00-7:00 pm with 1 dive from 7:00 to 8:00 am. Dives in 2022 were generally conducted between 10:30 am to 12:00 pm and 4:30-6:00 pm, with one dive from 7:30-8:00 am. According to the FSA monitoring protocol recommended for the Mesoamerican Region (Heyman et al., 2004), when establishing spawning times, at least one dive should occur between 3:00-4:00 pm, a mid-day dive and a dive 60-30 minutes before sunset to check for actual spawning. Abundance varies throughout the day and therefore once an established monitoring time is set, this same time should be repeated on subsequent monitoring trips. Most dives lasted between 28-50 minutes starting at depth and ending shallower due to dive safety requirements to avoid decompression sickness.

FSA MONITORING PROTOCOL

The monitoring protocol used to survey for fish spawning aggregations was the one recommended for the Mesoamerican Reef, "**Reef Fish Spawning Aggregation Monitoring Protocol for the Meso-American Reef and the Wider Caribbean, Version 2.0 (Heyman et al., 2004)**", utilized nationally by the Belize Spawning Aggregation Working Group. It consists of visual census surveys that count the abundance of the target species, estimates sizes and records any spawning behaviour such as color changes, chasing, biting, etc. Teams ranged from two to five persons conducting surveys. Data was recorded and numbers discussed and averaged at the end of each day.

DATA ANALYSIS

Data collected over the three seasons (2020-2022) were sorted and analyzed by month, DAFM, and species abundance, with maximum count per species determined over the total number of survey days for each month sampled. When replicate counts were conducted on the dives, the maximum mean count was determined for the month. Size frequency analysis was conducted on the most abundant grouper, snapper and jack species encountered with numbers of individuals observed in each size class at the sites.

Major limitations with the data included having a consistent dive time for sites, and consistently diving for at least 3 consecutive days during the spawning period at each site. Given that fourteen sites were surveyed over the three years, this made it difficult to routinely target and survey a particular site for consecutive days, especially since these dives were mostly exploratory to establish their potential as FSAs.

Also, at some sites in 2020, counts were conducted by only one individual, which did not allow for replicate counts that could be more reliable than a single entry. Visual size estimates were also a limitation, and given the conditions (visibility, currents, distance from fish, etc.), obtaining accurate size estimates is usually a challenge and requires prior training and verification. Finally, counts of large groups of fish become less accurate, especially more densely packed schools or groupings, such as fish greater than 1000 individuals.

RESULTS

DESCRIPTION OF SITES

A total of fourteen sites were surveyed between February 2020 and May 2022. In 2020, exploratory dives were carried out at seven sites at the Cayman Crown Reef to establish the presence of FSAs. In 2021, a total of ten sites were surveyed, eight sites were from the Cayman Crown and two were documented FSAs in the SCMR (Nicholas and Rise and Fall). Of the eight sites surveyed in Cayman Crown, five were new sites from those visited

in 2020. In 2022, six sites were visited with five of them from Cayman Crown and one from SCMR, all were repeat sites from the previous years (Tables 1a-c).

The sites on Cayman Crown were located mostly on the northern portion of the reef and only two sites, South Bezel AGRRA and Corona AGRRA, were on the southern portion of the reef (Figure 5b). The areas monitored were along the spur edges of the reef between 20-42 m. Some sites such as Ship Lane, Exploration 1 and Omoa Fisher Marker, had some surveys at shallower depths of 10-24 m.

MOON PHASE

Surveys were conducted in February 2020 at four sites between 3 to 7 DAFM. Three of the four sites only had surveys conducted on one day. North Bezel was surveyed 3 DAFM, Omoa Fisher Anchor was 4 DAFM and South Bezel/AGRRA was 5 DAFM. The Jewel Wall was the only site that had four days of surveys, from 3-7 DAFM (Table 2a). In June 2020, of the four sites surveyed, each had two days of observations, The Jewel Wall was surveyed 3 and 7 DAFM; West Bezel was surveyed 4-5 DAFM; West Bezel Fisher Marker was surveyed 5 and 8 DAFM; and Corona AGRRA was surveyed 6-7 DAFM (Table 2a). July 2020 also had four sites surveyed. West Bezel Fisher Marker was surveyed only once, 2 DAFM; Omoa Fisher Anchor was surveyed for two days on 3 and 5 DAFM; The Jewel Wall was also surveyed two days on 5 and 6 DAFM; and North Bezel was surveyed three consecutive days, from 4-6 DAFM (Table 2a).

Table 2a. Period monitored for February, June and July 2020, DAFM.

2020	Day After the Full Moon							
Site	1	2	3	4	5	6	7	8
Corona AGRRA						●	●	
North Bezel			●	●	●	●		
Omoa Fisher Anchor			●	●	●			
South Bezel/AGRRA Site					●			
The Jewel Wall			● ●	●	●	● ● ●	●	
West Bezel				●	●			
West Bezel Fisher Marker		●			●			●

February ●
June ●
July ●

In 2021, there was significant time spent on surveys at multiple sites to identify FSAs. In February, monitoring started 1 day before the full moon (DBFM) on The Jewel Wall and was surveyed again 1 DAFM. North Bezel was surveyed only once on the full moon (0 DAFM) and Omoa Fisher Anchor was surveyed for two days, 0 and 2 DAFM (Table 2b). In March, two sites were surveyed only once: West Bezel Fisher Marker on 5 DAFM and Exploration 1, 3 DAFM. The Jewel Wall and Ship Lane were both surveyed for two days, 2

and 4 DAFM, and 4 and 5 DAFM, respectively (Table 2b). For April, only The Jewel Wall was surveyed more than one day, 1-2 DAFM. Exploration 2 and Exploration 3 were only surveyed once on 2 and 3 DAFM, respectively (Table 2b). May 2021, The Jewel Wall received the majority of surveying effort with 4 consecutive days of monitoring, 3-6 DAFM. Omoa Fisher Anchor was surveyed 6-7 DAFM, while Exploration 3 was surveyed only on 4 DAFM. Rise and Fall in the SCMR was surveyed on 5 DAFM (Table 2b). In June, The Jewel Wall was once again the target of the majority of survey efforts, 0-1, 3 and 4 DAFM. Omoa Fisher Anchor was surveyed 2-3 DAFM and West Bezel Fisher Marker only once, 2 DAFM (Table 2b). Finally, December was a busy month with five sites surveyed over a five-day period. The Jewel Wall had five days of surveys, three of which were consecutive from 3-8 DAFM. West Bezel Fisher Marker was surveyed for two days, 4 and 6 DAFM. Grouper Ship Lane also had two days of surveys, 5 and 7 DAFM. Omoa Fisher Anchor was surveyed only once on 6 DAFM, and so was Nicholas, 8 DAFM (Table 2b).

In 2022, the FSA surveys were conducted at five sites for the month of January, of which The Jewel Wall had four survey days, 6, 8-10 DAFM. Ship Lane was surveyed for two days, 7 and 9 DAFM. The remaining sites: Exploration 1, Exploration 2 and West Bezel were surveyed only once, on 7, 8 and 10 DAFM, respectively. The Nicholas FSA in the SCMR was surveyed on 11 DAFM (Table 2c). In February, the only site surveyed was the Nicholas FSA from 2-7 DAFM (Table 2c). In March, The Jewel Wall was surveyed for three days, 3-4 and 6 DAFM. Omoa Fisher Anchor was surveyed 5 and 7 DAFM, and Exploration 1 and West Bezel Fisher Marker were surveyed only once on 4 and 6 DAFM, respectively. Nicholas in the SCMR was surveyed on 5 and 7 DAFM (Table 2c). For April, The Jewel Wall had five consecutive survey days from 0-4 DAFM. West Bezel Fisher Marker, Ship Lane and Omoa Fisher Anchor were surveyed one day only (Figure 8d). Nicholas was surveyed 3-4 DAFM (Table 2c). May was the final survey period with The Jewel Wall having three consecutive days of surveys, 5-7 DAFM. Omoa Fisher Anchor was also surveyed for three consecutive days, 3-5 DAFM, while West Bezel Fisher Marker was surveyed only once on 4 DAFM. Nicholas was surveyed 2-3 DAFM (Table 2c). No surveys were conducted in June due to bad weather conditions that made it unsafe to dive.

GENERAL TRENDS

Overall, The Jewel Wall was the most frequently surveyed site in the Cayman Crown, with it being surveyed every monitoring trip between 2020 and 2022. On average the most a site was surveyed for was two days, with the exception of The Jewel Wall that regularly had 4-5 days of surveys. The most frequently monitored sites over the three-year period were: The Jewel Wall, Omoa Fisher Anchor and West Bezel Fisher Marker, with Ship Lane and Exploration 1, 2 and 3, the second most visited.

Table 2b. Period monitored for February to June and December 2021.

2021	Day After the Full Moon									
SITES	-1	0	1	2	3	4	5	6	7	8
Exploration 1					●					
Exploration 2				●						
Exploration 3					●	●				
Grouper Ship Lane							●		●	
Nicholas										●
North Bezel		●								
Omoa Fisher Anchor		●		● ●	●			● ●	●	
Rise and Fall							●			
Ship Lane						●	●			
The Jewel Wall	●	●	● ● ●	● ●	● ● ●	● ● ● ●	● ●	●	●	●
West Bezel Fisher Marker				●		●	●	●		

February ● May ●
March ● June ●
April ● December ●

Table 2c. Period monitored for January to May 2022.

2022	Day After the Full Moon											
SITES	0	1	2	3	4	5	6	7	8	9	10	11
Exploration 1					●			●	●			
Nicholas			● ●	● ●	● ●	● ●	●	● ●				●
Omoa Fisher Anchor				●	●	● ●		●				
Ship lane			●					●		●		
The Jewel Wall	●	●	●	● ●	● ●	●	● ● ●	●	●	●	●	
West Bezel											●	
West Bezel Fisher Marker		●			●		●					

January ● April ●
February ● May ●
March ●

ABUNDANCE OF SPECIES

SPECIES LIST

A total of thirty-eight (38) fish species of commercial interest were recorded from all fourteen sites surveyed over the three-year period. In 2020, twenty-two species were sighted; thirty-five species in 2021 and twenty-four species in 2022 (Table 3). The list includes several species from the Serranidae (groupers), Lutjanidae (snappers), Haemulidae (grunts) and Carangidae (Jacks) families. It also includes some large pelagics such as the blue marlin, bonito and wahoo.

The most commonly sighted species were the Atlantic spade, Bar jack, Horse eye jack, Schoolmaster, Rainbow runner, White grunt, Bonito, Crevalle jack, Yellowtail snapper and Dog snapper (Appendix 1-3).

Table 3. List of fish species of commercial interest encountered from all sites surveyed

Common Name	Scientific Name	2020	2021	2022
Atlantic Spade	*Chaetodipterus faber*	x	x	x
Bar Jack	*Caranx ruber*	x	x	x
Barracuda	*Sphyraena barracuda*	x	x	x
Black Grouper	*Mycteroperca bonaci*	x	x	x
Black Jack	*Caranx lugubris*		x	
Black Margate	*Anisotremus surinamensis*	x	x	
Blue Marlin	*Makaira nigricans*		x	
Blue Runner	*Caranx cryosus*		x	x
Bluestriped grunt	*Haemulon sciurus*	x	x	
Bonito (Little Tunny)	***Euthynnus alletteratus***		x	
Cero Mackerel	*Scomberomorus regalis*		x	x
Coney	*Cephalopholis fulva*		x	
Crevalle Jack	*Caranx hippos*		x	x
Cubera Snapper	*Lutjanus cyanopterus*		x	x
Dog Snapper	*Lutjanus jocu*	x	x	x
Graysby	*Cephalopholis cruentata*		x	x
Greater amberjack	*Seriola dumerili*		x	
Hogfish	*Lachnolaimus maximus*	x		x
Horse-eye Jack	*Caranx latus*	x	x	x
Mahogany Snapper	*Lutjanus mahogani*	x		x
Mutton Snapper	*Lutjanus analis*	x	x	x
Nassau Grouper	*Epinephelus striatus*	x	x	x
Permit	*Trachinotus falcatus*	x	x	x
Pork Fish	*Anisotremus virginicus*	x	x	
Rainbow Runner	*Elagatis bipinnulata*	x	x	x
Red Grouper	*Epinephelis morio*		x	
Red Hind	*Epinephelus guttatus*		x	x
Rock Hind	*Epinephelus adscensionis*		x	
Schoolmaster	*Lutjanus apodus*	x	x	x
Spanish grunt	*Haemulon macrostomum*	x		
Southern Sennet	*Sphyraena picudilla*		x	x
Tiger Grouper	*Mycteroperca tigris*	x	x	x
Wahoo	*Acanthocybium solandri*		x	
White Grunt	*Haemulon plumierii*	x	x	
Yellow Jack	*Caranx bartholomaei*	x	x	x
Yellowfin Grouper	*Mycteroperca venenosa*	x	x	x
Yellowmouth Grouper	*Mycteroperca interstitialis*		x	
Yellowtail Snapper	*Ocyurus chrysurus*	x	x	x
TOTAL SPECIES OF COMMERCIAL INTEREST OBSERVED		**22**	**35**	**24**

FISH ABUNDANCE

In 2020, FSA surveys were completed for February, June and July as described above. Although four sites were surveyed in February, only two had groups of fish large enough for commercial interest: The Jewel Wall and North Bezel. Omoa Fisher Anchor and South Bezel/AGRRA only had one dive conducted with a few lionfish and white grunts observed. The Jewel Wall had a small aggregation of tiger grouper (200 fish), Nassau grouper (40), Atlantic spade and schoolmaster (50) each, while North Bezel had white grunts (100), porkfish (80) and schoolmaster (50) (Figure 6). Notably, no black grouper aggregations were observed.

During June 2020, more species and larger numbers were observed at four different sites. The Jewel Wall and West Bezel Fisher Marker had the most fish observed with Atlantic spade, bar jack, horse eye jack, and schoolmaster forming groups of 150-400 fish (Figure 7). In July 2020, The Jewel Wall and West Bezel Fisher Marker had the most fish aggregating with 1700-2000 bar jacks and 300-800 horse eye jacks, at both sites. Schoolmaster aggregations of 100-400 fish were also observed at The Jewel Wall, West Bezel Fisher Marker and North Bezel, with small groups of white grunt and rainbow runner also observed (Figure 8).

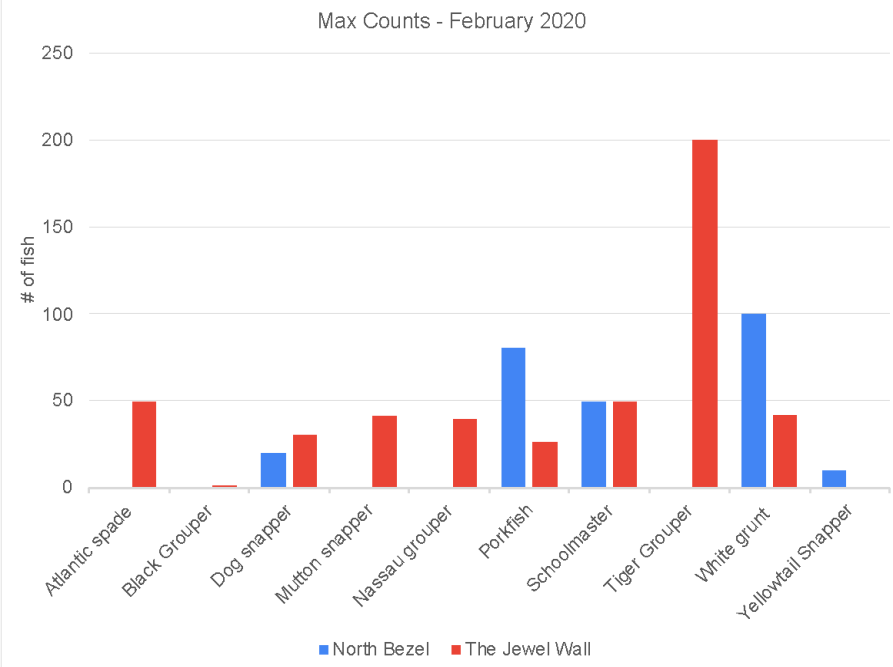


Figure 6 Fish abundance from surveys conducted in February 2020.

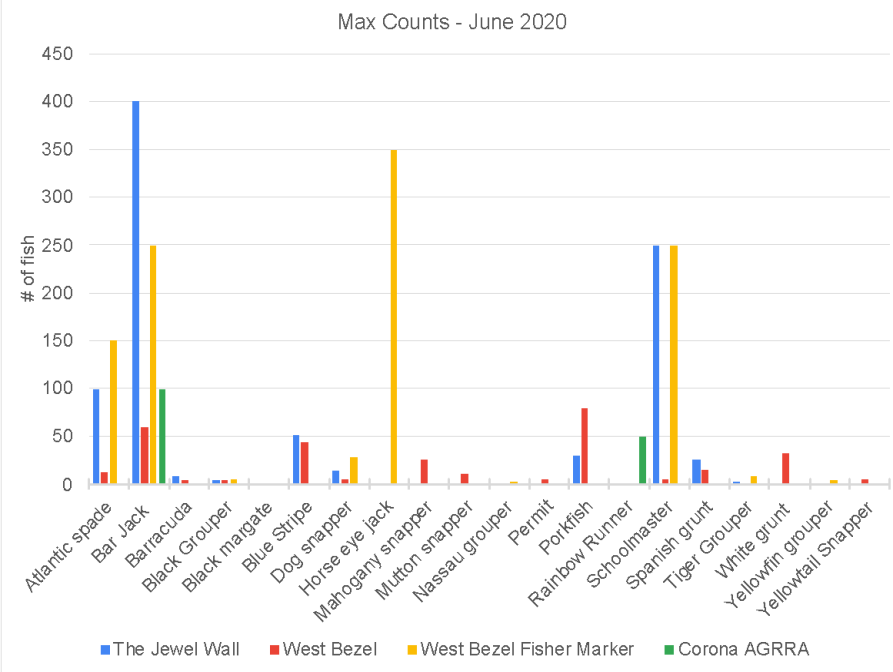


Figure 7 Fish abundance from surveys conducted in June 2020.

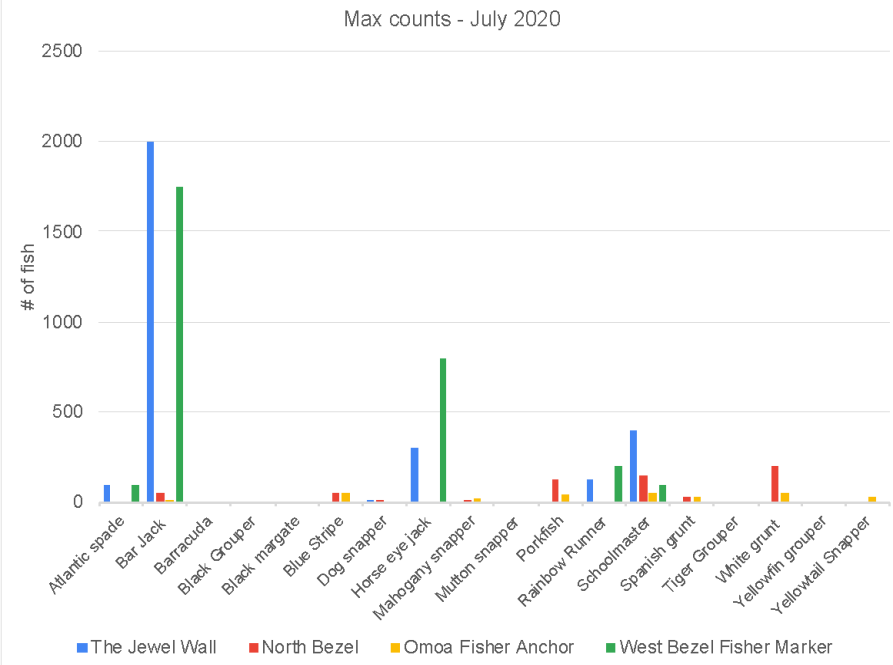


Figure 8 Fish abundance from surveys conducted in July 2020.

In 2021, there was data from across six months, February to June and then in December. The three sites surveyed in February: The Jewel Wall, West Bezel Fisher Marker and Omoa Fisher Marker, had aggregations of jacks – bar jack, crevalle jack and horse eye jack. There was a small grouping of schoolmaster, 105 fish, and notably no aggregations of groupers (Figure 9). In March, The Jewel Wall and West Bezel Fisher Marker also had the most fish with bar jack and horse-eye jack being the most abundant species, 92-300 bar

jacks and 200-1000 horse-eye jacks (Figure 10). In April, The Jewel Wall was the only site that had any considerable fish abundance, with bar jack and horse eye jack being the most abundant, 300-500. Bonito was also observed schooling and there were small groupings of Atlantic spade, blue runner, crevalle jack and schoolmaster, 60-95 fish (Figure 11). Three of the sites surveyed in 2021 yielded aggregating behaviour. May surveys showed continued aggregations at The Jewel Wall by jacks – bar jack (500), crevalle jack (120), and horse eye jack (1245); along with Atlantic spade and schoolmaster (145-250). Dog snapper was present in small aggregations at both Omoa Fisher Anchor and Rise and Fall, and schoolmaster had small aggregations at Rise and Fall (Figure 12).

In June 2021, The Jewel Wall and West Bezel Fisher Anchor once again showed the most activity, along with Omoa Fisher Anchor. Bar jack, horse eye jack, rainbow runner, schoolmaster, southern sennet and yellowtail snapper were the most abundant species (Figure 13). Finally, in December 2021, The Jewel Wall, West Bezel Fisher Anchor and Omoa Fisher Anchor, again had the most fish present. A new site, Grouper Ship Lane was surveyed that also showed aggregations. Species observed in large enough numbers included: bar jacks (100-350) at all sites except Nicholas, horse eye jack (270-350) at 2 of the sites, southern sennet (200) at The Jewel Wall and yellowtail snapper at 2 sites. A small aggregation of Atlantic spade was also observed at The Jewel Wall (Figure 14). A very small gathering of Nassau grouper (36) was observed at Nicholas Caye.

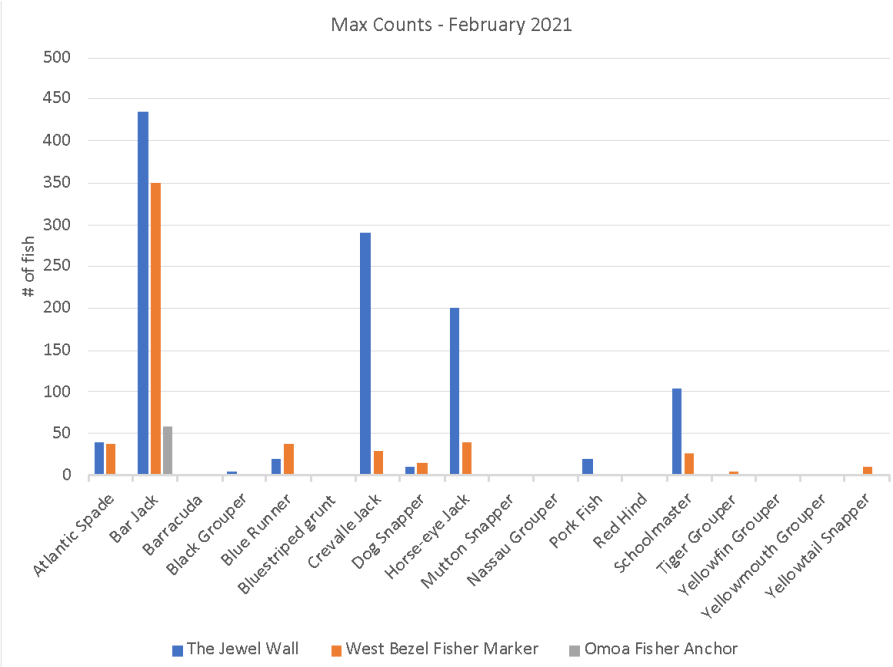


Figure 9 Fish abundance from surveys conducted in February 2021.

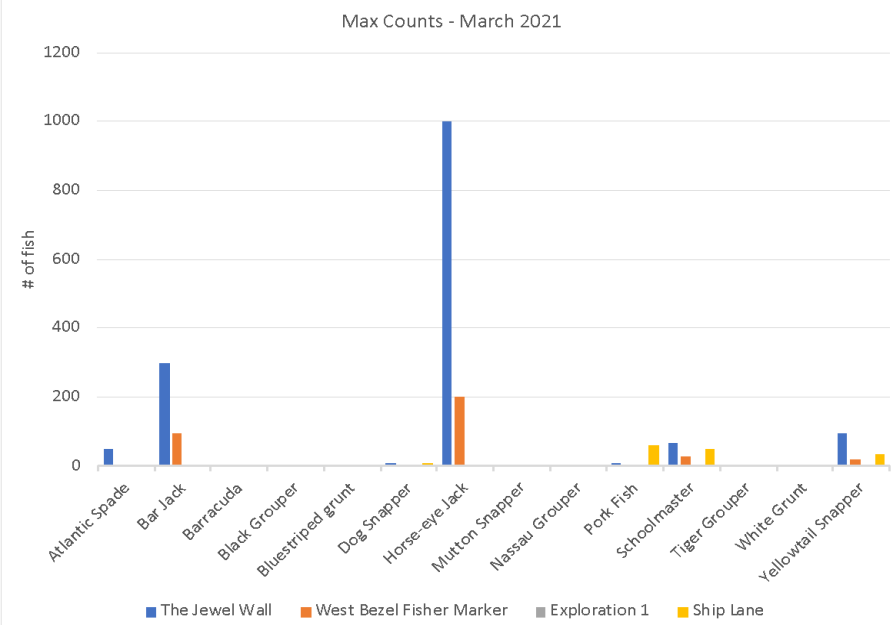


Figure 10 Fish abundance from surveys conducted in March 2021.

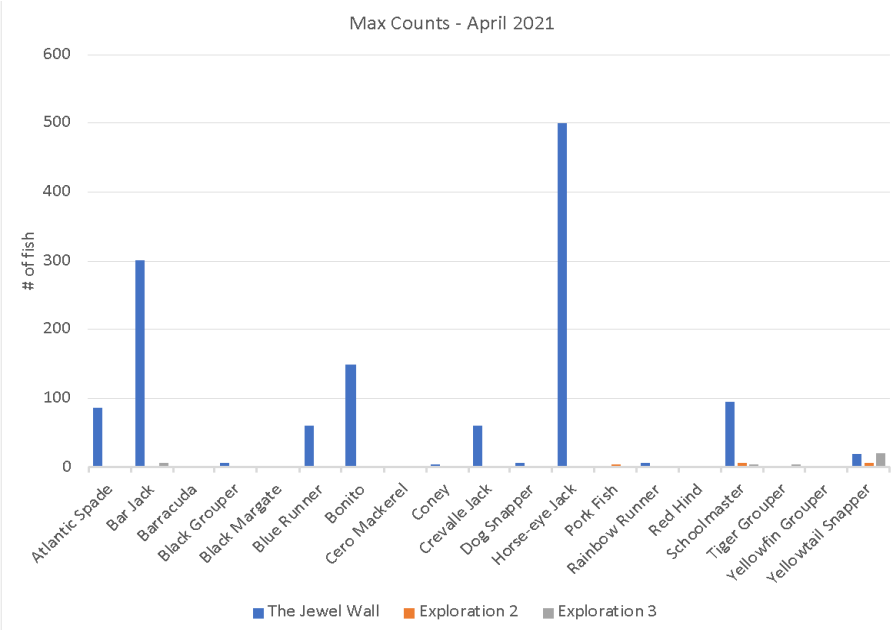


Figure 11 Fish abundance from surveys conducted in April 2021.

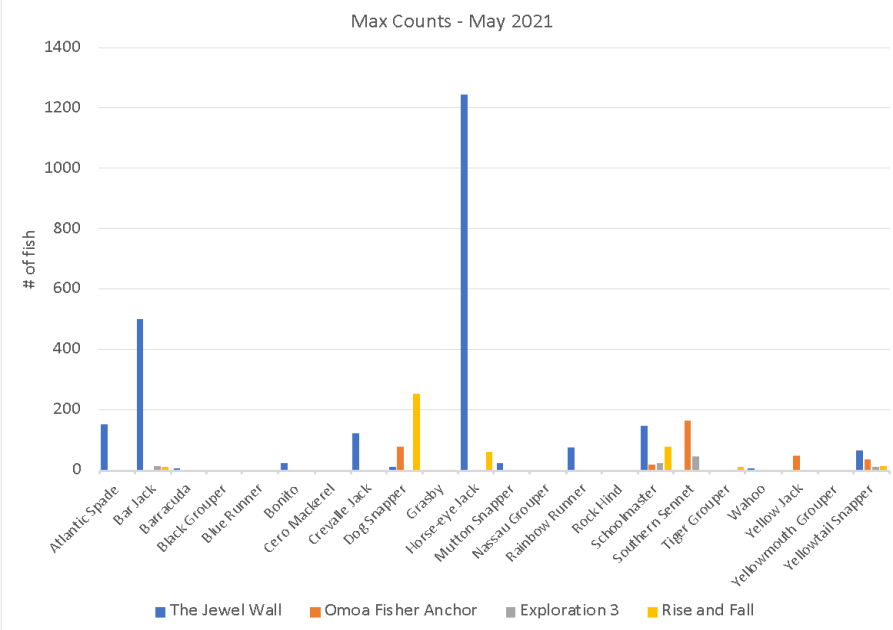


Figure 12 Fish abundance from surveys conducted in May 2021.

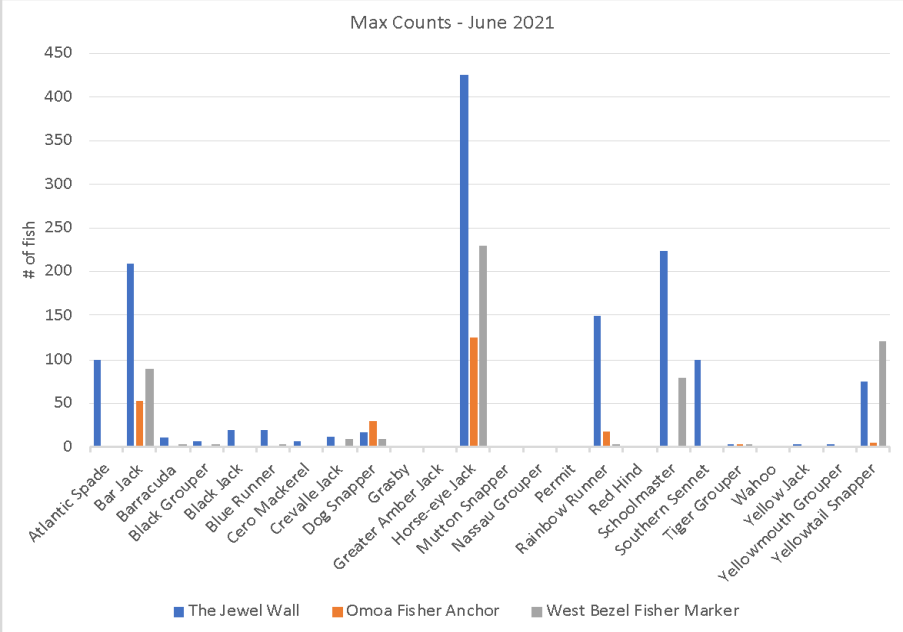


Figure 13 Fish abundance from surveys conducted in June 2021.

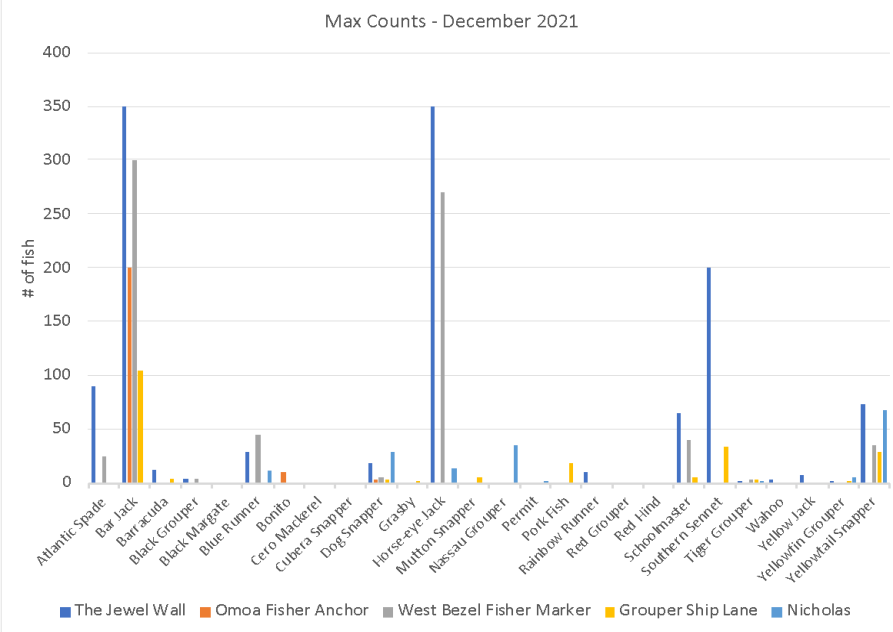


Figure 14 Fish abundance from surveys conducted in December 2021.

In 2022, surveys were conducted from January to March during the grouper spawning season and in April through May during the snapper spawning season. In January, 4 sites in Cayman Crown were surveyed along with Nicholas in the SCMR. The Jewel Wall followed by Nicholas had the most fish, with the largest aggregations comprised of: bar jack (300), horse eye jack (150) and southern sennet (175). At Nicholas, there were 155 Nassau grouper present. While West Bezel and Exploration 1, had between 145-175 bar jack and southern sennet (Figure 15). Small groups of Atlantic spade, schoolmaster, tiger grouper and yellowtail snapper (28-55) were observed across sites. Of note, 44 tiger groupers were recorded at Nicholas (Figure 15). For February 2022, only Nicholas was surveyed. Abundance was fairly low with small groups of fish, all below 100 individuals. Nassau grouper was the most abundant with 77 fish. There were also small numbers of three other grouper species: tiger grouper (35), black grouper (28) and yellowfin grouper (15) (Figure 16).

In March 2022, five sites were surveyed. Horse eye jack and dog snapper were the most abundant with 400 and 170 fish respectively (Figure 17). Atlantic spade, bar jack, schoolmaster, southern sennet and yellowtail snapper were between 70-110 fish (Figure 17). The Jewel Wall and Nicholas had the most fish abundance recorded. Groupers were few in numbers, in the range of 20-35 found primarily at Nicholas (Figure 17). In April, The Jewel Wall was the site with the most fish observed but in low numbers, 75-172 fish (Figure 18). The most abundant species seen were Bar jack, Bonito, Horse eye jack and schoolmaster (Figure 18). May showed more abundance with Atlantic spade, bar jack, horse eye jack, schoolmaster and southern sennet being the more abundant species, ranging from 110-316 fish (Figure 19). Once again, The Jewel Wall had the most fish abundance. Nicholas and West Bezel Fisher Anchor also had some of the higher abundances (Figure 19).

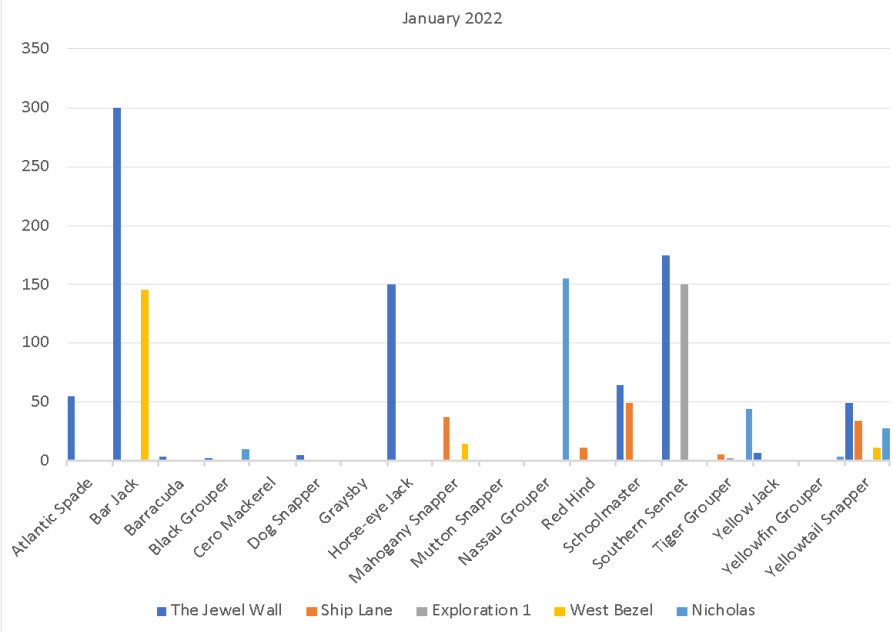


Figure 15 Fish abundance from surveys conducted in January 2022.

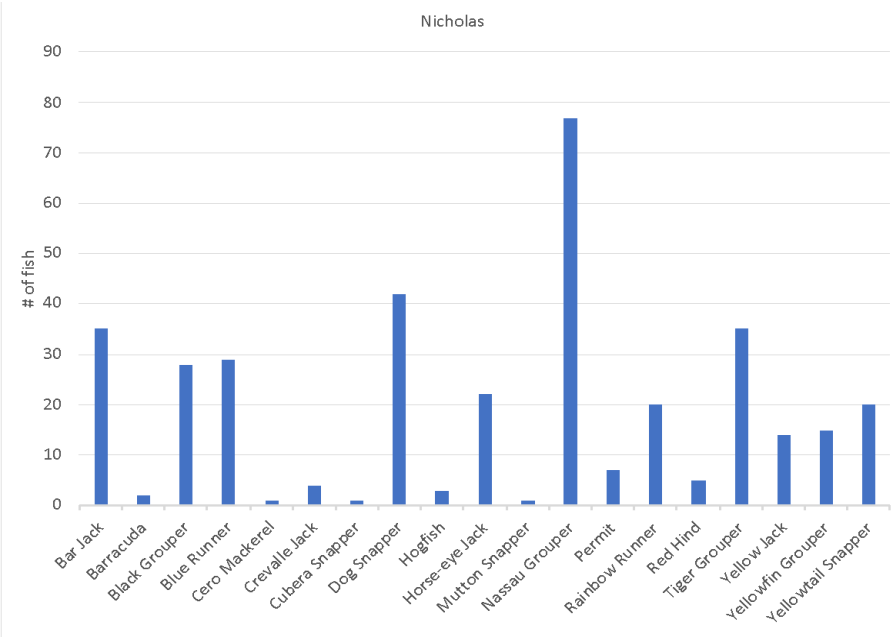


Figure 16 Fish abundance from surveys conducted in February 2022.

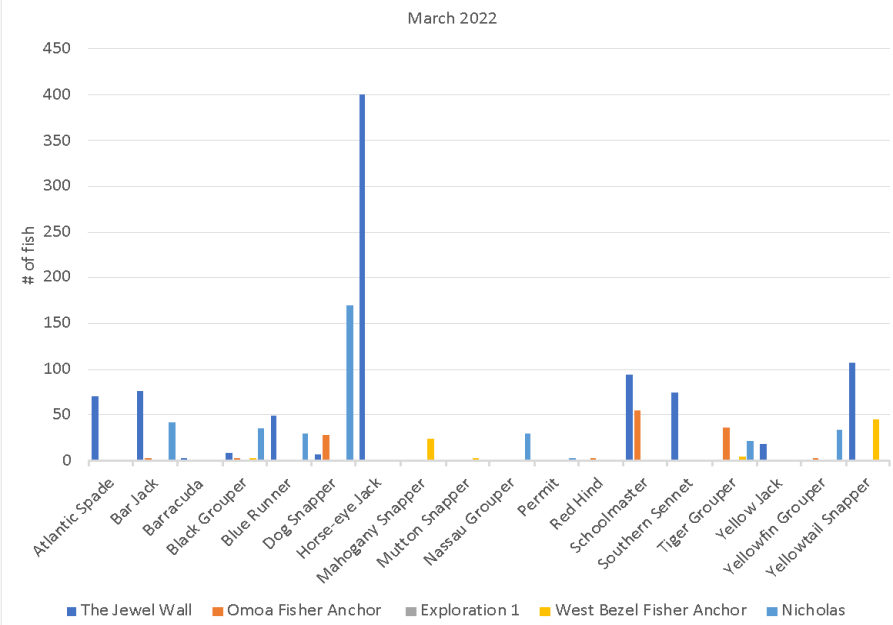


Figure 17 Fish abundance from surveys conducted in March 2022.

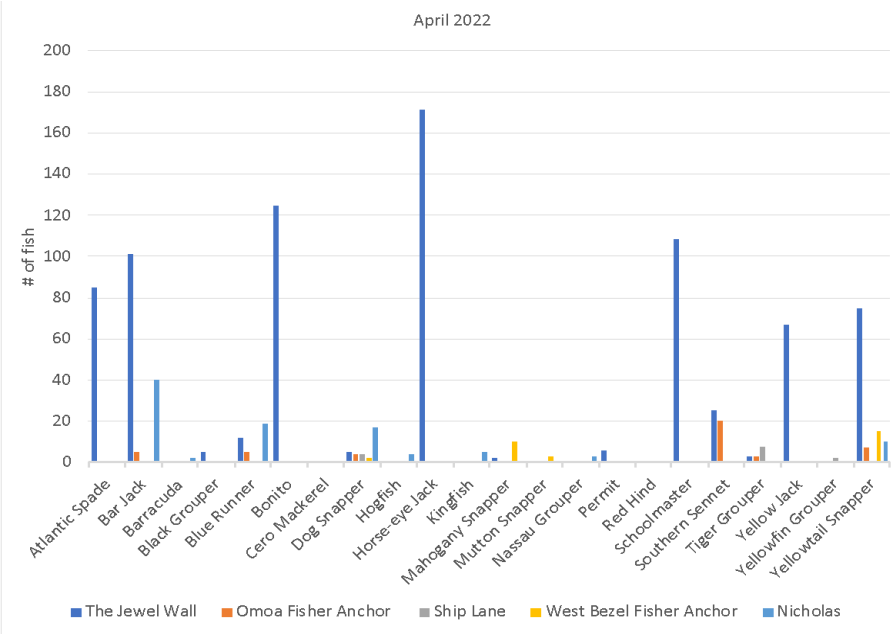


Figure 18 Fish abundance from surveys conducted in April 2022.

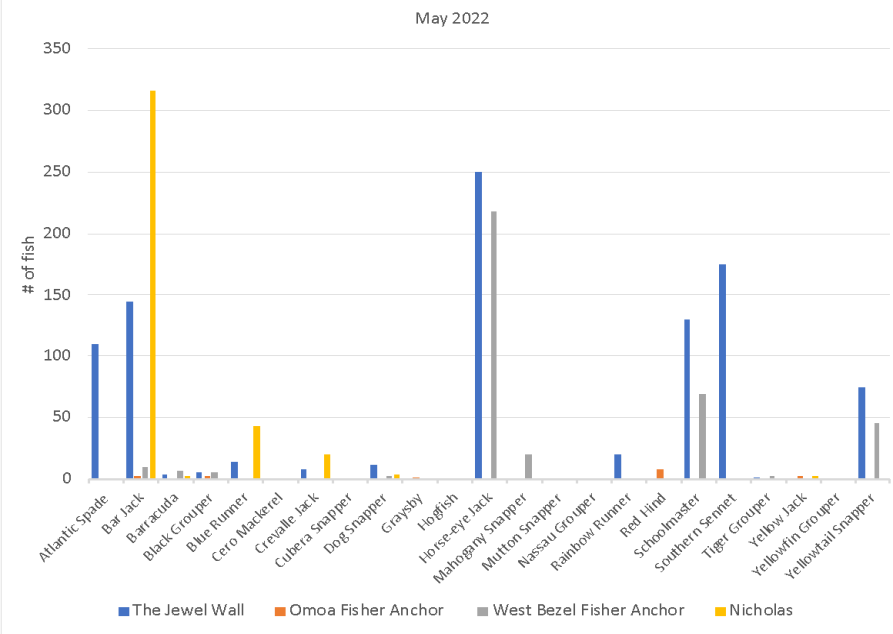
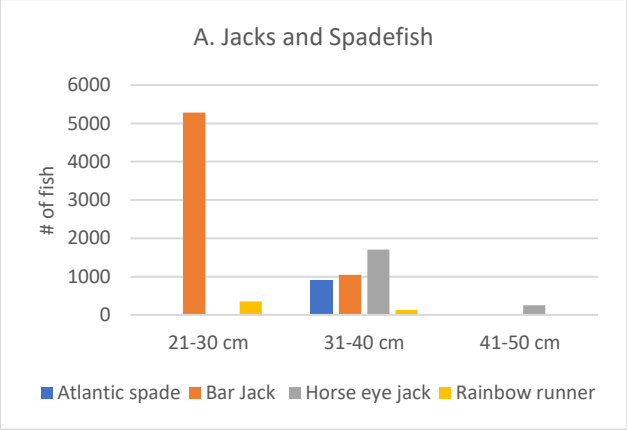


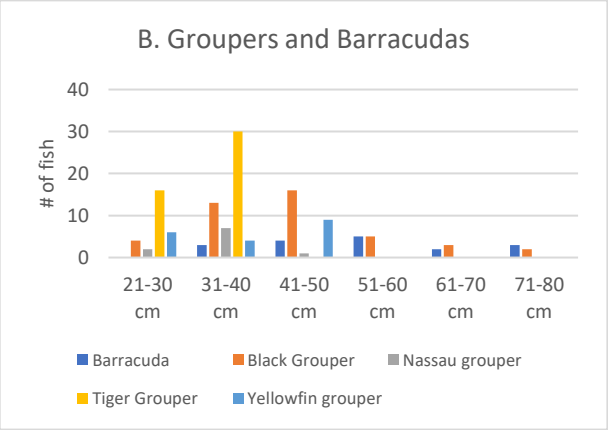
Figure 19 Fish abundance from surveys conducted in May 2022.

FISH SIZE

The fish size estimates were organized as size frequency distribution graphs to show the quantities of fish per species according to size classes. Size estimates are presented cumulatively by year, according to the following main groups: jacks, other pelagics, groupers, snappers and grunts.

In 2020, jacks and spadefish belonged mostly to size classes: 21-30 and 31-40 cm (Figure 20a). Groupers and barracudas spanned mostly across 31-60 cm (Figure 20b). Snappers were mostly between 21-40 cm (Figure 20c) and grunts were within 31-40 cm (Figure 20d).





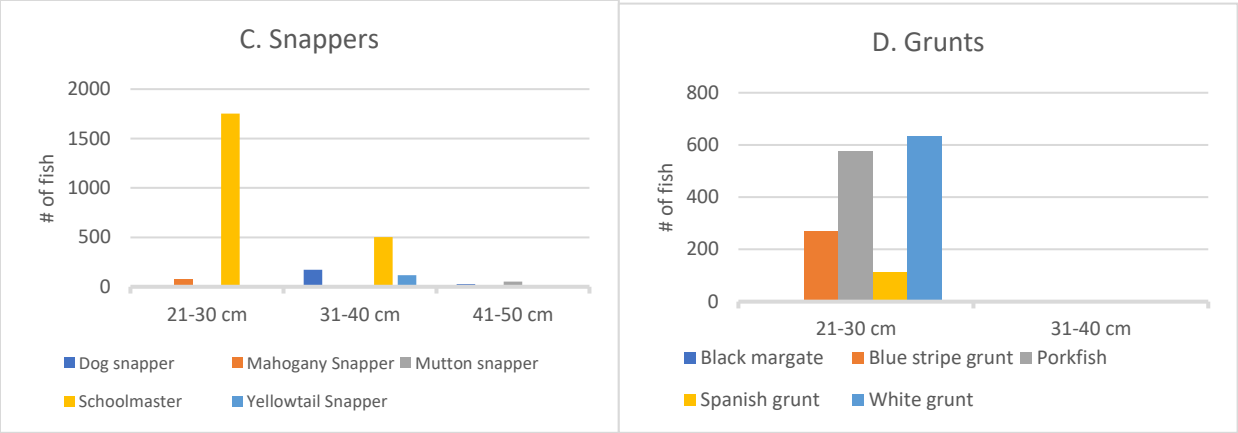
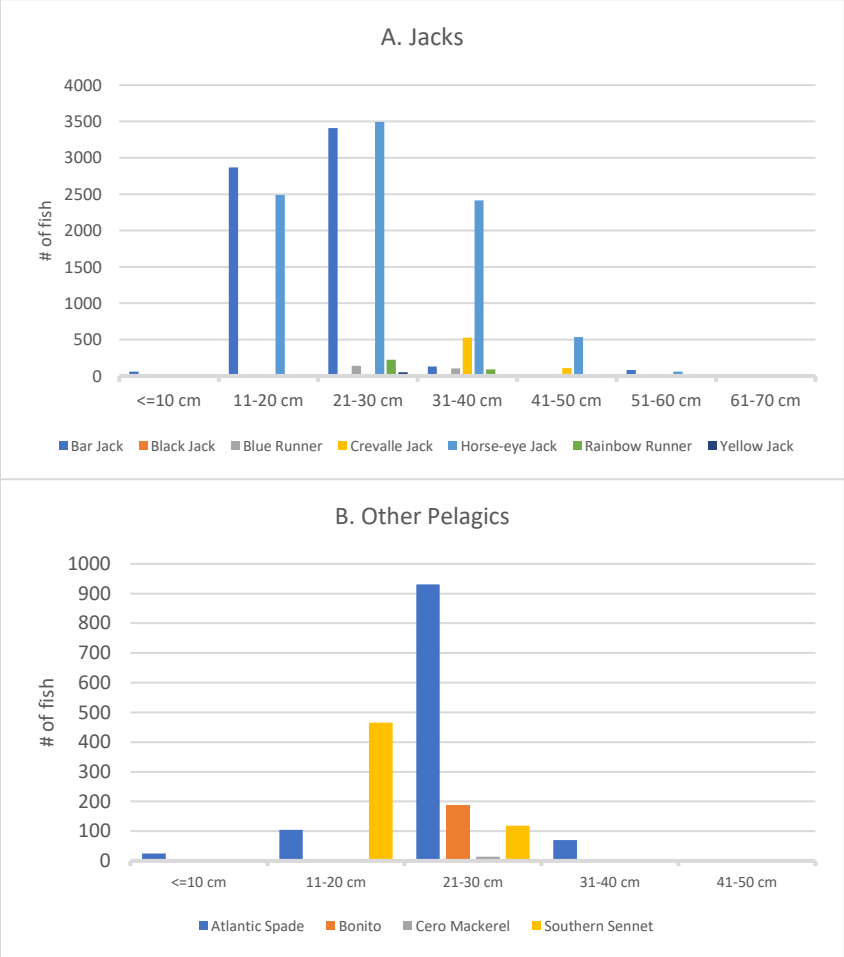


Figure 20 a-d Fish size estimates from all sites surveyed in 2020.

In 2021, the size of the observed fish species varied greatly. The majority of jacks were between 11-40 cm (Figure 21a). Other pelagics were mainly between 11-30 cm (Figure 21b). On the other hand, most of the groupers were between 21-50 cm (Figure 21c) and majority of snappers and grunts were between 11-40 cm, with a moderately sized aggregation of dog snappers between 41-50 cm (Figure 21d).



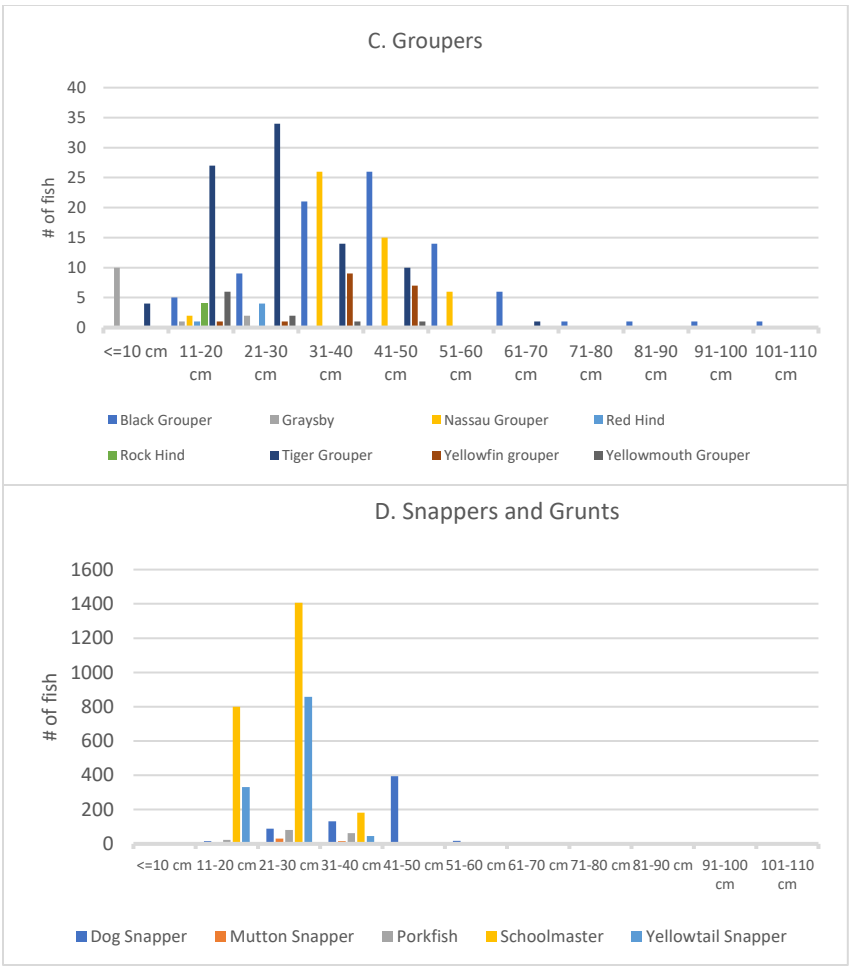
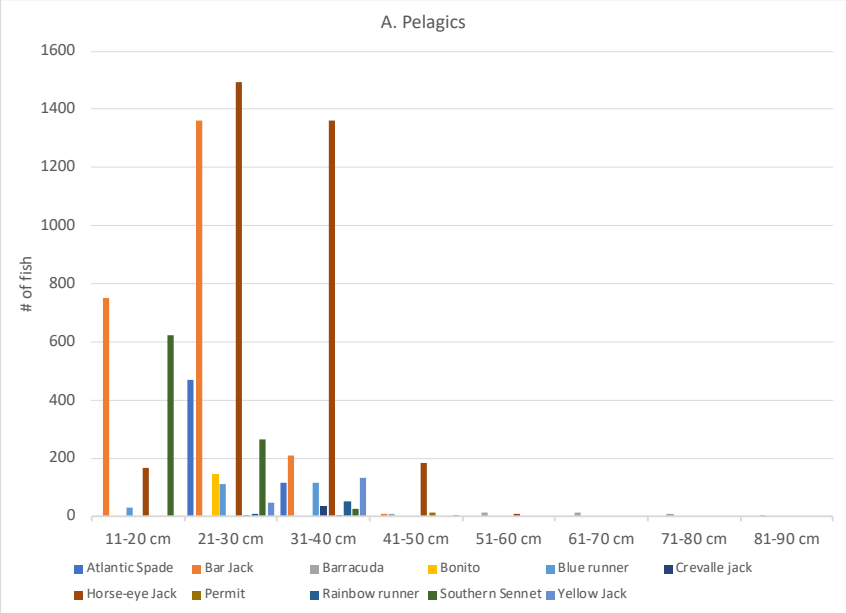
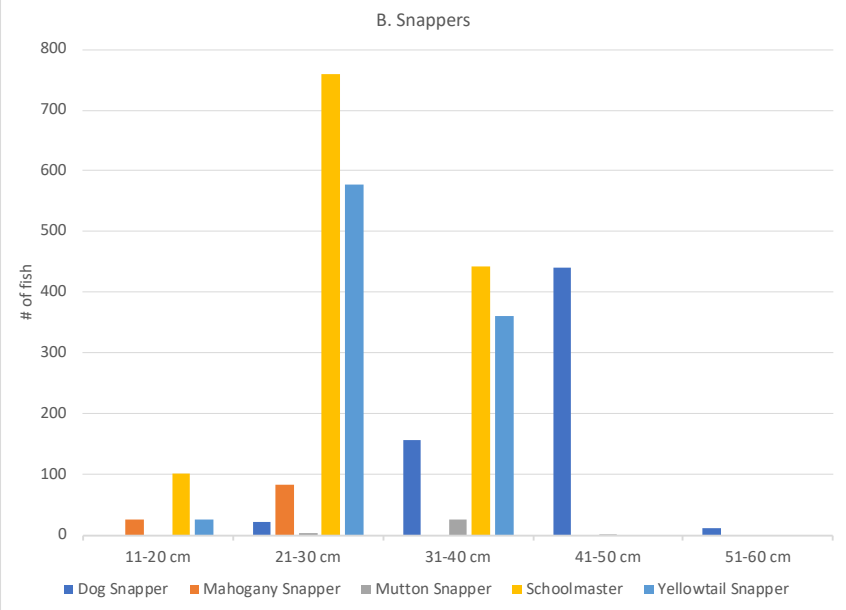


Figure 21 a-d Fish size estimates from all sites surveyed in 2021.

In 2022, the size of pelagic species was mostly between 11-40 cm (Figure 22a). The most abundant size classes were 21-30 cm and 31-40 cm, with bar jacks and horse eye jacks dominating. For snappers, they were mostly between 21-50 cm (Figure 22b), with the most abundant size classes being 21-30 and 31-40 cm from schoolmaster and yellowtail snappers respectively. Groupers were mostly between 31-60 cm (Figure 22c). The most abundant size classes were 31-40 and 41-50 cm from Nassau and black groupers respectively.


A. Pelagics
# of fish
1600
1400
1200
1000
800
600
400
200
0
11-20 cm
21-30 cm
31-40 cm
41-50 cm
51-60 cm
61-70 cm
71-80 cm
81-90 cm
Atlantic Spade
Bar Jack
Barracuda
Bonito
Blue runner
Crevalle jack
Horse-eye Jack
Permit
Rainbow runner
Southern Sennet
Yellow Jack


B. Snappers
# of fish
800
700
600
500
400
300
200
100
0
11-20 cm
21-30 cm
31-40 cm
41-50 cm
51-60 cm
Dog Snapper
Mahogany Snapper
Mutton Snapper
Schoolmaster
Yellowtail Snapper

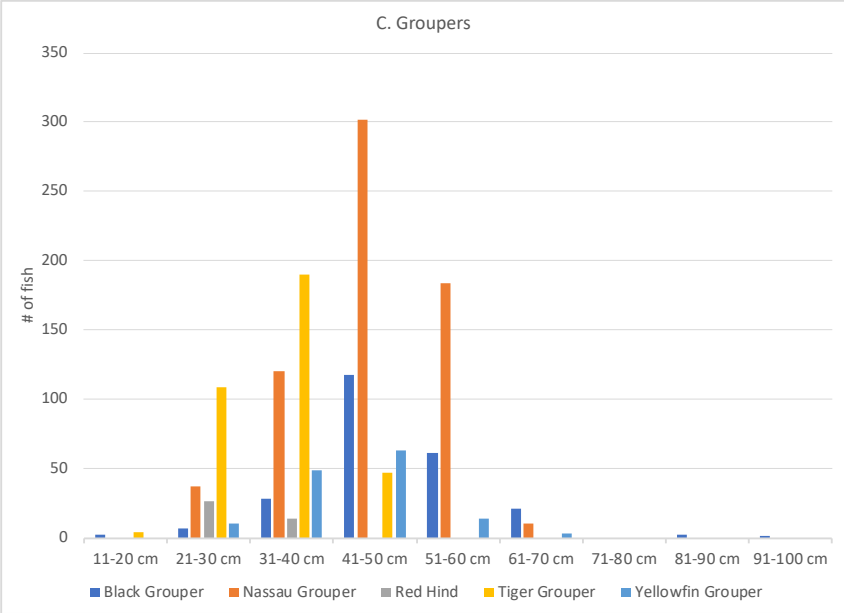


Figure 22 a-c Fish size estimates from all sites surveyed in 2022.

SPAWNING BEHAVIOUR

An important part of monitoring for FSA, besides counting fish sat the sites, is the observation of various fish behavior that may signal spawning. Behaviours include biting, chasing, color changes, courtship, grouping and ascents into the water column, as well as actual signs of reproductive readiness such as gravid females and gametes being released. Several observations were documented in 2020-2022 that indicate reproductive behaviour or readiness, although actual spawning was not documented.

In 2020, there were no behaviours indicative of spawning activity noted, such as biting, color changes, or gravid females. Generally, chasing and grouping activities were observed over the days after the full moon that were surveyed (Table 4a) and correlated with low numbers of fish. Although there was an aggregation of 200 tiger groupers, no reproductive behaviour was noted.

In 2021, there was more direct evidence of reproductive and spawning behavior displayed for several species. In December, tiger grouper and black grouper showed changes in color and bicolor patterns at Nicholas, Grouper Ship Lane and The Jewel Wall. Dog snapper displayed courtship, grouping and aggregating behavior during June at Omoa Fisher Anchor. Several of the jack species displayed grouping and chasing behavior (Table 4b). Similar to 2020, however, there was no direct evidence of spawning, as in the release of gametes and gamete clouds.

In 2022, all the species of groupers that were recorded displayed reproductive and spawning behaviour for January through March. Tiger, Nassau, black and yellowfin grouper showed color change and were gravid. Nassau and tiger groupers were also displaying the bicolor phase. There was also some courtship behavior displayed by black

groupers (Table 4c). Atlantic spades present showed grouping and courtship, and dog snapper showed grouping (Table 4c). The majority of behaviours displays were found amongst the groupers.

Table 4a. Behaviour associated with spawning activities noted during the February, June and July moons in 2020.

February, June, July 2020			
Location	**Date**	**Species**	**Spawning behavior**
North Bezel	11-Feb-2020	Dog snapper	Chasing
North Bezel	11-Feb-2020	Porkfish	Chasing
North Bezel	11-Feb-2020	Schoolmaster	Chasing
North Bezel	11-Feb-2020	White grunt	Chasing
The Jewel Wall	11-Feb-2020	Atlantic spade	Grouping
The Jewel Wall	11-Feb-2020	Black Grouper	Chasing
The Jewel Wall	11-Feb-2020	Dog snapper	Chasing
The Jewel Wall	11-Feb-2020	Schoolmaster	Chasing
The Jewel Wall	11-Feb-2020	Yellow Jack	Grouping
The Jewel Wall	12-Feb-2020	Atlantic spade	Schooling
The Jewel Wall	12-Feb-2020	Schoolmaster	Schooling
The Jewel Wall	8-Jun-2020	Schoolmaster	Chasing
West Bezel	10-Jun-2020	Dog snapper	Chasing
West Bezel Fisher Marker	13-Jun-2020	Dog snapper	Grouping
West Bezel Fisher Marker	13-Jun-2020	Horse eye jack	Grouping
West Bezel Fisher Marker	13-Jun-2020	Schoolmaster	Grouping
West Bezel Fisher Marker	7-Jul-2020	Atlantic spade	Chasing

Table 4b. Behaviour associated with spawning activities noted during the February to June and December moons in 2021.

February to June, and December 2021			
Location	**Date**	**Species**	**Spawning behavior**
Grouper Ship Lane	23-Dec-2021	Tiger Grouper	bicolor
Nicholas	26-Dec-2021	Tiger Grouper	color change
Omoa Fisher Anchor	2-Jun-2021	Dog Snapper	grouping
Omoa Fisher Anchor	26-Jun-2021	Dog Snapper	courtship/grouping
Rise and Fall	31-May-2021	Dog Snapper	aggregating/ grouping
The Jewel Wall	27-Apr-2021	Atlantic spade	Grouping, chasing, spawning
The Jewel Wall	27-Apr-2021	Bar Jack	Grouping, chasing
The Jewel Wall	27-Apr-2021	Bonito	Grouping
The Jewel Wall	27-Apr-2021	Horse-eye jack	Grouping, chasing
The Jewel Wall	28-Apr-2021	Atlantic spade	Grouping, chasing
The Jewel Wall	28-Apr-2021	Bar Jack	Grouping
The Jewel Wall	28-Apr-2021	Crevalle Jack	Grouping
The Jewel Wall	28-Apr-2021	Horse-eye jack	Grouping, chasing
The Jewel Wall	29-May-2021	Atlantic spade	courtship
The Jewel Wall	30-May-2021	Bar Jack	grouping
The Jewel Wall	31-May-2021	Horse-eye Jack	grouping
The Jewel Wall	27-Jun-2021	Horse-eye Jack	grouping
The Jewel Wall	28-Jun-2021	Horse-eye Jack	grouping
The Jewel Wall	23-Dec-2021	Black Grouper	color change
The Jewel Wall	25-Dec-2021	Bar Jack	grouping
The Jewel Wall	25-Dec-2021	Black Grouper	color change
The Jewel Wall	25-Dec-2021	Horse-eye Jack	grouping
The Jewel Wall	26-Dec-2021	Bar Jack	grouping
The Jewel Wall	26-Dec-2021	Horse-eye Jack	grouping
The Jewel Wall	26-Dec-2021	Tiger Grouper	color change
West Bezel Fisher Marker	26-Jun-2021	Horse-eye Jack	grouping

Table 4c. Behaviour associated with spawning activities noted during the January to May moons in 2022.

February to January 2022			
Location	**Date**	**Species**	**Spawning behaviour**
Exploration 1	25-Jan-2022	Tiger Grouper	Bicolor
Nicholas	28-Jan-2022	Black Grouper	color change
Nicholas	28-Jan-2022	Nassau Grouper	Gravid/ Color change
Nicholas	28-Jan-2022	Tiger Grouper	Gravid/ Color Change
Nicholas	17-Feb-2022	Black Grouper	color change/gravid
Nicholas	17-Feb-2022	Nassau Grouper	color change/gravid
Nicholas	17-Feb-2022	Tiger Grouper	color change/gravid
Nicholas	17-Feb-2022	Yellowfin Grouper	color change
Nicholas	18-Feb-22	Black Grouper	color change/ gravid
Nicholas	18-Feb-22	Nassau Grouper	color change/ gravid
Nicholas	18-Feb-22	Tiger Grouper	color change/ gravid
Nicholas	18-Feb-22	Yellowfin Grouper	color change/ gravid
Nicholas	19-Feb-22	Black Grouper	color change/ gravid
Nicholas	19-Feb-22	Dog Snapper	grouping
Nicholas	19-Feb-22	Nassau Grouper	color change/ gravid
Nicholas	19-Feb-22	Tiger Grouper	color change/ gravid
Nicholas	19-Feb-22	Yellowfin Grouper	color change/ gravid
Nicholas	20-Feb-22	Nassau Grouper	color change/ gravid
Nicholas	20-Feb-22	Tiger Grouper	color change/ gravid
Nicholas	20-Feb-22	Yellowfin Grouper	gravid
Nicholas	21-Feb-22	Black Grouper	color change/ gravid
Nicholas	21-Feb-22	Nassau Grouper	color change/ gravid
Nicholas	21-Feb-22	Tiger Grouper	color change/ gravid
Nicholas	21-Feb-22	Yellowfin Grouper	color change/ gravid
Nicholas	22-Feb-22	Black Grouper	courtship/ color change
Nicholas	22-Feb-22	Nassau Grouper	color change/ gravid
Nicholas	22-Feb-22	Tiger Grouper	color change/ gravid
Nicholas	22-Feb-22	Yellowfin Grouper	color change/ gravid
Nicholas	22-Mar-2022	Black Grouper	Color Change
Nicholas	22-Mar-2022	Nassau Grouper	Bicolor/ Gravid
Nicholas	22-Mar-2022	Tiger Grouper	Color Change/ Bicolor
Nicholas	22-Mar-2022	Yellowfin grouper	Gravid
Nicholas	24-Mar-2022	Black Grouper	color change
Nicholas	24-Mar-2022	Nassau Grouper	bicolor/color change/ gravid
Nicholas	24-Mar-2022	Tiger Grouper	bicolor/ color change/ gravid
Omoa Fisher Anchor	22-Mar-2022	Tiger Grouper	gravid/color change/bicolor
Omoa Fisher Anchor	24-Mar-2022	Tiger Grouper	bicolor/ color change/ gravid
Ship Lane	26-Jan-2022	Tiger Grouper	bicolor/ gravid
The Jewel Wall	23-Jan-2022	Atlantic Spade	grouping
The Jewel Wall	23-Jan-2022	Tiger Grouper	color change
The Jewel Wall	25-Jan-2022	Tiger Grouper	Bicolor
The Jewel Wall	26-Jan-2022	Atlantic Spade	courtship
The Jewel Wall	26-Jan-2022	Tiger Grouper	Bicolor
The Jewel Wall	27-Jan-2022	Black Grouper	courtship
The Jewel Wall	20-Mar-2022	Tiger Grouper	Bicolor
The Jewel Wall	21-May-2022	Tiger Grouper	bicolor
West Bezel Fisher Marker	19-May-2022	Black Grouper	Gravid

DISCUSSION

Fish spawning aggregations occur predictably in space and time for a range of reef fish (Salas, 2001; Claro and Lindeman, 2003; Graham and Castellanos, 2005; Erisman et al., 2018). These aggregations of fish are usually the main method of reproduction for these species and are critical for ensuring replenishment of the fish populations. Based on these characteristics, FSAs are fairly easy to identify and monitor over time as long as fishing, logistical or other confounding factors don't affect locating and accessing the sites. Effective FSA monitoring and management must ensure that enough data on the site and the moon phase is available to identify the peak aggregating and spawning period,

for the most efficient means of assessing the status of the aggregations. This requires that for every site, dives should occur at least twice a day over several consecutive days to observe peaking and waning of aggregating fish.

For the surveys completed in the Cayman Crown, the majority were exploratory surveys to describe and identify potential FSAs. Once aggregating behavior was noted, or reliable anecdotal reports of aggregations obtained, repeat visits were made to several of these sites. In total, three sites were fairly well surveyed over the course of the three years: The Jewel Wall, West Bezel Fisher Marker and Omoa Fisher Anchor, with The Jewel Wall receiving the most of the monitoring effort. As a result, the majority of the aggregating counts were attributed to The Jewel Wall. Nevertheless, while surveys occurred on average over 2-4 days at a particular site, the surveys were not always on consecutive days. Accurate and effective FSA monitoring should occur over consecutive days for at least a 3-6 day period around the predicted peak days. The available literature can provide a moderately good guide to selecting these days, especially for areas within the Mesoamerican Reef near to the site.

The major groups of species observed at the various sites were jacks, groupers and snappers. The peak spawning period for jacks varies based on the individual species but is generally from February to October (SCRFA database, 2022). For groupers, it is during the period December to March with different peaks within this block based on the species, for example, Nassau grouper is from January to February. Snapper reproduction occurs between April to June, with some species such as the dog snapper having an extended season from July to January. Given this information, evidence of FSAs was observed and confirmed, despite no actual spawning recorded.

Based on the sightings of multiple species in aggregations at a few of the sites, it is most likely that these sites are multi-species spawning aggregation sites. In particular three sites were identified as FSA sites: The Jewel Wall, West Bezel Fisher Marker and Omoa Fisher Anchor, based on the fish abundance data recorded with hundreds to thousands of fish, and over more than one season. The Jewel Wall in particular seems to be an active FSA for jacks: bar jack, crevalle and horse eye, based on the high abundance of these fish and the different behaviours associated with spawning that were observed.

A few other sites, such as Grouper Ship Lane and West Bezel, may potentially be FSAs but require further monitoring to more conclusively confirm this. The other sites only displayed a minimal abundance of fish. While fish size was estimated on the dive, the results do not seem entirely accurate for quite a few species since the majority of fish seen were in smaller size classes between 11-20 and 21-30 cm, in particular the snappers, groupers and larger jacks. Sexually mature fish that would be aggregating are usually larger than these sizes and fish size would be distributed more abundantly in the higher size classes. Therefore, more accurate methods for estimating size should be considered such as catch data or preferably laser sizing, especially since the Cayman Crown is a no-take area where fishing is not allowed.

Given the remote location of the Cayman Crown, over 50 km from the mainland and over 10 km from the nearest caye, accessibility is an issue when it comes to monitoring of

the site and time of day. Likewise, other factors, including weather, safety and general logistics, can affect how and when these sites are monitored. The completion of a full round of monitoring, in terms of multiple dives a day and multiple days consecutively, is a challenge that needs to be addressed for future monitoring trips. Also, a proper characterization of each site is required. There was no data on this and no available information from the literature that describes the Cayman Crown Reef in depth.

CONCLUSION AND RECOMMENDATIONS

SUMMARY FINDINGS

In summary, based on surveys at twelve sites within the Cayman Crown Reef, three sites were identified as Fish Spawning Aggregation sites: The Jewel Wall, West Bezel Fisher Marker and Omoa Fisher Marker. These sites support multi-species aggregations of mostly jacks and snappers with some groupers. Jacks were most abundant, in the hundreds to thousands; snappers were in the hundreds; and groupers were the least abundant, occurring in tens to hundreds. Species of commercial importance recorded with moderate aggregations during the spawning season and displaying color changes and gravid appearance included: black, Nassau and tiger groupers. Species of commercial importance recorded in large schools engaged in chasing behavior and some courtship, included: bar, horse-eye and crevalle jacks. Several large pelagic species were observed either singly or a few, including blue marlin, bonito, wahoo and king mackerel. A whale shark was also observed at The Jewel Wall. Fish size varied with a majority of fish, of all species, falling within a size range of 21-50 cm, with some of the groupers, snappers and pelagics up to 80 cm in size. Very few fish were recorded above 100 cm, only barracudas, and a few large groupers and snappers.

RECOMMENDATIONS FOR IMPROVED DATA

Several limitations were identified in the data collection that need to be addressed to improve data accuracy and data quality for future monitoring.

1. Monitoring efforts must be strategic and focus on target species, once the FSA has been established. In the case of The Jewel Wall, West Bezel Fisher Marker and Omoa Fisher Anchor, if multiple survey teams are available, then all sites should be monitored during the months of January to July for 3-6 DAFM to better define and confirm spawning activity. There should be at least a team of two persons but a team of 3-4 persons is the ideal size for FSA surveys. If teams are limited, then one of these sites must be selected for each month and surveyed for the 3-6 consecutive days to clearly define aggregating and spawning behavior. Given the data trend from 2020-2022, The Jewel Wall is the most strategic site to focus on if resources are limited.

2. Further monitoring of Grouper Ship Lane and West Bezel may prove valuable to confirm whether these are FSA sites, since they were not comprehensively monitored but showed some signs of aggregations.
3. Confirmed FSAs must be fully characterized to describe the site, bearing, features, depth, area, habitat, etc. in order to ensure that the same site is visited year after year.
4. More accurate methods of size estimation should be implemented, such as the use of laser sizing that has been recommended by the Belize SPAG Working Group, and which is very accurate and easy to use to obtain size measurements.
5. Target species must be selected for monitoring surveys rather than general counts of every fish seen, whether aggregating or not. The recommendation from the Belize SPAG Working Group has been to focus on snappers and groupers, but the presence of aggregations of several species of jacks, makes this group a worthwhile addition. Attention and focus on the dive can then be spent more effectively on species of management importance.
6. It is recommended that TIDE obtains training in site characterization, use of laser sizing and size estimates, through a SPAG training course. Coordination with the Belize SPAG Working Group and regional partners involved in FSA management, such as COBI, should also be explored for training and capacity building.
7. Effective data management is crucial to ensure data is properly stored, catalogued, formatted and entered accurately, for easy analysis and access. TIDE needs to build its data management capacity and systems to manage monitoring data.
8. Continuous biological monitoring should be complemented with oceanographic monitoring and technologies such as acoustic methods (Fulton et al., 2020), to obtain more accurate verification of spawning.

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APPENDICES

Appendix 1 Max counts of fish species observed in 2020 at FSA sites

Max Counts - February 2020		
Species	**North Bezel**	**The Jewel Wall**
Atlantic spade	0	50
Black Grouper	0	1
Dog snapper	20	30
Mutton snapper	0	41
Nassau grouper	0	40
Porkfish	80	26
Schoolmaster	50	50
Tiger Grouper	0	200
White grunt	100	42
Yellowtail Snapper	10	0

Max Counts - June 2020				
Species	**The Jewel Wall**	**West Bezel**	**West Bezel Fisher Marker**	**Corona AGRRA**
Atlantic spade	100	12	150	0
Bar Jack	400	60	250	100
Barracuda	8	4	0	0
Black Grouper	4	4	6	0
Black margate	0	1	0	0
Blue Stripe	51	44	0	0
Dog snapper	14	5	28	1
Horse eye jack	0	0	350	0
Mahogany snapper	0	26	0	0
Mutton snapper	0	11	0	2
Nassau grouper	1	1	3	0
Permit	0	5	0	0
Porkfish	30	80	0	0
Rainbow Runner	0	0	0	50
Schoolmaster	250	5	250	0
Spanish grunt	25	15	0	0
Tiger Grouper	3	2	8	0
White grunt	0	32	0	0
Yellowfin grouper	2	2	4	0
Yellowtail Snapper	0	6	0	0

Max Counts - July 2020				
Species	**The Jewel Wall**	**North Bezel**	**Omoa Fisher Anchor**	**West Bezel Fisher Marker**
Atlantic spade	100	0	0	100
Bar Jack	2000	50	15	1750
Barracuda	3	0	0	0
Black Grouper	5	2	1	2
Black margate	0	2	0	0
Blue Stripe	0	50	50	0
Dog snapper	10	15	5	5
Horse eye jack	300	0	0	800
Mahogany snapper	0	12	20	0
Mutton snapper	0	2	2	0
Porkfish	0	125	45	0
Rainbow Runner	125	0	0	200
Schoolmaster	400	150	50	100
Spanish grunt	0	30	30	0
Tiger Grouper	2	3	3	0
White grunt	0	200	50	0
Yellowfin grouper	2	2	2	0
Yellowtail Snapper	0	0	30	0

Appendix 2 Max counts of fish species observed in 2021 at FSA sites

Max Counts February 2021			
Species	**The Jewel Wall**	**West Bezel Fisher Marker**	**Omoa Fisher Anchor**
Atlantic Spade	40	38	0
Bar Jack	435	350	60
Barracuda	1	1	1
Black Grouper	5	2	0
Blue Runner	20	38	0
Bluestriped grunt	0	3	0
Crevalle Jack	290	30	0
Dog Snapper	11	15	0
Horse-eye Jack	201	40	0
Mutton Snapper	0	1	3
Nassau Grouper	1	0	0
Pork Fish	20	0	0
Red Hind	0	0	1
Schoolmaster	105	26	0
Tiger Grouper	2	6	0
Yellowfin Grouper	3	2	0
Yellowmouth Grouper	1	0	0
Yellowtail Snapper	0	10	0

Max Counts March 2021				
Species	**The Jewel Wall**	**West Bezel Fisher Marker**	**Exploration 1**	**Ship Lane**
Atlantic Spade	48	0	0	0
Bar Jack	300	92	0	0
Barracuda	3	0	0	0
Black Grouper	0	3	0	2
Bluestriped grunt	1	0	0	0
Dog Snapper	6	3	1	8
Horse-eye Jack	1000	200	0	0
Mutton Snapper	0	0	0	1
Nassau Grouper	0	1	1	0
Pork Fish	8	0	2	60
Schoolmaster	68	28	1	50
Tiger Grouper	1	2	2	4
White Grunt	1	0	0	0
Yellowtail Snapper	93	20	0	35

Max Counts April 2021			
Species	The Jewel Wall	Exploration 2	Exploration 3
Atlantic Spade	85	0	0
Bar Jack	300	2	5
Barracuda	2	1	0
Black Grouper	5	2	1
Black Margate	1	0	0
Blue Runner	60	0	0
Bonito	150	0	0
Cero Mackerel	1	0	0
Coney	4	0	0
Crevalle Jack	60	0	0
Dog Snapper	5	1	2
Horse-eye Jack	500	0	0
Pork Fish	0	3	0
Rainbow Runner	6	0	0
Red Hind	0	0	1
Schoolmaster	95	6	4
Tiger Grouper	2	2	3
Yellowfin Grouper	1	0	0
Yellowtail Snapper	18	5	20

Max Counts May 2021				
Species	The Jewel Wall	Omoa Fisher Anchor	Exploration 3	Rise and Fall
Atlantic Spade	150	0	0	0
Bar Jack	500	2	17	13
Barracuda	6	0	1	0
Black Grouper	0	1	0	0
Blue Runner	0	2	0	4
Bonito	25	0	0	0
Cero Mackerel	2	0	0	0
Crevalle Jack	120	0	0	0
Dog Snapper	12	80	1	254
Grasby	0	4	0	1
Horse-eye Jack	1245	0	0	60
Mutton Snapper	25	1	0	0
Nassau Grouper	1	1	1	0
Rainbow Runner	75	0	0	0
Rock Hind	0	2	0	0
Schoolmaster	145	18	23	80
Southern Sennet	0	165	45	0
Tiger Grouper	1	4	1	9
Wahoo	6	0	0	0
Yellow Jack	4	50	0	0
Yellowmouth Grouper	1	0	0	0
Yellowtail Snapper	65	35	12	14

Max Counts June 2021			
Species	The Jewel Wall	Omoa Fisher Anchor	West Bezel Fisher Marker
Atlantic Spade	100	0	0
Bar Jack	210	53	90
Barracuda	11	0	3
Black Grouper	7	1	3
Black Jack	20	0	0
Blue Runner	20	0	4
Cero Mackerel	6	1	0
Crevalle Jack	12	0	10
Dog Snapper	16	30	9
Grasby	2	1	0
Greater Amber Jack	1	0	1
Horse-eye Jack	425	125	230
Mutton Snapper	1	1	0
Nassau Grouper	2	1	0
Permit	0	0	1
Rainbow Runner	150	18	4
Red Hind	0	1	0
Schoolmaster	225	2	80
Southern Sennet	100	0	0
Tiger Grouper	4	3	4
Wahoo	1	0	0
Yellow Jack	3	0	0
Yellowmouth Grouper	4	0	0
Yellowtail Snapper	75	5	120

Max Counts December 2021					
Species	The Jewel Wall	Omoa Fisher Anchor	West Bezel Fisher Marker	Grouper Ship Lane	Nicholas
Atlantic Spade	90	0	25	0	0
Bar Jack	350	200	300	104	0
Barracuda	13	0	1	5	1
Black Grouper	5	0	4	1	0
Black Margate	0	1	0	0	0
Blue Runner	30	0	45	0	12
Bonito	0	10	0	0	0
Cero Mackerel	1	0	0	0	1
Cubera Snapper	1	0	0	0	0
Dog Snapper	19	3	6	3	29
Grasby	0	0	0	2	0
Horse-eye Jack	350	0	270	0	14
Mutton Snapper	0	0	1	6	1
Nassau Grouper	0	0	1	0	36
Permit	0	0	0	0	2
Pork Fish	0	0	0	19	0
Rainbow Runner	10	0	0	0	0
Red Grouper	0	0	1	0	0
Red Hind	0	0	0	1	0
Schoolmaster	65	0	40	6	0
Southern Sennet	200	0	0	34	0
Tiger Grouper	2	0	3	3	2
Wahoo	3	0	0	0	0
Yellow Jack	8	0	0	0	0
Yellowfin Grouper	2	0	1	2	6
Yellowtail Snapper	74	0	35	30	68

Appendix 3 Max counts of fish species observed in 2022 at FSA sites

Max Counts January 2022					
Species	**The Jewel Wall**	**Ship Lane**	**Exploration 1**	**West Bezel**	**Nicholas**
Atlantic Spade	55	0	0	0	0
Bar Jack	300	0	0	146	0
Barracuda	4	1	1	0	0
Black Grouper	3	2	1	0	10
Cero Mackerel	1	0	0	0	0
Dog Snapper	5	0	1	0	0
Graysby	1	1	0	0	0
Horse-eye Jack	150	0	0	0	0
Mahogany Snapper	0	38	0	15	0
Mutton Snapper	2	2	2	2	0
Nassau Grouper	0	0	0	0	155
Red Hind	0	11	0	0	0
Schoolmaster	65	49	0	0	0
Southern Sennet	175	0	150	0	0
Tiger Grouper	2	6	3	1	44
Yellow Jack	7	0	0	1	0
Yellowfin Grouper	1	0	0	0	4
Yellowtail Snapper	49	34	1	11	28

Max Counts February 2022	
Species	**Nicholas**
Bar Jack	35
Barracuda	2
Black Grouper	28
Blue Runner	29
Cero Mackerel	1
Crevalle Jack	4
Cubera Snapper	1
Dog Snapper	42
Hogfish	3
Horse-eye Jack	22
Mutton Snapper	1
Nassau Grouper	77
Permit	7
Rainbow Runner	20
Red Hind	5
Tiger Grouper	35
Yellow Jack	14
Yellowfin Grouper	15
Yellowtail Snapper	20

Max Counts March 2022					
Species	**The Jewel Wall**	**Omoa Fisher Anchor**	**Exploration 1**	**West Bezel Fisher Anchor**	**Nicholas**
Atlantic Spade	70	0	0	0	2
Bar Jack	76	3	0	0	43
Barracuda	3	0	0	1	0
Black Grouper	9	4	0	3	35
Blue Runner	50	0	0	0	30
Dog Snapper	7	29	0	1	170
Horse-eye Jack	400	0	0	0	2
Mahogany Snapper	0	0	0	25	0
Mutton Snapper	0	2	0	3	1
Nassau Grouper	0	0	0	0	30
Permit	1	0	0	0	3
Red Hind	0	4	0	0	0
Schoolmaster	95	55	0	0	0
Southern Sennet	75	0	0	0	0
Tiger Grouper	2	37	1	5	21
Yellow Jack	19	0	0	0	0
Yellowfin Grouper	1	3	0	0	34
Yellowtail Snapper	107	0	0	45	0

	Max Counts April 2022				
Species	**The Jewel Wall**	**Omoa Fisher Anchor**	**Ship Lane**	**West Bezel Fisher Anchor**	**Nicholas**
Atlantic Spade	85	0	0	0	1
Bar Jack	101	5	0	0	40
Barracuda	1	0	0	1	2
Black Grouper	5	1	1	0	0
Blue Runner	12	5	0	0	19
Bonito	125	0	0	0	0
Cero Mackerel	0	0	0	0	1
Dog Snapper	5	4	4	2	17
Hogfish	0	0	0	0	4
Horse-eye Jack	172	0	0	0	0
Kingfish	0	0	0	0	5
Mahogany Snapper	2	0	0	10	0
Mutton Snapper	0	0	1	3	1
Nassau Grouper	0	0	0	0	3
Permit	6	0	0	0	1
Red Hind	0	0	0	1	0
Schoolmaster	109	0	0	0	0
Southern Sennet	25	20	0	0	0
Tiger Grouper	3	3	8	0	1
Yellow Jack	67	0	0	0	0
Yellowfin Grouper	1	0	2	0	1
Yellowtail Snapper	75	7	0	15	10

	Max Counts May 2022			
Species	**The Jewel Wall**	**Omoa Fisher Anchor**	**West Bezel Fisher Anchor**	**Nicholas**
Atlantic Spade	110	0	0	1
Bar Jack	145	3	10	316
Barracuda	4	0	7	3
Black Grouper	6	3	6	1
Blue Runner	14	0	0	43
Cero Mackerel	0	0	0	1
Crevalle Jack	8	0	0	20
Cubera Snapper	1	0	1	0
Dog Snapper	12	0	3	4
Graysby	0	2	0	0
Hogfish	0	0	0	1
Horse-eye Jack	250	0	218	0
Mahogany Snapper	0	0	20	0
Mutton Snapper	1	0	0	0
Nassau Grouper	0	1	0	0
Rainbow Runner	20	0	0	0
Red Hind	0	8	0	0
Schoolmaster	130	0	70	0
Southern Sennet	175	0	0	0
Tiger Grouper	2	0	3	0
Yellow Jack	1	3	0	3
Yellowfin Grouper	1	0	0	0
Yellowtail Snapper	75	0	45	1