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CARIBBEAN MARINE BIODIVERSITY PROGRAM

Cooperative Agreement No. AID-OAA-A14-00064

Reef biophysical conditions across CMBP seascapes (2019)

Submitted March 15, 2019

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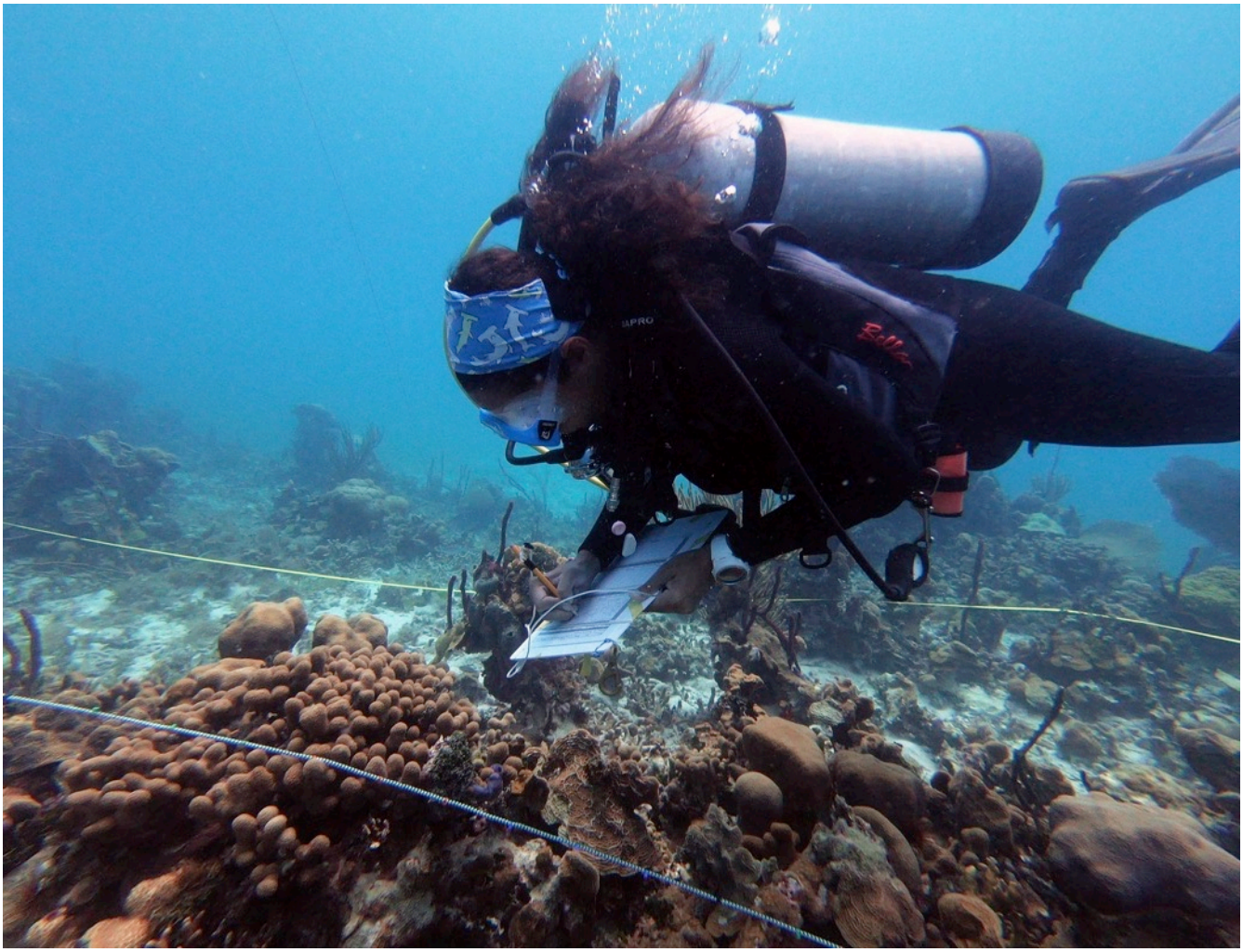

A benthic surveyor conducts a transect on a shoal reef lobe in the Bluefields Bay Special Fishery Conservation Area; a fish survey transect tape can be seen in the background. L. Meggs, 2018

ON THE COVER: Brown and white spotted moray and plate coral, macroalgae, turf algae and peyssonnelids, K. Marks, 2015

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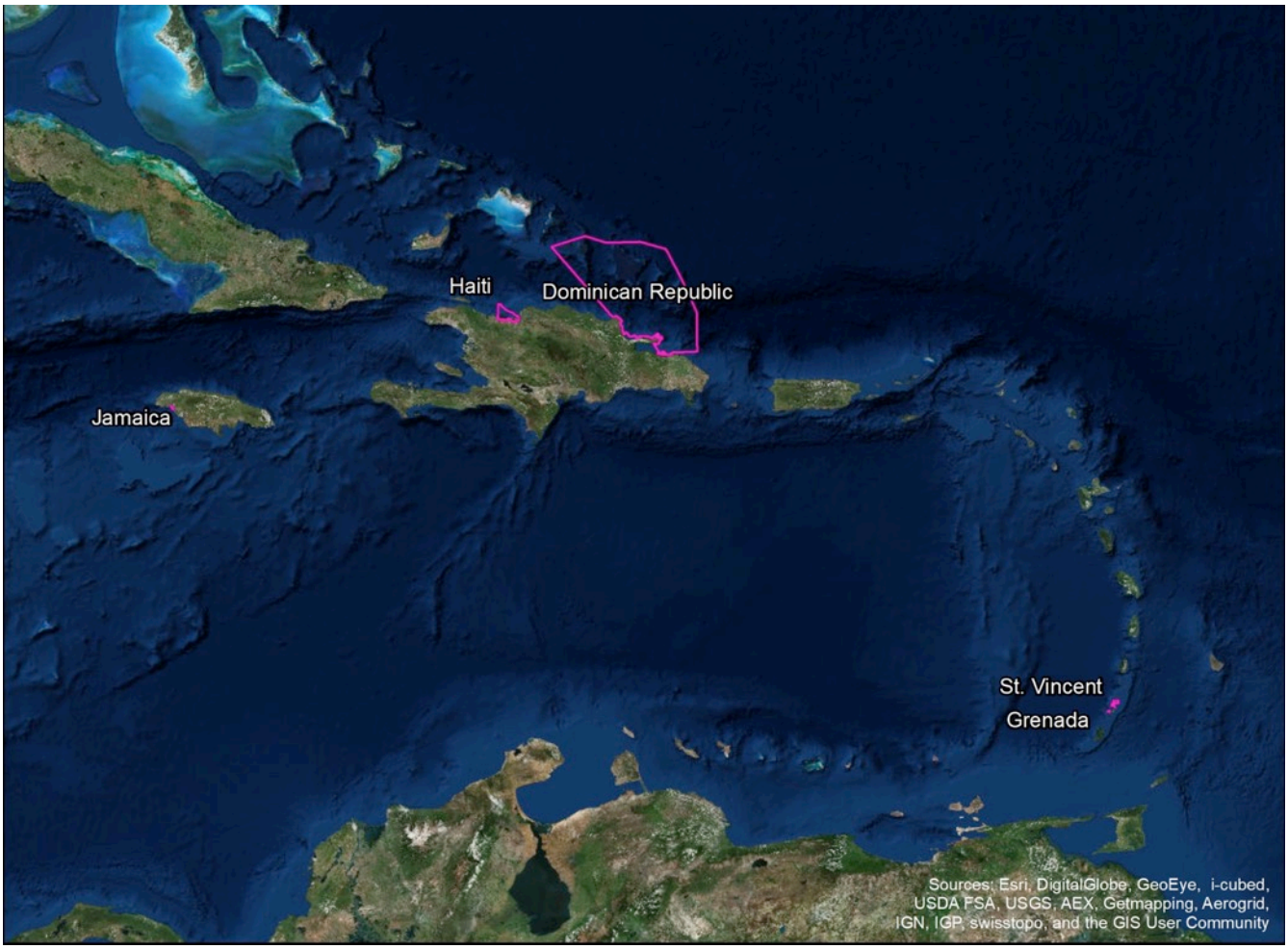
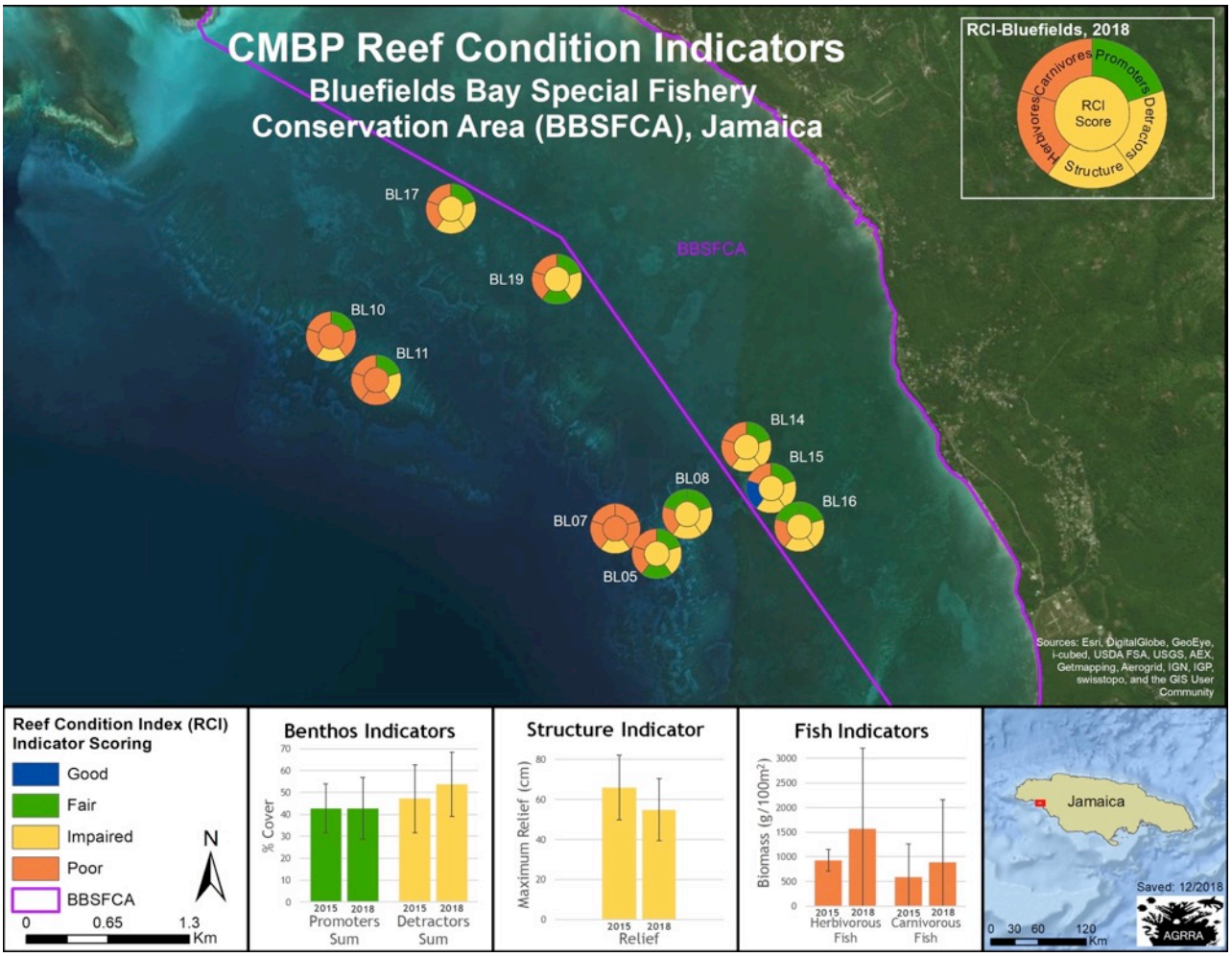


ON THE COVER: Brown and white spotted moray and plate coral, macroalgae, turf algae and peyssonnelids, K. Marks, 2015

Jamaica:
CMBP Coral Reef Index Sites and Condition



Corals grow on shoals near the seaward border of the BBSFCA, but most reefs in Bluefields Bay are located in deeper water. The bay is overfished and poaching is a recurring problem even inside the managed BBSFCA, but fish stocks are improving. The scaled cover[1] of reef promoters is relatively high, as are organisms that displace corals.

Five indicators that contribute substantially to reef structure and function are recorded and graded in the CMBP Reef Condition Index (RCI)[1]. The RCI of ten surveyed sites averaged **Impaired** in both 2015 and 2018.

		2015 2018
	Promoters, corals, crustose coralline algae and other organisms that aid reef growth, as cover measured in points along benthic transects in %.	43 ≈ 43 Fair
	Detractors, organisms on hard bottoms that can overgrow or displace corals, as cover measured in points along benthic transects in %.	47 ≈ 54 Impaired
	Structure, a proxy for the amount of habitat space created by corals, as maximum vertical relief along fish transects in cm.	66 ≈ 55 Impaired
	Herbivores, fish that graze the algae that can overgrow reef corals, as biomass along fish transects in gm/100 m^2.	930 ↑ 1571 Poor
	Carnivores, fish that help balance food webs by eating *Herbivores* and animals that prey on corals, as biomass along fish transects, in gm/100 m^2.	593 ↑ 893 Poor

[1]See Appendix; benthic cover values are scaled to exclude any areas occupied by sand, mud, seagrasses or associated sediment-dwelling algae.

Jamaica: CMBP Coral Reef Index Sites and Condition Indicators

Habitats. Reef corals grow on leeward shoals in fields among seagrass or sand (eight sites) or on low spurs oriented perpendicular to the shore (two sites). Two *subtidal crests* at 5-6 m and two sites at 6-8 m are *outside* the BBSFCA. Three *subtidal crests* at 6-7 m are on its *inside* (BL14-16). One *fore-reef* at 10 m *outside* the BBSFCA has tall (to 3 m) spurs between sand channels (BL07).

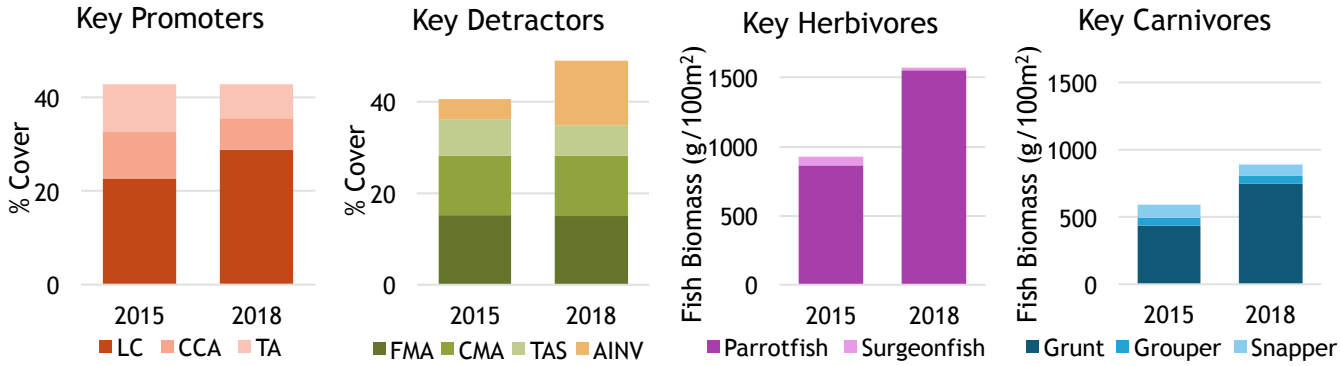
Coral spurs on a shoal ~7m, BL15, YE-2018

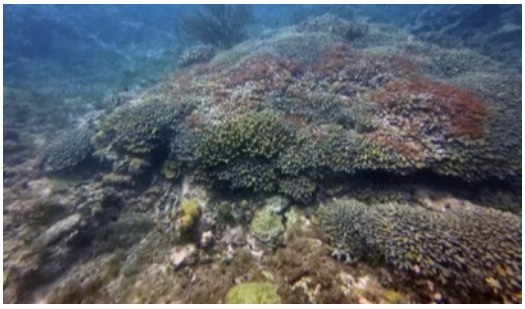
Indicator component changes, 2015* vs. *2018, all surveys.

Promoters Scaled Cover*: Live Corals* (LC), the primary constructors of reefs, increased (from 23 to 28%).

Detractors Scaled Cover: *Aggressive Invertebrates* that kill corals increased, especially *Chondrilla caribensis* (which expanded from 0 to10%).

Fish Biomass: Increases in *Parrotfishes*, a key guild of reef algal feeders (865 to 1550 gm/100m^2) and *Grunts*, small reef invertebrate predators (436 to 748 gm/100m^2).





Colonies of finger corals in a coral field ~7 m, BL19, YE-2018

Benthos Scaled Cover averages on shoal crests in 2018.

Promoters: *Live Corals* were higher at three sites *inside* the BBSFCA than at six sites on the *outside (*40 *vs*. 27%).

Detractors*: Fleshy Macroalgae* (FMA*)*, an important competitor with corals, were lower *inside* the BBSFCA (7 *vs.* 18%), but *Chondrilla caribensis* was higher (17 *vs.* 9%).

Benthos Cover averages by depth in 2018, all sites.

Promoters decreased slightly with increasing depth, whereas *Detractors*, especially mats of the green calcareous macroalga, *Halimeda*, increased as depth increased.

Chondrilla overgrowing a brain coral, ~ 7 m, BL11, YE-2018

Rock hind and star coral inside BBSCFA, JS-2015

Macroalgal Index (MAI, macroalgal cover x height) in 2018, an* inverse proxy *for herbivory. MAI averaged high (120) overall, but was lower at sites *inside* the BBSFCA than *outside* (67 *vs*. 142).

Fish Biomass averages. *Herbivores* and *Carnivores* are very variable within and among sites, with no evident locational effects.

Abundant *Diadema* prevent macroalgae and other algal groups from displacing corals and crustose coralline algae, ~9 m, BL08. JS-2015.

Herbivorous Sea Urchin density averages.

Diadema antillarum: Rare (<0.5/m^2) to fairly common (2-4/m^2 at BL8, BL11, both years). *Other Urchins:* common (6-8/m^2) to very common (19/m^2) at BL17 in 2018.

In 2018, the density of *Diadema*, a key herbivore, was positively correlated with the cover of the reef promoters while the density of the other urchin species was negatively correlated with the cover of fleshy macroalgae.

Main Conclusions

Although parrotfish and grunts are increasing in size and biomass, fishery stocks remain low in Bluefields Bay. Future increases are probably limited by the relatively small amount of coral reef habitat that's currently under active protection within the BBSFCA.

Corals are relatively abundant. A few are diseased, but as of Fall 2018 there are no signs of the new stony coral tissue loss disease (SCTLD) that's been devastating the north coast reefs.

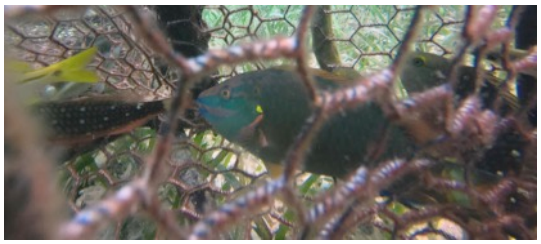
Coral recruits (< 4 cm. diameter) average ~15/m^2, affording good potential for continued reef growth, especially if the reef surfaces currently occupied by their detractors (macroalgae, turf algal sediment mats, cyanobacteria and aggressive invertebrates) can be minimized by increases in herbivory and water quality.

In 2015, the key herbivore, *Diadema antillarum,* was present in such high densities at some locations on two shoal crest sites (BL08, BL11) that crustose coralline algae and the underlying reef rock were being whittled away by their bioeroding feeding activities. Transplanting any "excessive" individuals as still remain onto reefs lacking urchins might help prevent the build-up of the macroalgae that are currently outcompeting corals on the deeper reefs outside the BBSFCA.

Sediment and nutrients in runoff and groundwater, especially near the river mouths, may be stimulating the growth of cyanobacteria and algae in Bluefields Bay. Effects, if any, of additional water-borne pollutants (pesticides or other synthetic chemicals, enteric bacteria, viruses, *etc.)* are unknown.

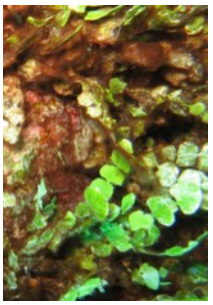
Local improvements in water quality would enhance the ability of the BSFCA reef communities to resist and/or recover from the expected detrimental effects of ongoing climate change.

Illegal fish trap in seagrass inside the BBSCA; its buoy had been suspended below the surface, ~7m, BL16, YE-2018

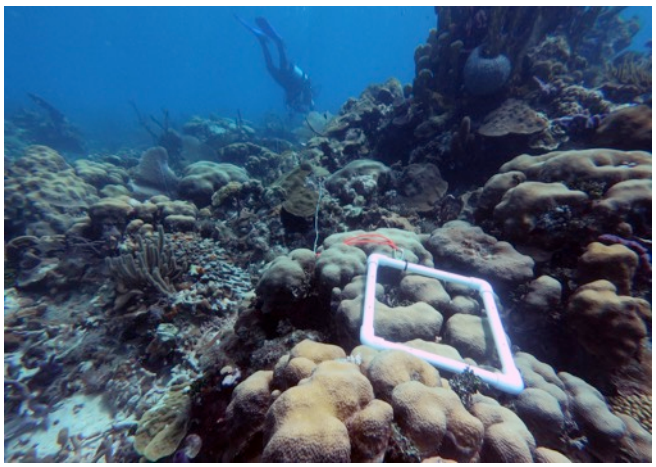


Three stoplight parrotfish and a French grunt in the above illegal fish trap. Stoplights are scarce in AGRRA surveys (~3/100m2) and may avoid humans underwater, YE-2018

A foureye butterflyfish and its tiny feeding scars on a lobed star coral, ~6 m, BL14, YE-2018



Cyanobacteria grow on *Halimeda,* ~10 m, BL07, SV-2015



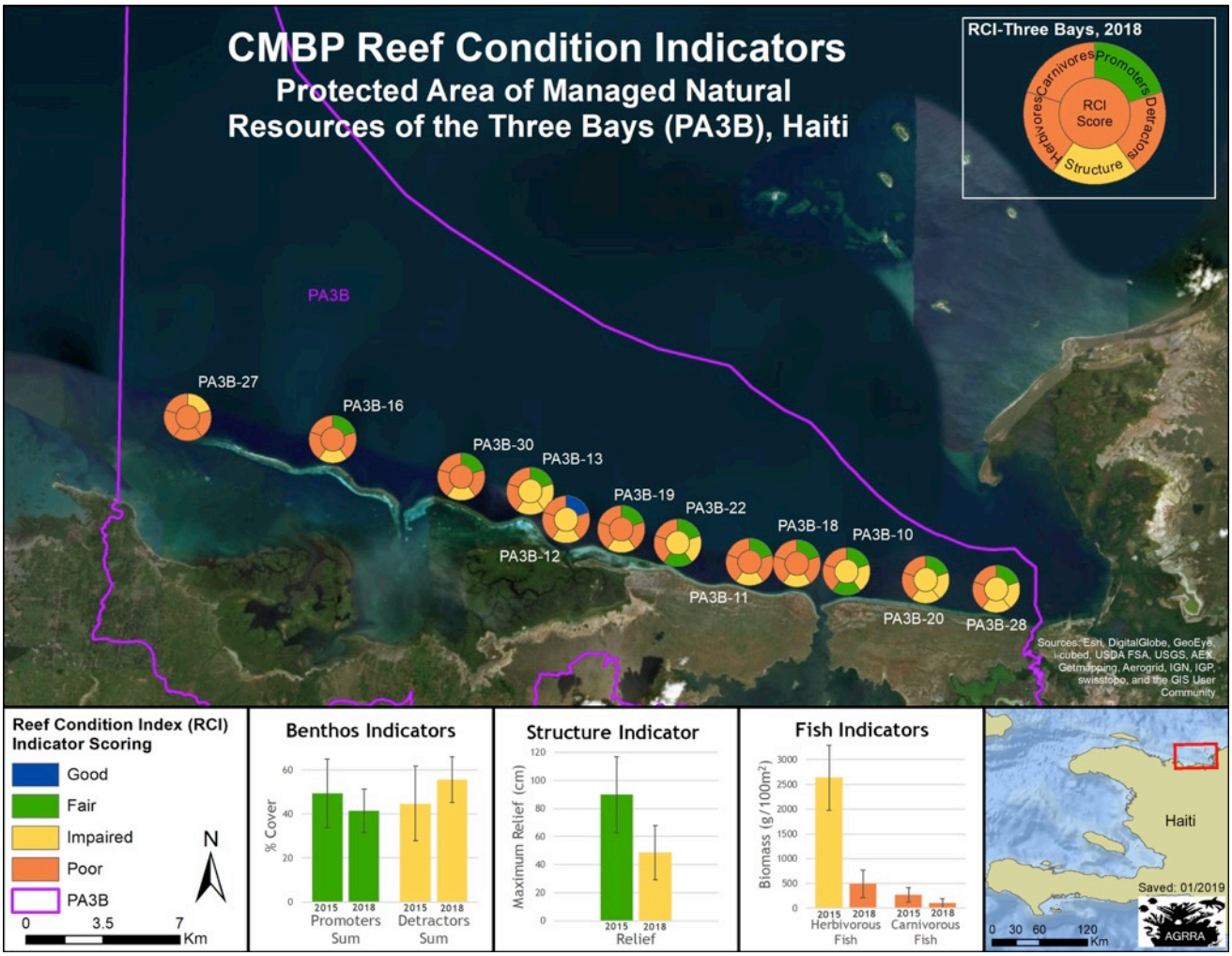
Benthos transect line terminating on a large lobed star coral in a spur reef with high live coral cover outside the BBSCFA, ~6 m, BL15, YE-2018

Surveyor reeling in the fish tape at the end of a transect, ~7 m, BL16, YE-2018

Photos. 2015: SV = S. Voegeli, JS = J. Schulke; 2018: YE = Yardie Environmental Conservationists Ltd.

Haiti:

CMBP Coral Reef Index Sites and Condition



The scaled cover of reef promoters and benthic organisms that displace corals are both relatively high on the PA3B fore reefs. All sites are overfished: herbivorous fishes have significantly declined since 2015 and carnivorous fishes are scarce. Lower relief (structure) in 2018 than in 2015 may be an artifact of overall shallower survey depths (7 vs. 10 m).

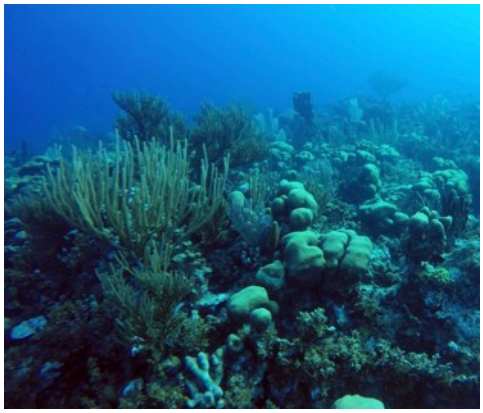
Five indicators that contribute substantially to reef structure and function are recorded and graded in the CMBP Reef Condition Index (RCI)[1]. The RCI of 12 surveyed sites averaged **Impaired** in 2015 and **Poor** in 2018.

		2015 2018
	*Promoters,* corals, crustose coralline algae and other organisms that aid reef growth, as cover measured in points along benthic transects in %.	50 ≈ 42 Fair
	*Detractors,* organisms on hard bottoms that can overgrow or displace corals, as cover measured in points along benthic transects in %.	45 ≈ 56 Impaired
	*Structure,* a proxy for the amount of habitat space created by corals, as maximum vertical relief along fish transects in cm.	90 ↓ 48 2018:Impaired
	*Herbivores*, fish that graze the algae that can overgrow reef corals, as biomass along fish transects in gm/100 m^2.	2635 ↓ 493 2018:Poor
	*Carnivores,* fish that help balance food webs by eating *Herbivores* and animals that prey on corals, as biomass along fish transects, in gm/100 m^2.	270 ↓ 100 Poor

[1]See Appendix; benthic cover values are scaled to exclude any areas occupied by sand, mud, seagrasses or associated sediment-dwelling algae.

Haiti: CMBP Coral Reef Index Sites and Condition Indicators

Habitats. Linear, windward fore reefs *fringe* the eastern PA3B and form a *barrier* off its two western bays. The six fringing sites and adjacent barrier site (PA3B-19) are *coral fields*; four barrier sites have *spur and groove* reefs and the most western site (PA3B-27) is a *hardground* with few corals.



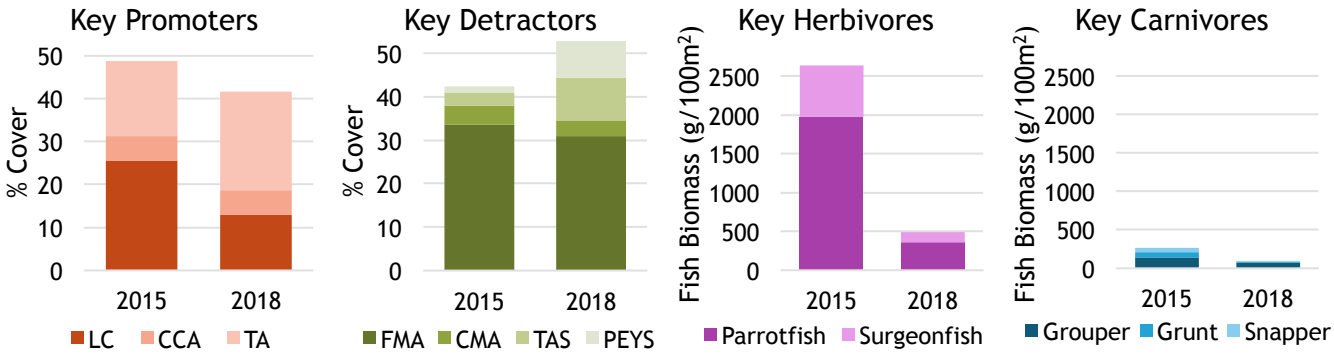
Star corals, bushy octocorals and fleshy macroalgae in a fore-reef coral field, ~6 m, PA3B-18, F-2018

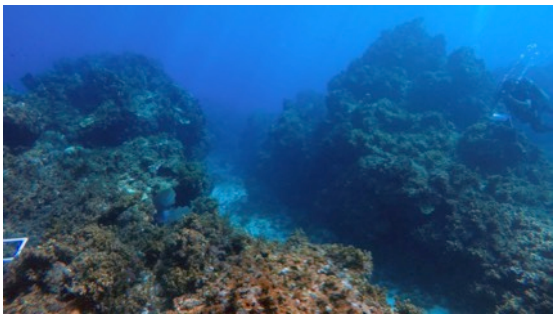
Indicator component changes, 2015* vs. *2018, all surveys.

Promoters Scaled Cover: A large decrease in *Live Corals* (LC, from 26 to 13%) was only partially offset by a slight increase in sparse *Turf Algae* (TA, 18 to 23%), where coral larvae can settle.

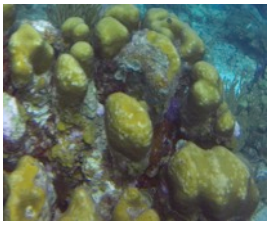
Detractors Scaled Cover: *Turf Algal Sediment* mats (TAS) and *Peyssonnelid* algae (PEY) increased from 3 to 10% and from 2 to 9%, respectively.

Fish Biomass: Decreases were proportionately greatest in *Parrotfishes*, a key guild of reef herbivores (from 1970 to 358 gm/100m^2) and *Grunts*, a guild of small reef invertebrate predators (from 67 to 6 gm/100m^2).





Macroalgae on barrier fore-reef spurs, ~8 m, PA3B-30, F-2018



Star corals *(Orbicella). Left:* large, healthy-looking; *Right:* with numerous threespot damselfish bites ~6 m, PA3B-10, F-2018

Striped hamlet before and after collection, KM-2015

Benthic Scaled Cover averages by location or dates.

Promoters: *Live Corals* were correlated with location, being greater on the six eastern *fringing reef* sites than the six western *barrier reef* sites (32 *vs*. 19 % in 2015; 18 *vs*. 8% in 2018). Sparse *Turf Algae* nearly doubled on the *barrier* sites between 2015 and 2018 (12 to 22%).

Detractors: *Peyssonnelids* and *Fleshy Macroalgae* (FMA) were lower on the *fringing* than the *barrier* sites, and *Turf Algal Sediment* mats were higher on the *fringing* sites (both years).

Macroalgal Index (MAI, macroalgal cover x height) in 2018, an* inverse proxy *for herbivory. MAI averaged high (127); was greater on the *barrier* sites than on the *fringing* (147 *vs*. 108).

Fish Biomass averages by location:

Parrotfish were higher on the *fringing* sites than the *barrier* in 2015 (2452 *vs.* 1459 gm/100m^2), but overlapped in 2018 when key herbivorous and carnivorous fishes were rare at all sites.

Herbivorous Sea Urchin density averages.

Diadema: extremely rare overall (0/m^2 in 2015; 0.1/m^2 in 2018) and only slightly less rare (0.2/m^2) on the *fringing* and *coral field* sites. *Other Urchins*: averaged much higher in the *coral fields* than in the *spurs and grooves* (5.7 *vs.* 0.5/m^2 in 2018).

New species of hamlet found in Ft. Liberté Bay:

The striped hamlet *(Hyploplectus liberte*), discovered and collected in Ft. Liberté Bay during the 2015 surveys by D. Grenda and K. Marks, was formally described by B. Victor and K. Marks in 2018.

Main Conclusions

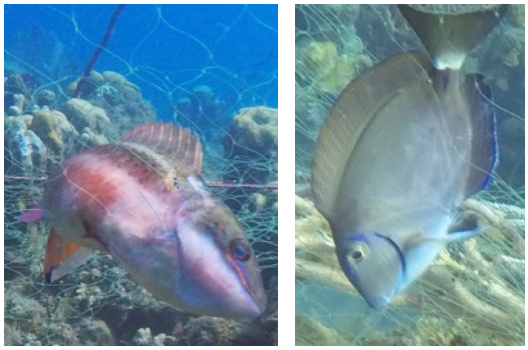
The large decrease in parrotfish biomass between 2015 and 2018 was caused by reductions in both their density and sizes. Although team-specific differences regarding transect depths and fish size discriminations may be contributing factors, fishing pressures have probably increased since 2015, especially along the fringing reef. Herbivores were prominent in a gill net observed at the most easterly survey site (PA3B-28) in 2018.

Coral recruit density was somewhat reduced in 2018 (4 *vs.* 10/m^2 in 2015). A decrease since 2015 of about half of the PA3B's live coral cover, especially on the eastern sites, is troubling; some mortality may have followed the bleaching event seen in fall 2015. Newly dead coral tissues seen in the 2018 photos of massive corals in the eastern, fringing reefs may portend an outbreak of stony coral tissue loss disease, which elsewhere is proving very lethal to important species of reef constructors.

Sargassum and other tall (~4 cm in 2018), fleshy macroalgae are conspicuous at most fore-reef sites, and attest to the scarcity of key herbivores *(Diadema,* parrotfishes and surgeonfishes) on the PA3B. Sediment and nutrients in runoff and groundwater may be stimulating the growth of these smothering algae and some cyanobacteria.

The health of corals and other reef organisms may also be compromised by any synthetic chemicals *(e.g.*, pesticides, herbicides, pharmaceuticals) or pathogens *(e.g.,* enteric bacteria, viruses) as may be present in the ambient seawater.

Local successes at improving habitat and water quality, and in enforcing the new fishing regulations, would enhance the ability of the PA3B reef communities to resist and/or recover from the expected detrimental effects of ongoing climate change.



Herbivores caught in a gill net on the fringing reef.
Left: a terminal phase redband parrotfish;
Right: an ocean surgeonfish ~8 m, PA3B-28, F-2018

Diseased corals. *Left: Orbicella annularis*, ~7 m, PA3B-18;
Right: Diploria labyrinthiformis, ~8m, PA3B-28, F-2018

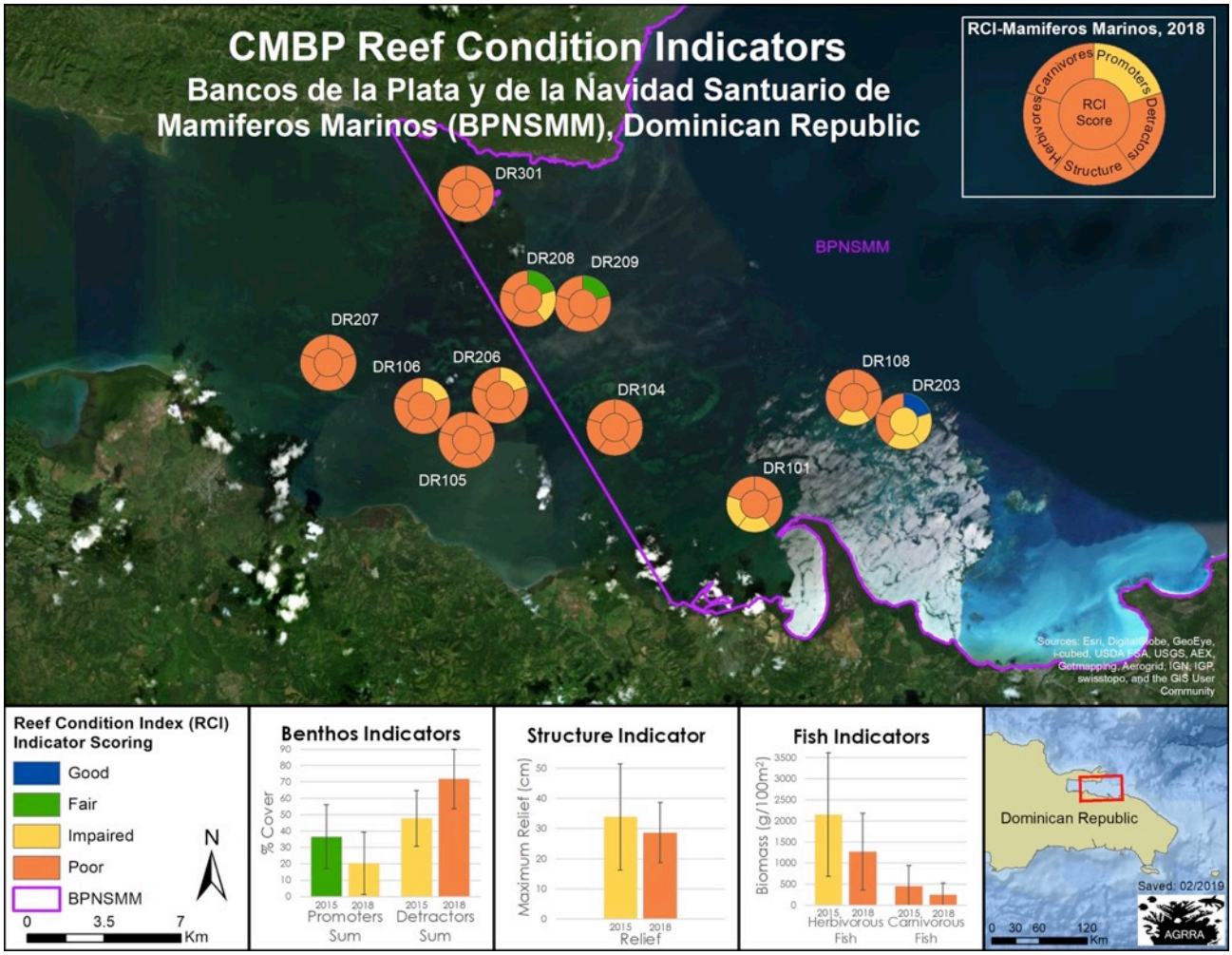
Sargassum and other fleshy macroalgae overgrowing coral spurs and sand channels on the barrier reef, ~5 m, PA3B-19, F-2018

Benthos surveyor on the fringing fore reef, ~5 m, PA3B-11, F-2018

Fish surveyor on the fringing fore reef, ~7 m, PA3B-10, F-2018

Photos: 2015: KM = K. Marks; 2018: F = FUNDEMAR

Dominican Republic (DR):
CMBP Coral Reef Index Sites and Condition



Corals grow in low-relief fields, or are scattered on hardgrounds among sand and mud, on shoals located inside and outside of the BPNSMM in Samaná Bay. The bay is overfished and fish stocks are declining. The scaled cover[1] of reef promoters is also decreasing and organisms that displace corals are increasing.

Five indicators that contribute substantially to reef structure and function are recorded and graded in the CMBP Reef Condition Index (RCI)[1]. The RCI of 11 surveyed sites averaged **Impaired** in 2015 and **Poor** in 2018.

		2015 2018
	Promoters, corals, crustose coralline algae and other organisms that aid reef growth, as cover measured in points along benthic transects in %.	37 ≈ 20 2018:Impaired
	Detractors, organisms on hard bottoms that can overgrow or displace corals, as cover measured in points along benthic transects in %.	48 ↓ 72 2018:Poor
	Structure, a proxy for the amount of habitat space created by corals, as maximum vertical relief along fish transects in cm.	34 ≈ 29 2018:Poor
	Herbivores, fish that graze the algae that can overgrow reef corals, as biomass along fish transects in gm/100 m^2.	2155 ↓ 1275 2018:Poor
	Carnivores, fish that help balance food webs by eating *Herbivores* and animals that prey on corals, as biomass along fish transects, in gm/100 m^2.	452 ↓ 249 Poor

[1]See Appendix; benthic cover values are scaled to exclude any areas occupied by sand, mud, seagrasses or associated sediment-dwelling algae.

DR: CMBP Coral Reef Index Sites and Condition Indicators

Habitats. Corals, mostly small, grow among octocorals and sponges on the flanks and crests of large shoals in Samaná Bay. Fine-grained (sand or muddy-sand) sediments cover about a quarter (22-23%) of the benthos, increasing westward across the bay (significant at p<.01in 2015; p<.05 in 2018).

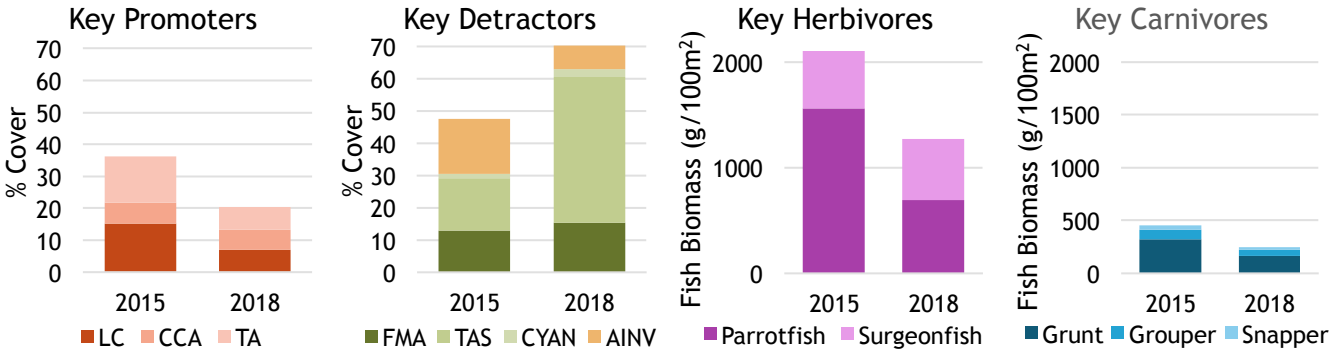
Octocorals and pale corals during a mild bleaching event, in a mid-bay shoal ~8m, DR106, SW-2015

Indicator component changes, 2015* vs. *2018, all surveys.

Promoters Scaled Cover: High site variation; *Live Corals* (LC) decreased overall (from 15 to 7%), as did sparse *Turf Algae* (TA, from 14 to 7%).

Detractors Scaled Cover: Expansion of coral-displacing *Turf Algal Sediment* mats (TAS, from 16 to 45%) more than offset a decline of the *Aggressive Invertebrates* (AINV, from 17 to 6%) that also overgrow corals.

Fish Biomass: Decreases were greatest in *Parrotfishes,* a key guild of reef herbivores (from 1560 to 695 gm/100m^2) and *Grunts*, a guild of small reef invertebrate predators (from 332 to 167 gm/100m^2).



Small boulder corals, crustose coralline algae and some octocorals dominate the benthos at a wave-swept shoal in the mouth of Samaná Bay, 4 m, DR203, F-2018

Benthos Scaled Cover averages by location or dates.

Promoters: Much higher *outside* the BPNSMM in 2015 than in 2018 (37 *vs.* 14%). *Live Corals* were lower at seven sites *inside the BPNSMM* than at four sites on the *outside* in 2015 (11 *vs*. 23%), but similarly low in 2018 (6 vs. 9%).

Detractors: *Turf Algal Sediment* mats, important competitors with corals, were higher on sites *outside* the BPNSMM in 2018 than in 2015 (52 *vs.* 22%), but had also increased on its *inside.*

Macroalgal Index (MAI, macroalgal cover x height), an* inverse proxy *for herbivory. MAI was higher in 2018 than in 2015 (56 vs. 18), and in both years was somewhat higher at sites *inside* the BPNSMM.

Fish Biomass averages. All *Herbivore* and *Carnivore* groups were at least slightly greater *inside the BPNSMM* than *outside* (both years).

Herbivorous Sea Urchin density averages.

Diadema antillarum: uncommon (0.5/m^2 in 2015, 0.8/m^2 in 2018) but somewhat higher densities *inside the BPNSMM* than outside (both years); was positively correlated with cover of *Crustose Coralline Algae* (CCA, both years) and negatively with *Turf Algal Sediment* mats in 2018.

Other Urchins: somewhat more common in 2015 than 2018 (4.0 *vs*. 1.4/m^2); in 2018 was positively correlated with cover of *Crustose Coralline Algae* and negatively with *Turf Algal Sediment* mats.

Diadema on a shoal inside BPNSMM prevent *Turf Algal Sediment* mats from expanding above *Crustose Coralline Algae* and *Turf Algae.* Markers on the transect line at 10-cm internals are used for the point counts of benthic cover, 4m, DR208, F-2018.

Main Conclusions

In addition to its seasonal bans on eels and commercially important molluscs and crustaceans, the DR has prohibited all capture of important reef herbivores (*Diadema,* parrotfishes, surgeonfishes) and of sharks, rays and sea cucumbers from mid 2017-mid 2019. To the extent that the bans are being respected by local fishers, the 2018 surveys would have occurred too soon after their enactment to record any noticeable improvements in herbivorous fish biomass. Moreover, the prohibitions may need to last more than two years to be effective at replenishing any of these fishery stocks.

The decrease in live coral and crustose coralline algal cover is locally attributed to a period of unusually heavy rains in late 2017. Large volumes of sediments entered Samaná Bay, increasing turbidity, reducing light penetration and, presumably, enabling the large expansion of mats formed by sediment-trapping, turf algae that were found in 2018, particularly at the four western sites nearest the rivers and outside the BPNSMM.

The density of coral recruits (< 4 cm. diameter) also decreased between 2015 and 2018 (from ~25 to ~5/m^2). If sustained, and if sediment inflows remain a problem, the coral communities on the shoals are unlikely to be rebuilt after their recent losses.

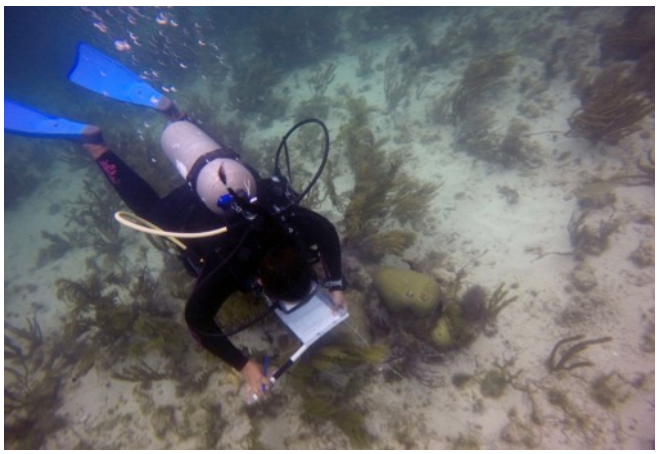
The effects on the benthic organisms of any pollutants (pesticides and other synthetic chemicals, enteric bacteria, viruses, *etc.)* present in runoff and groundwater are unknown. However, there were no obvious signs of excessive nutrient inputs to the bay.

Any additional improvements in local water quality and its reef fish populations would enhance ability of the shoal coral communities in Samaná Bay to resist and/or recover from the expected detrimental effects of ongoing climate change.

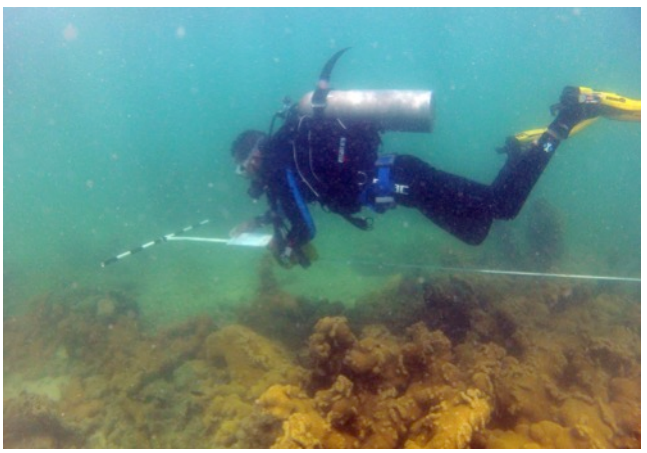
A rare, large clump of healthy looking elkhorn corals on the wave-swept shoal in the mouth of Samaná Bay, 4 m, DR203, F-2018

White encrusting zoanthids grow on dead elkhorn corals in high turbidity near the SE Samaná Bay coast, ~3 m, DR101, F-2018

Small, massive starlet corals grow among octocorals and dead staghorn coral sticks on a mid-bay shoal, ~8 m, DR104, F-2018



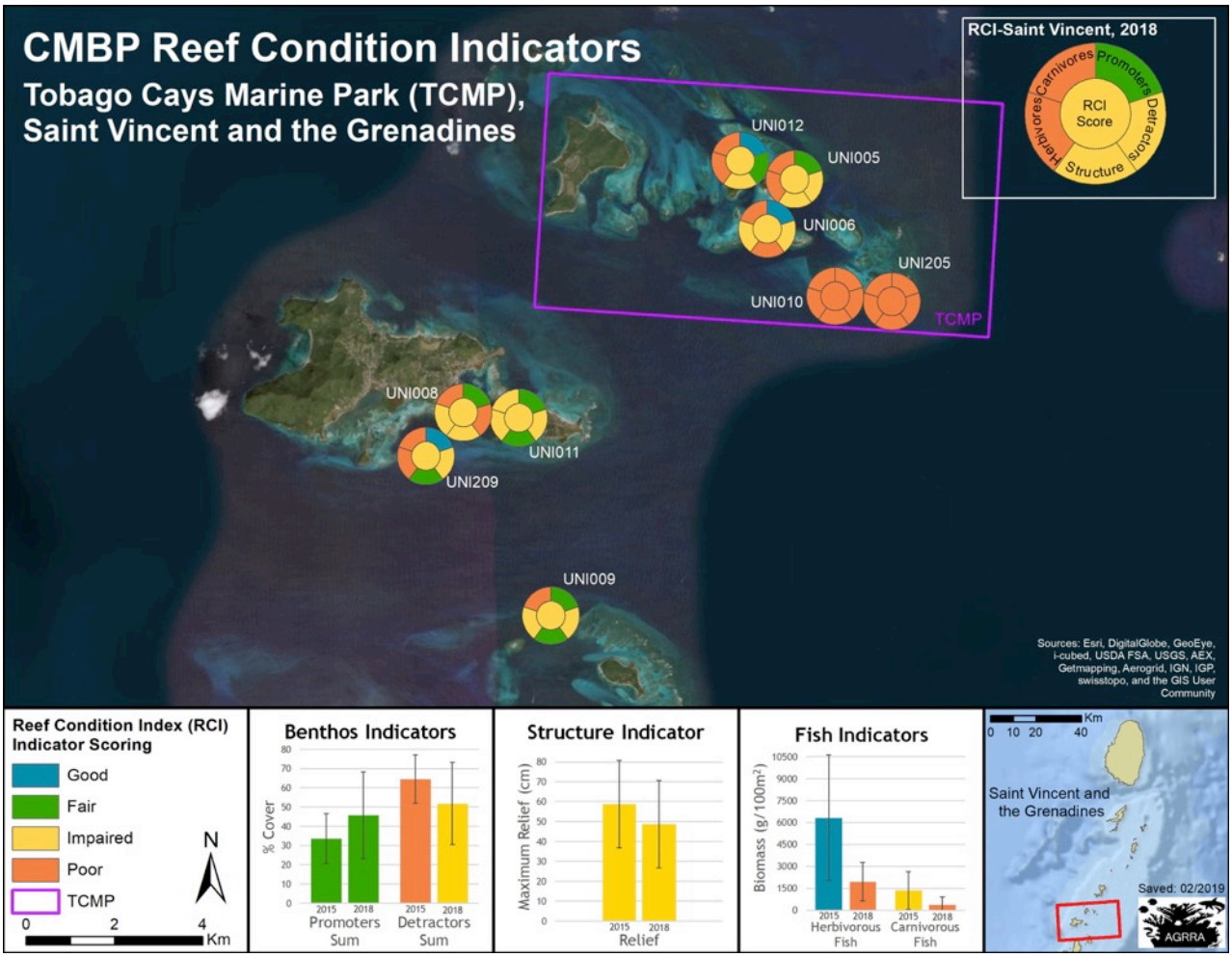
Benthos surveyor conducting a belt transect to record AGRRA motile invertebrates *(Diadema,* other urchins, lambi, *etc.)* ~5 m, DR106, F-2018



Fish surveyor conducting a belt transect in low visibility conditions, over a near-coastal shoal with remaining few live corals, ~ 2 m, DR101, F-2018

Photos. 2015: SW = S. Williams; 2018: FUNDEMAR

St. Vincent and The Grenadines (SVG):
CMBP Coral Reef Index Sites and Condition



Corals grow on barrier and fringing fore reefs in the TCMP and on fringing reefs to its south. Stocks of important herbivorous fishes have decreased since 2015. The scaled cover[1] of benthic organisms that promote reef growth have increased somewhat, while the cover of the benthic organisms that can displace corals may be declining.

Five indicators that contribute substantially to reef structure and function are recorded and graded in the CMBP Reef Condition Index (RCI)[1]. The RCI of nine surveyed sites averaged **Impaired** in both 2015 and 2018.

		2015 2018
	Promoters, corals, crustose coralline algae and other organisms that aid reef growth, as cover measured in points along benthic transects in %.	34 ≈ 46 Fair
	Detractors, organisms on hard bottoms that can overgrow or displace corals, as cover measured in points along benthic transects in %.	65 ↑ 52 2018:Impaired
	Structure, a proxy for the amount of habitat space created by corals, as maximum vertical relief along fish transects in cm.	58 ≈ 48 Impaired
	Herbivores, fish that graze the algae that can overgrow reef corals, as biomass along fish transects in gm/100 m^2.	6325 ↓ 1956 2018:Poor
	Carnivores, fish that help balance food webs by eating *Herbivores* and animals that prey on corals, as biomass along fish transects, in gm/100 m^2.	1340 ↓ 388 2018:Poor

[1]See Appendix; benthic cover values are scaled to exclude any areas occupied by sand, mud, seagrasses or associated sediment-dwelling algae.

SVG: CMBP Coral Reef Index Sites and Condition Indicators

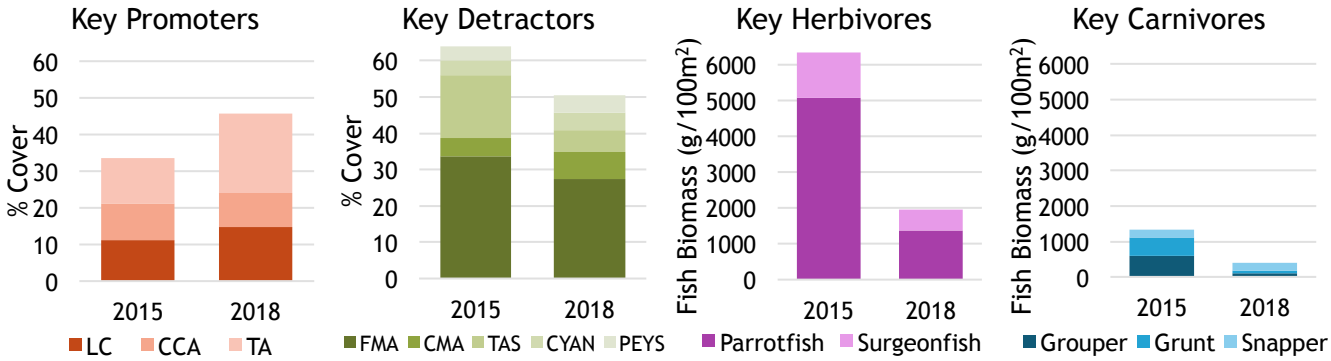
Habitats. The fore reefs on two *windward barrier,* and one *leeward, fringing reef inside* the TCMP have fields of corals. On the fore reefs *outside* the TCMP, coral fields are present at two *leeward* and two *protected windward fringing reefs*. One each *windward inside barrier* and *outside fringing site* has scattered corals on a hardground–as did an *inside barrier* in 2015 that, with higher coral cover, was reclassified as a coral field in 2018.

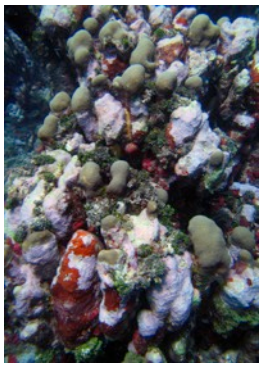
Lobed star and finger corals among macroalgae on dead corals at a leeward fringing reef, 9 m, UNI009, CM-2015

Indicator component changes, 2015 vs. 2018, all surveys. Promoters Scaled Cover: Sparse *Turf Algae* (TA), which provide habitat space for coral larvae to settle, increased from 12 to 22%.

Detractors Scaled Cover: *Fleshy Macroalgae* (FMA) and *Turf Algal Sediment* (TAS) mats declined from 34 to 27% and 17 to 6%, respectively.

Fish Biomass: Decreases were proportionately greatest in *Parrotfishes* (key reef herbivores, from 5072 to 1378 gm/100m^2) *Grunts* (small invertebrate predators, from 515 to 80 gm/100m^2) and *Grouper* (larger predators of invertebrates and fish, from 587 to 100 gm/100m^2).





Crustose coralline algae and peyssonnelids grow on dead lobe star coral skeletons, ~10 m, UNI005, CM-2015

Disesed peyssonnelid that has died where it had overgrown a lobed star coral, ~7 m,UNI009, KM-2015

Benthic Scaled Cover averages by location or dates. Promoters: *Turf Algae* increased between 2015 and 2018, *inside* and *outside* the TCMP. *Live Corals* (LC) *and Crustose Coralline Algae* (CCA) were higher on the slopes than the flat plains (both years).

Detractors: *Turf Algal Sediment* mats decreased between 2015 and 2018, both *inside* and *outside* the TCMP, and were significantly lower on the *slopes* than the *plains* in 2018; *Fleshy Macroalgae* were also lower on the slopes (both years).

Macroalgal Index (MAI, macroalgal cover x height) averages, an* inverse proxy *for herbivory. MAIs were higher, *inside* and *outside* the TCMP in 2018 relative to 2015, and especially high on the flat plains compared to the moderate slopes (154 *vs.* 84) in 2018.

Fish Biomass averages by location or dates. All fish guilds, but especially parrotfishes, were higher on the *inside* of the TCMP in 2015, and lower than on its *outside* in 2018. All guilds were higher on the moderate *slopes* than the flat *plains* in both years, and all were lower in 2018 than in 2015.

Herbivorous Sea Urchin density averages. *Diadema*: Not seen on the *plains* in both years; on most *slopes* very rare (0-0.2/m^2, both years), but 0.4/m^2 at UNI008 in 2018 and 0.8/m^2 at both UNI008 and UNI209 in 2018. *Other Urchins:* not seen or very rare (0-0.2/m^2, both years) except at CAR008, where 0.7/m^2 in 2015.

Red hind swims among *Halimeda* (green calcareous macroalgae) and sand with dead *Halimeda* fragments, 7 m, UNI009, KM-2015

Main Conclusions

Survey team-specific differences with respect to fish size discriminations may have contributed to their decreased biomass estimates in 2018 compared to 2015. However, fishing pressures also appear to have increased since 2015, perhaps in response to increases in demand driven by a significant rise in yacht visitor arrivals. Of particular concern is the decline of the larger stoplights, which comprised 55% of the total parrotfish biomass in 2015 but only 34% in 2018. Levels of patrolling were reduced inside the TCMP due to mechanical problems with their boats in 2017. Full capacity is expected to resume by summer 2019 with new boat engines and increased staff.

Live coral cover had averaged 38% in AGRRA surveys conducted at three fore-reef sites on Horseshoe Reef in 1999. Many corals must have partially or completely died during the severe warming associated with the 2005 mass bleaching event in the eastern Caribbean. Diverse calcareous and soft-bodied algae and a few invertebrates *(e.g.*, sponges), have subsequently grown over the "standing dead" coral skeletons (especially lobed stars, a primary framework builder on these reefs), and are now encroaching on the surviving corals. Nevertheless, live corals have at least maintained their cover, if not increased slightly overall, between 2015 and 2018. Meantime, reasons for the large decline in the density of coral recruits in 2018 (1 *vs.* 20/m^2 in 2015) are not known but, if sustained, would be potentially detrimental to the long-term viability of the TCMP-area reefs.

Chances that the reef communities in and around the TCMP will resist and/or recover from the expected detrimental effects of ongoing climate change could be enhanced by local successes at increasing fishery stocks and, additionally, at improving habitat and water quality near the population centers on Union Island.

Surgeonfish swim over a healthy, clumps of lobed star corals inside TCMP, ~6 m, UNI012, KM-2015

Coral field on a windward, fore-reef plain, TCMP, CM-2015

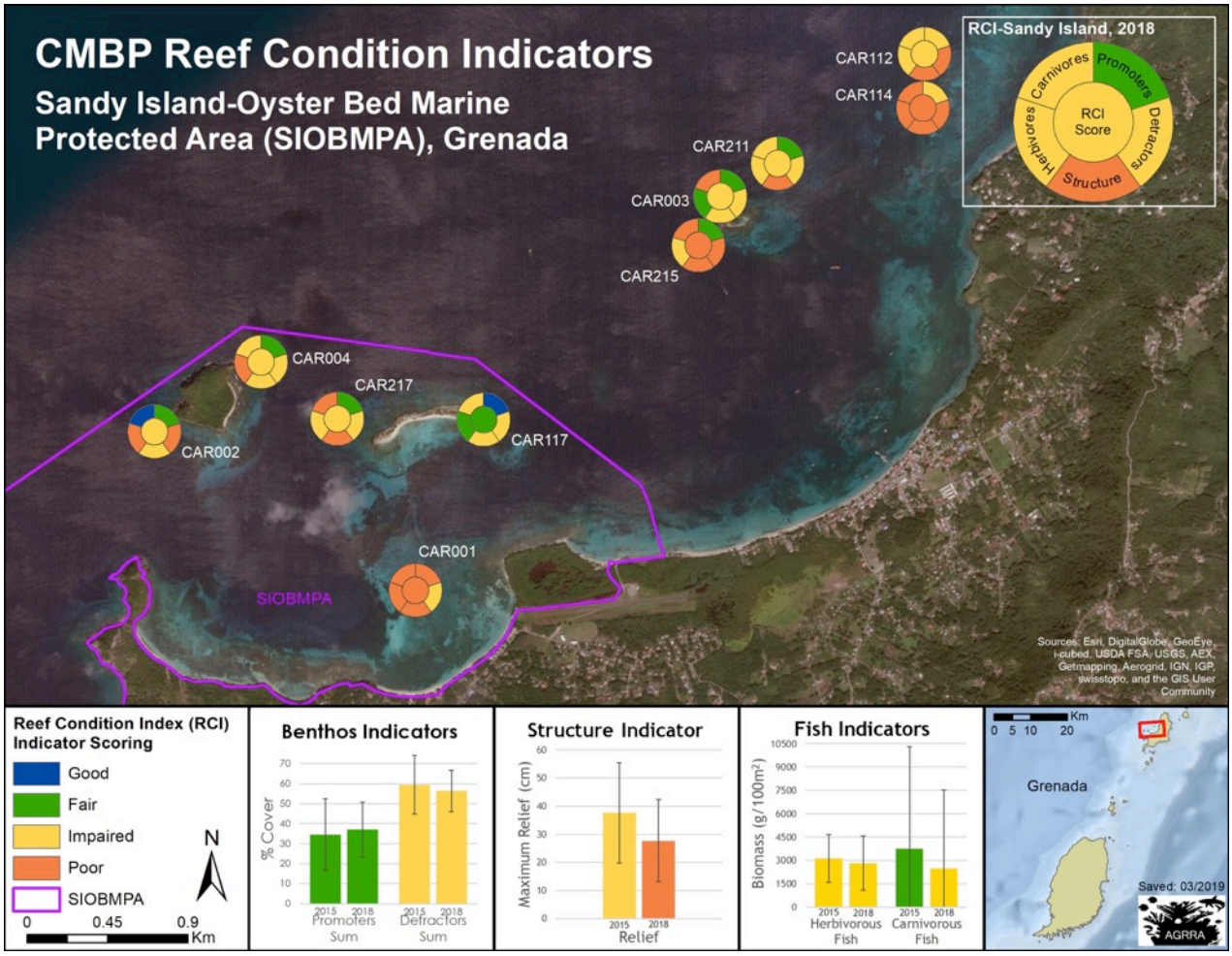
Competition for space? Yellow sponge is entwined with a finger coral and an azure vase sponge, SV-2018

Chain moray eel among green calcareous *Hallimeda* and encrusting peyssonnelids, SV-2018

AGRRA surveyors in transit to a SVG survey site, SV-2018

Photos: 2015: CM = C. Morrall, FM = K. Marks; 2018: SV = S. Voegeli

Grenada:
CMBP Coral Reef Index Sites and Condition



Corals fringe small islands and grow on shoals inside the leeward SIOBMPA and to its north. Carnivorous fish biomass is slightly lower than in 2015, but site variances are very large. Herbivorous fish biomass has remained steady, as has the scaled cover[1] of benthic promoters and detractors that can displace corals. Reef structure may have declined.

Five indicators that contribute substantially to reef structure and function are recorded and graded in the CMBP Reef Condition Index (RCI)[1]. The RCI of ten surveyed sites averaged **Impaired** in both 2015 and 2018.

		2015 2018
	Promoters, corals, crustose coralline algae and other organisms that aid reef growth, as cover measured in points along benthic transects in %.	35 ≈ 37 Fair
	Detractors, organisms on hard bottoms that can overgrow or displace corals, as cover measured in points along benthic transects in %.	59 ≈ 56 Impaired
	Structure, a proxy for the amount of habitat space created by corals, as maximum vertical relief along fish transects in cm.	38 ↓ 28 2018:Poor
	Herbivores, fish that graze the algae that can overgrow reef corals, as biomass along fish transects in gm/100 m^2.	3136 ≈ 2825 Impaired
	Carnivores, fish that help balance food webs by eating *Herbivores* and animals that prey on corals, as biomass along fish transects, in gm/100 m^2.	3741 ↓ 2487 2018:Impaired

[1]See Appendix; benthic cover values are scaled to exclude any areas occupied by sand, mud, seagrasses or associated sediment-dwelling algae.

Grenada: CMBP Coral Reef Index Sites and Condition Indicators

Habitats. Four *fringing, fore-reef* sites are *inside* SIOBMPA and three are *outside*. One of these inside sites (CAR004) is a *spur-and-groove reef*; the rest are *coral fields*, as is an *inside shoal* (CAR001). The two *outside shoals* have scattered corals on sand (CAR112) or among seagrass (CAR114). CAR001 and CAR117 are shallow (4 m) sites.

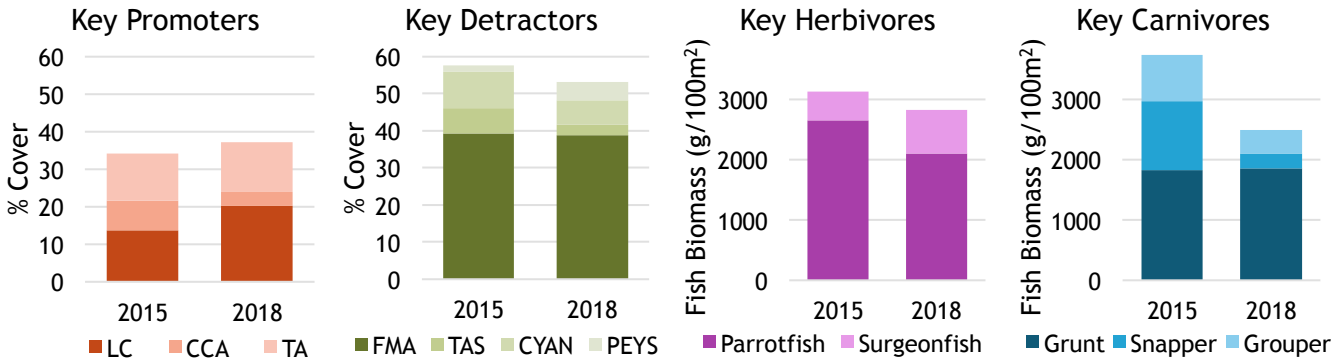
Lobed star corals: live (foreground, background); fleshy macroalgae on dead lobes (middle); 11 m, CAR004, CM-2015

Indicator component changes, 2015* vs. *2018, all surveys.

Promoters Scaled Cover: *Live Corals* (LC) increased (from 14 to 20%) but *Crustose Coralline Algae* (CCA) may have declined slightly.

Detractors Scaled Cover: Slight decreases in *Turf Algal Sediment* (TAS) mats and *Cyanobacteria* (CYAN), and increase in *Peyssonnelids* (PEY).

Fish Biomass: *Parrotfish* declines are partially offset by *Surgeonfish* increases. *Snapper* (especially) and *Grouper* have decreased but the high site variances may have a seasonal component (surveys in December 2015 *vs*. July surveys in 2018, respectively).



School of juvenile brown chromis swim above a large, clump of healthy lobed star corals, ~ 5 m, CAR117, KM-2015

Benthos Scaled Cover averages by location or dates.

Promoters: *Live Corals* on the *fore* reefs *outside* the SIOBMPA increased substantially between 2015 and 2018 (from 9–22%), but were higher on the *inside* (21% in 2015 and 27% in 2018). *Crustose Coralline Algae* showed a slight decline (both locations).

Detractors: *Fleshy Macroalgae* (FMA) on *outside* fore reefs were lower in 2018 than 2015 (40% *vs*. 53%), but higher on the *outside* shoal reefs (13% in 2015 *vs*. 46% in 2018), where *Cyanobacteria* had greatly decreased (from 38% to 10%).

Macroalgal Index (MAI macroalgal cover x height) averages, an* inverse proxy *for herbivory. MAI increased at *outside* SIOBMPA sites (from 116 to 164) between 2015 and 2018, due to increases in macroalgal heights from 2 to 3.5 cm.

Fish Biomass averages by location or dates.

Herbivorous fishes, snapper and grouper all declined in 2018 on the *inside* fore reefs (from 3341 to 2323, 2532 to 294 and 779 to 285 g/m^2, respectively), but *surgeonfish* increased on the *outside* fore reefs (from 365 to 705 g/m^2).

Herbivorous Sea Urchin density averages.

Diadema: Rare (0.1-0.2/m^2) at the 4-m (CAR001, CAR117) sites, but higher in 2018 at CAR001 (0.6/m^2); not seen deeper.
Other Urchins: More widespread but rare (0.1-0.2/m^2) overall.

Lobed star corals: with damselfish bites and algal gardens (left); being overgrown by mat tunicates (right); ~ 10 m, CAR002, KM-2015

Main Conclusions

The high snapper biomass averages in 2015 are the result of surveys at two inside (CAR002,117) and one outside (CAR004) SOIBMPA sites, and probably represent fortuitous inclusions of passing fish schools. Deleting these sites removes the apparent temporal biomass difference in snappers between 2015 and 2018.

Live corals on the fore reefs at Moboya, Sandy Island and Jack-A-Dan appear to be recovering well from losses that were reported after the severe, 2005 bleaching mortality event. Regardless of location, coral recruit densities were significantly reduced in 2018 (overall 1 *vs.* 12/m^2 in 2015), which is potentially very troublesome if sustained in the future.

The relatively high biomass of herbivorous parrotfish and surgeonfish (3554 and 2164 g/m^2, respectively) at CAR117 in 2018, and its population of *Diadema* (persistent since at least 2015), compared to the averages of the other sites in 2018, may collectively account for the low values of both its macroalgae (23 *vs.* 44%) and macroalgal heights (1.5 *vs.* 3 cm).

Given the substantial decrease in the cover of cyanobacteria over the shoal reefs in Sparrow Bay between between 2015 and 2018, water quality off Hillsborough may have improved since the relocation of the port to Tyrell Bay. At the same time, the presence of the new port and marina in Tyrell Bay are probably already having detrimental effects on the turbidity, nutrient and pollutants levels in both Oyster and Tyrell Bays.

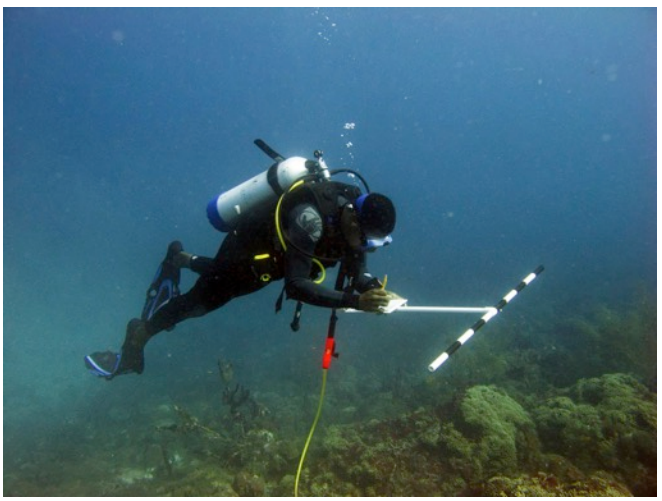
Additional success at continued community engagement, enforcing fishing regulations and controlling unauthorized commercial operations on its islands would enhance the ability of reef communities within SIOPMPA to resist and/or recover from the expected detrimental effects of ongoing climate change.

Coneys in pre-spawning mode swarm over finger corals and the brown fleshy macroalga, *Dictyota,* ~10 m, CAR217, KM-2015

Crustose coralline algae overgrowing a dead brain coral create space for coral larvae to settle ~ 10 m, CAR002, KM-2015

Competition among plate corals and peyssonnelid algae on a spur reef inside SIOBMPA, 11 m, CAR004, KM-2015

Benthos surveyor swims over a benthic transect line, K TV-2015



Fish surveyor records an observation during a fish transect, KT-V 2015

Photos: 2015: KM = K. Marks, CM = C. Morrall, KT-V = K. Treiber-Vajda

Appendix

The CMBP Reef Condition Indicators and Index

Indices derived from measurable ranking criteria for indicators of abundance, size or health of structurally and/or functionally important components of ecosystems can serve as easy-to-understand summaries of their condition–even when the grades of the component indicators rank differently from their overall index grades. It's important to remember that regardless of the rating system used, the value of the indicators on any reef, and their derived indices, reflect natural environmental conditions in addition to any human impacts.

Report cards for Caribbean coral reefs that were originally developed by the Healthy Reef Initiative use indicators based on AGRRA data. The CMBP Reef Condition Index (RCI) incorporates additional information that is routinely collected during AGRRA benthic and fish surveys by observers with at least moderate levels of training in reef ecology and skills at surveying reef organisms. RCI presently consists of five indicators:

Reef Promoters–percent scaled[1] cover of benthic organisms that facilitate reef growth and allow coral larvae to settle, most importantly live corals, crustose coralline algae and sparse turf algae.

Reef Detractors–percent scaled cover of benthic organisms, most importantly macroalgae, turf algal sediment mats and certain invertebrates *(e.g.,* some sponges, cnidarians, tunicates) that can displace corals and/or prevent the settlement of coral larvae.

Reef Structure–a proxy for reef architectural complexity and based on maximum vertical relief in cm, it approximates the amount of reef habitat space available to both sedentary and motile reef organisms.

Key Herbivores–a measure of the biomass of the important fish grazers on the turf algae and macroalgae that, unchecked, can overgrow reef corals.

Key Carnivores–a measure of the biomass of important predators of corallivores (animals that prey on corals) and herbivores.

The site means for each indicator is compared to its threshold value and each is given a score from one to four, with corresponding to grades of Poor to Good. The RCI for each site is the average of these five indicator scores.

Threshold values and grades for the CMBP Reef Condition Index (RCI) indicators and index.

Indicators/Index	Poor (1)	Impaired (2)	Fair (3)	Good (4)
CMBP Reef Condition Indicators				
Reef Promoters (%)	<15	15-29.9	30-59.9	≥60
Reef Detractors (%)	≥60	30-59.9	15-29.9	<15
Reef Structure (cm)	<33	33-66	67-100	>100
Key Herbivores (gm/100m^2)	<2000	2000-3999	4000-5999	≥6000
Key Carnivores (gm/100m^2)	<1000	1000-2999	3000-6999	≥7000
CMBP Reef Condition Grade	**1.0-1.6**	**1.8-2.4**	**2.6-3.2**	**3.2-4.0**

[1]Scaled cover means that any areas occupied by sand, mud, seagrasses or associated sediment-dwelling algae are removed from the benthos point count data as these are unsuitable substrata for the settlement of coral larvae.