

**CORAL REEF MAPPING WITH REMOTE SENSING AND MACHINE
LEARNING: A nurture and nature analysis in Marine Protected Areas**
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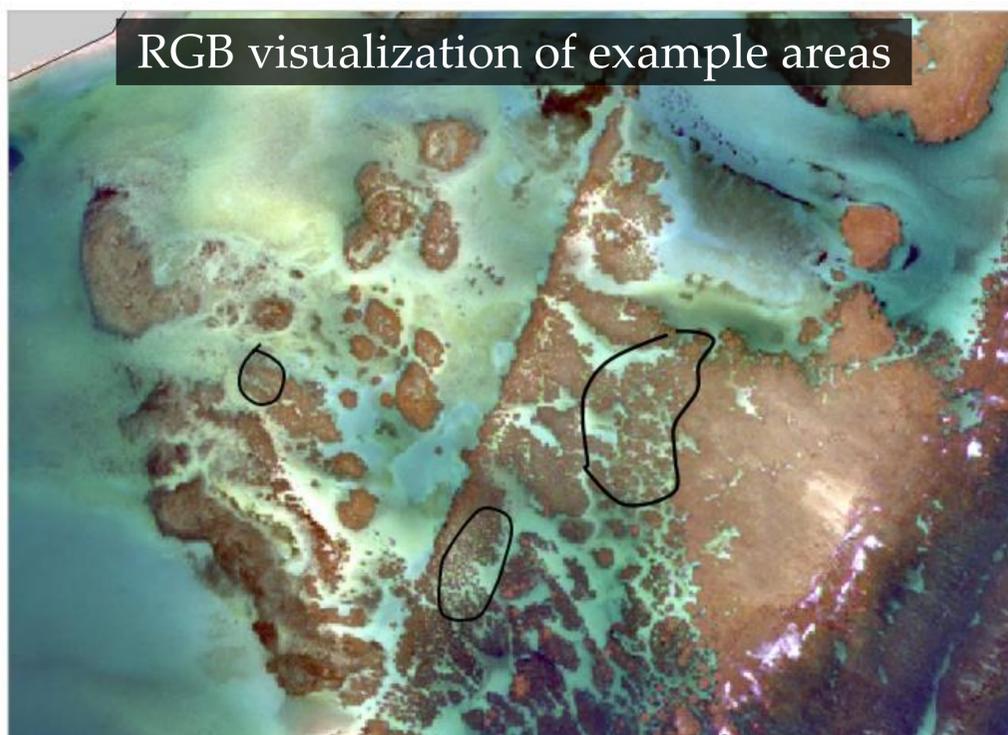
Supplementary Material S4 to S17

Example photos of the benthic covers found in the coastal reefs of Tamandaré

Figures **S4** to **S17** present the 14 benthic habitats found in the coral reefs of the study area, pictured by representative video-frames and photos taken during field survey (all videos and photos were made by the author). Additionally, we provide example areas of each benthic habitat, using a Red, Green, Blue (RGB) composite of the WorldView-3 scene used in this study.

Fig S4 Class 1 – Reef Rubble

Benthic Habitat: Reef Rubble; Habitat Classification: Fragmented Patchy Reefs; Reef Zones: Usually associated with the back reef and lagoon. Description/major covers: Substrate cover characterized by rubble, usually covered by turf algae and/or filamentous algae. Associated with fragmented parts of the reef.



Example photos: Class 1 “Reef Rubble”

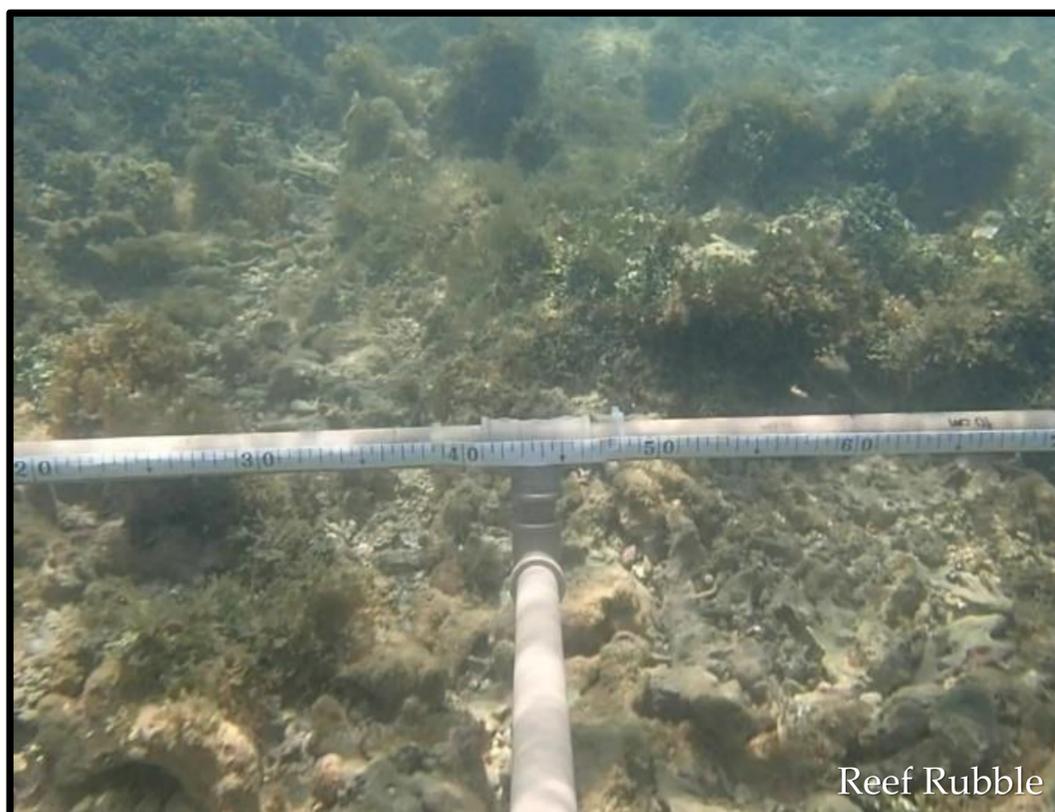
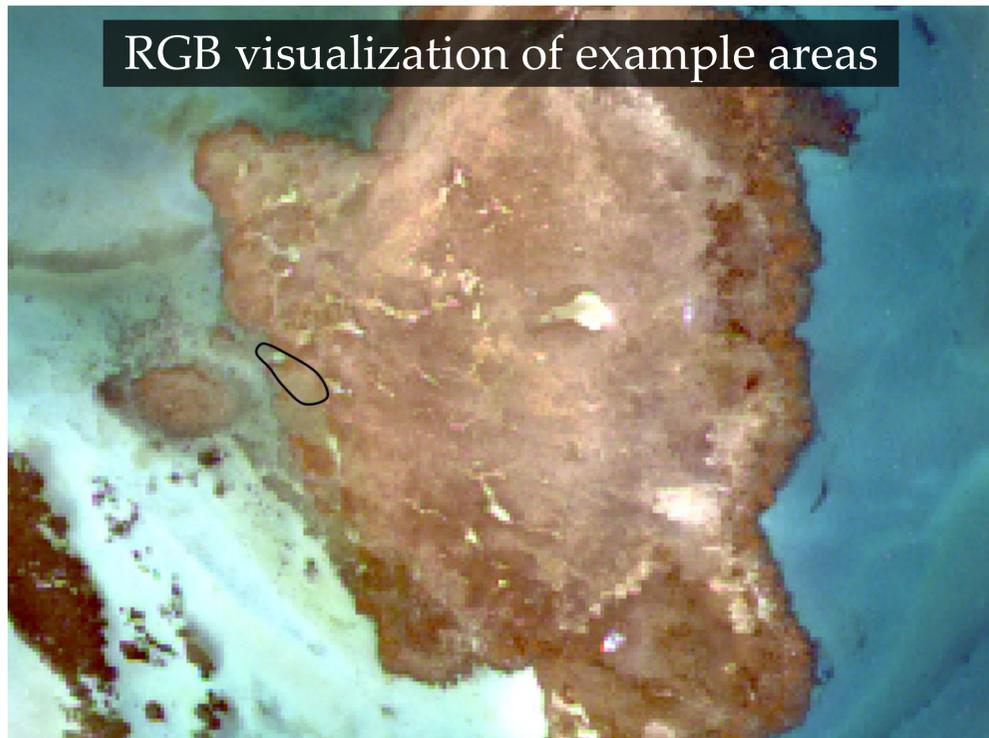


Fig S5 Class 2 - Rock, algae, urchin

Benthic Habitat: "Rock, algae, urchin"; Habitat Classification: Coral reef and colonized hardbottom; Reef Zones: Usually associated with back reefs zones, reef flats; Description/major covers: Consolidated substrate with regions showing bare rock and encrusting coralline algae. Turf algae is also present. High density of sea-urchin (*Echinometra lucunter*).



Example photos: Class 2 "Rock, algae, urchin"

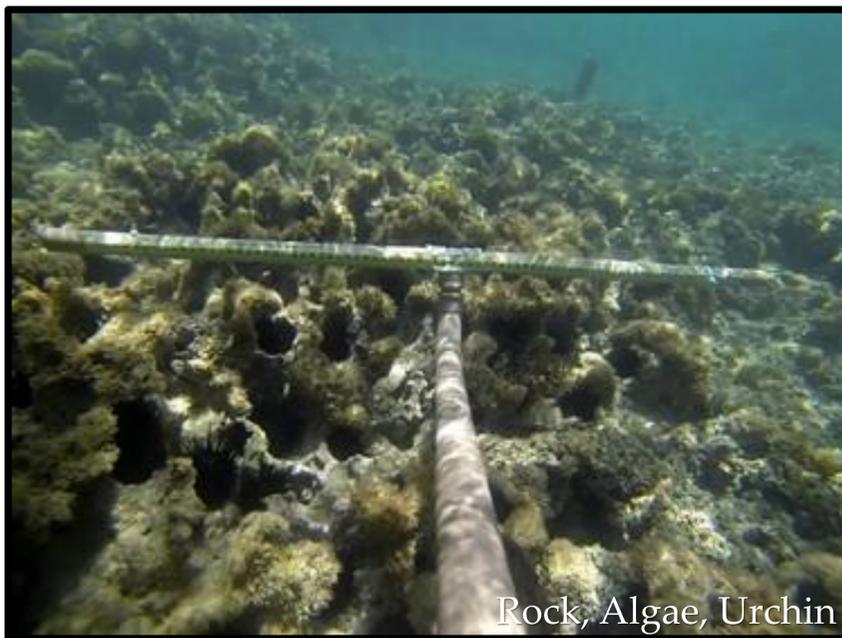


Fig S6 Class 3 - Rock, coral, urchin

Benthic Habitat: "Rock, coral, urchin" Habitat Classification: Coral reef and colonized hardbottom; Reef Zones: Usually associated with back reef zones, reef flats, linear reefs; Description/major covers: Region with high densities of (mainly) hydrocorals and brooding corals such as *Porites astreoides*, *Agaricia humilis* and *Favia gravida*. High density of sea-urchin (*E. lucunter*). Large areas with bare rock and encrusting coralline algae.

RGB visualization of example areas



Example photos: Class 3 "Rock, Coral, Urchin"

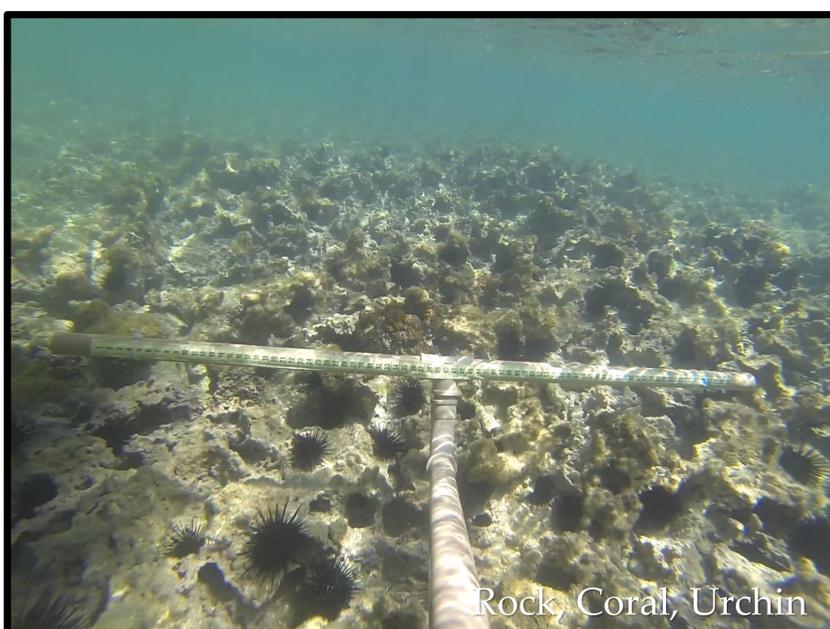
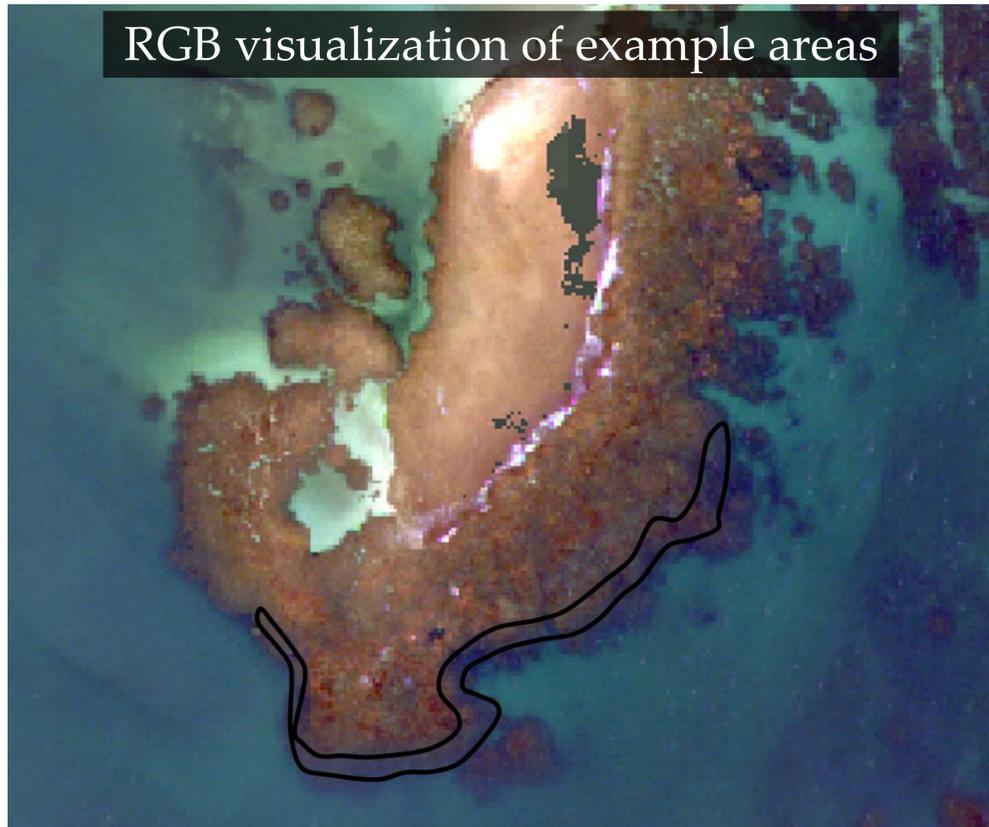


Fig S7 Class 4 – Fore-reef/“Itapitangas”

Benthic Habitat: “Fore-reef/Itapitangas”; Habitat Classification: Fore-reef; Reef Zones: Usually associated with the fore reef; Description/major covers: Areas of high wave energy, mostly on the third reef line in the study area. Isolated rocks, covered by *Palythoa caribaeorum* on the base and green algae, encrusting coralline algae on the top. The occurrence of the encrusting form of *Millepora alcicornis* that may present short ramifications at the top was also observed.



Example photos: Class 4 “Fore-reef/Itapitangas”

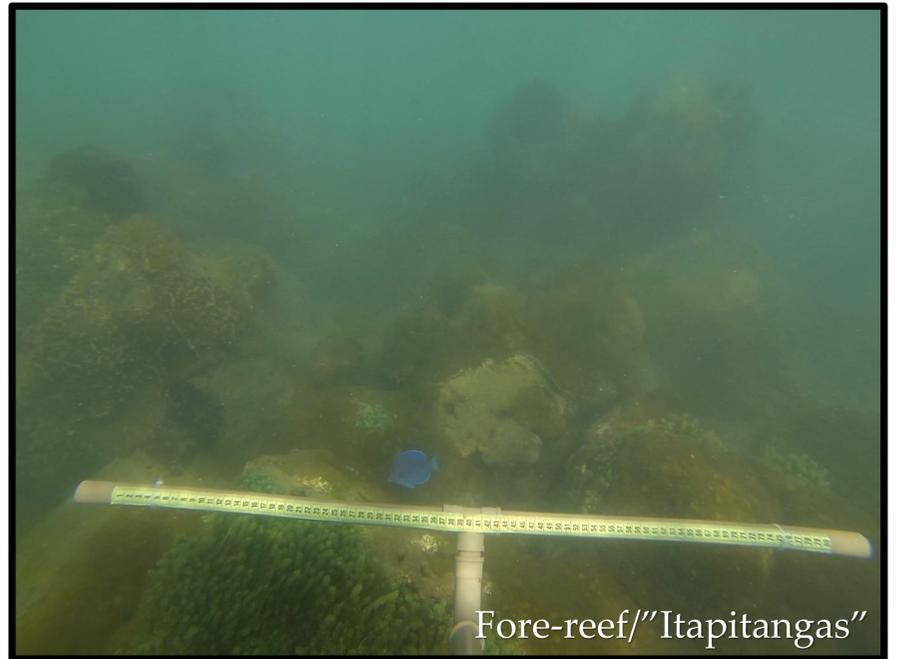
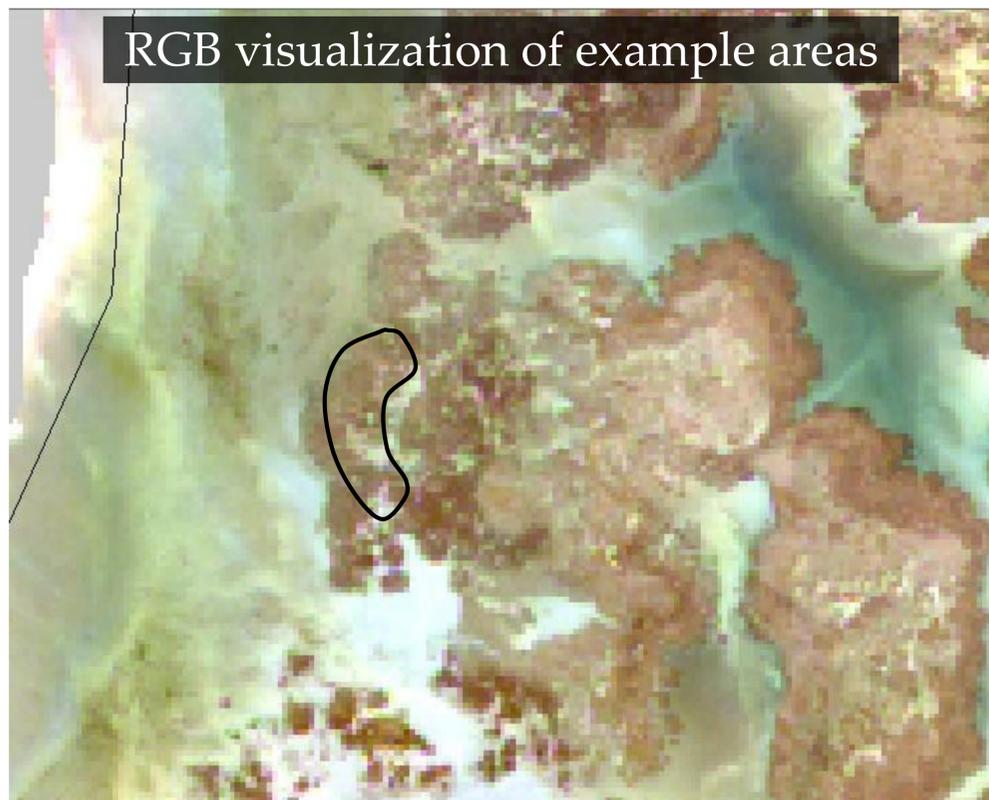


Fig S8 Class 5 - Macroalgae

Benthic Habitat: "Macroalgae"; Habitat Classification: Submerged vegetation; Reef Zones: Usually on unconsolidated substrate (sand), lagoons and surrounding areas of the reefs; Description/major covers: High density of brown and green algae, mostly *Sargassum* spp., *Dyctiota* spp., *Caulerpa* spp., *Halimeda* spp., and others.

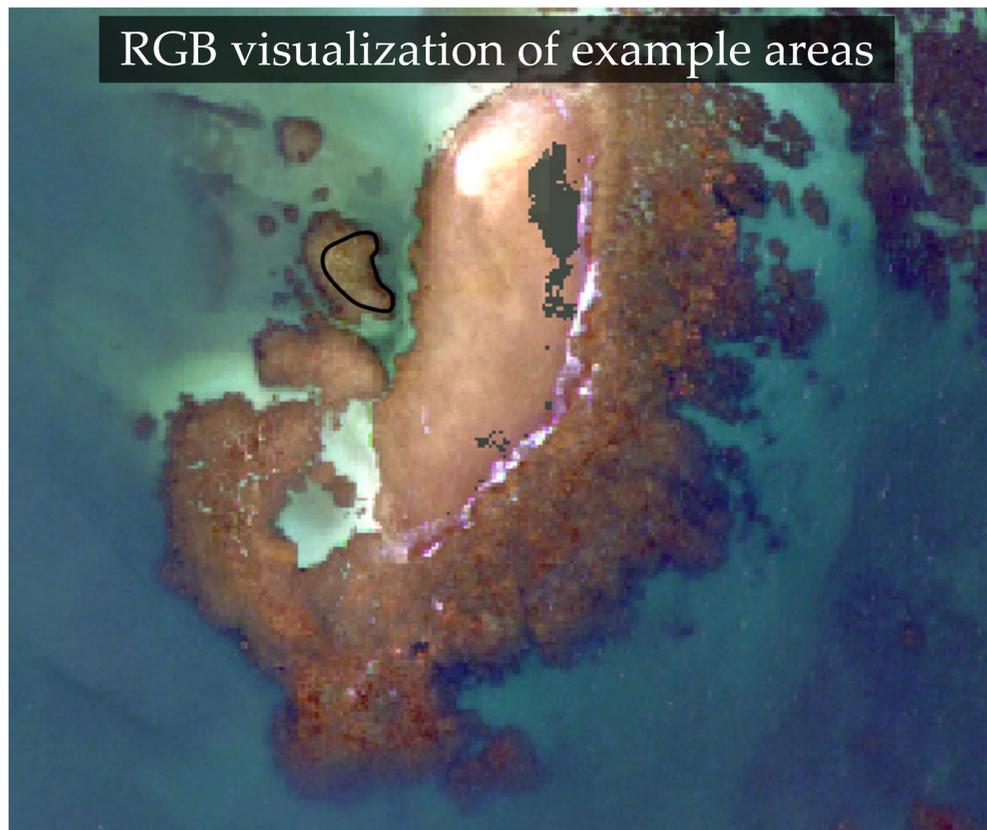


Example photos: Class 5 "Macroalgae"



Fig S9 Class 6 – *Millepora alcicornis*

Benthic Habitat: "*Millepora alcicornis*"; Habitat Classification: Coral reef and colonized hardbottom; Reef Zones: Mostly reef crests and back reefs, can also be found colonizing reef rubble; Description/major covers: Areas mostly covered by colonies of the hydrocoral *Millepora alcicornis*.

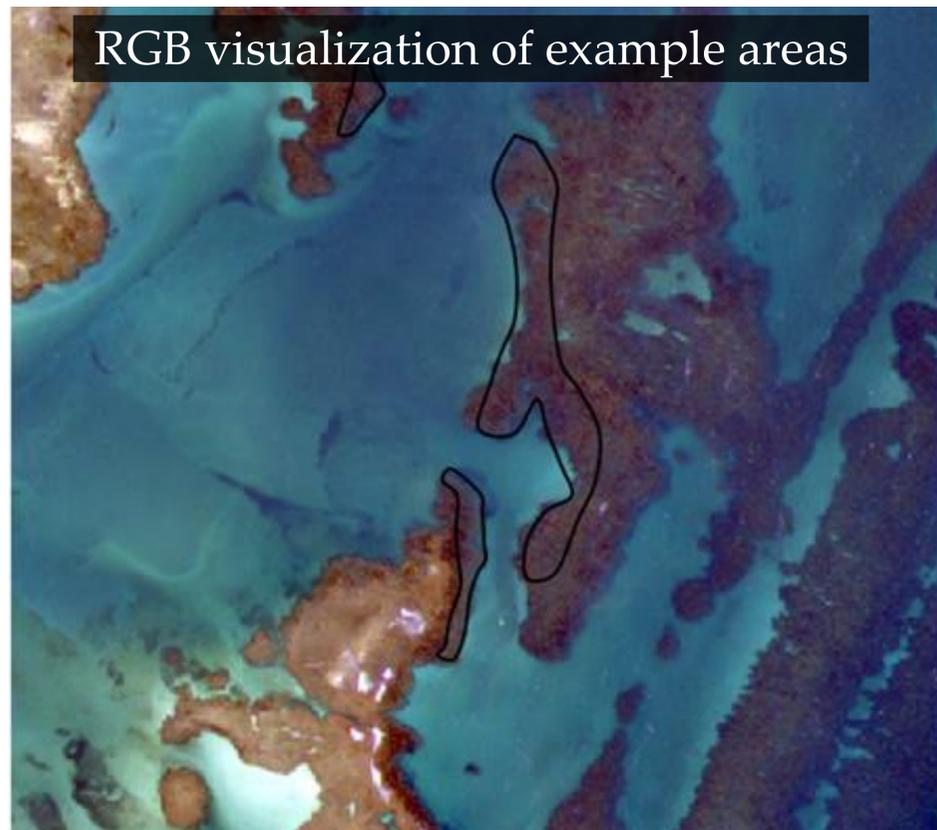


Example photos: Class 6 "*Millepora alcicornis*"



Fig S10 Class 7 – Turf algae

Benthic Habitat: “Turf algae”; Habitat Classification: Submerged vegetation (on reefs); Reef Zones: this class can be found in all zones associated with the reef, but mainly surrounding the reefs’ structure; Description/major covers: Multi-specific assembly of various algae (e.g. filamentous algae, green macroalgae such as *Caulerpa* spp. and *Halimeda* sp., juvenile macroalgae).



Example photos: Class 7 “Turf algae”

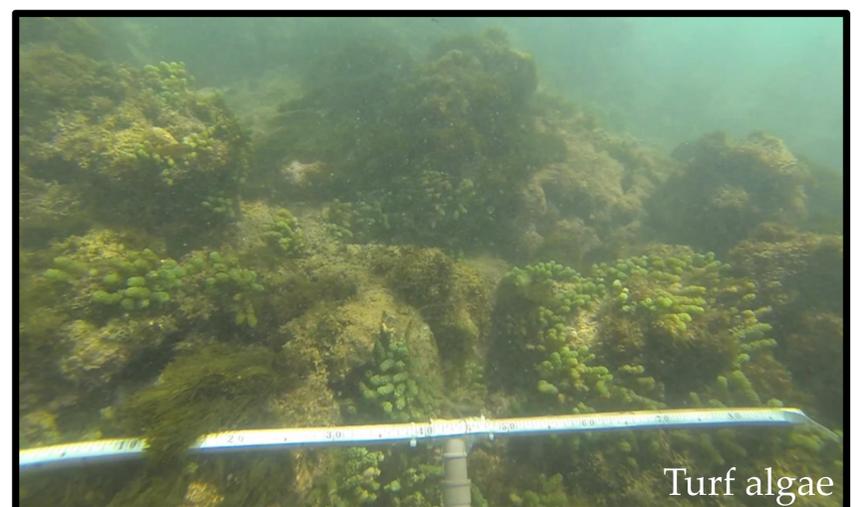
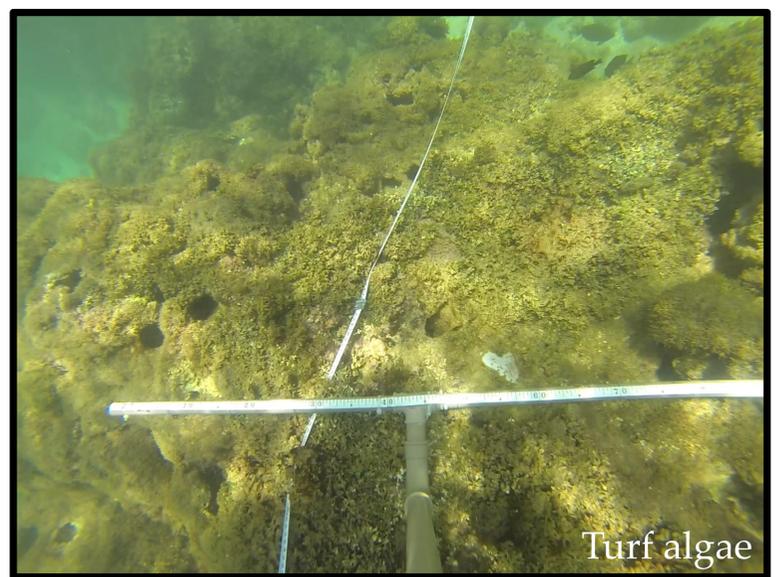
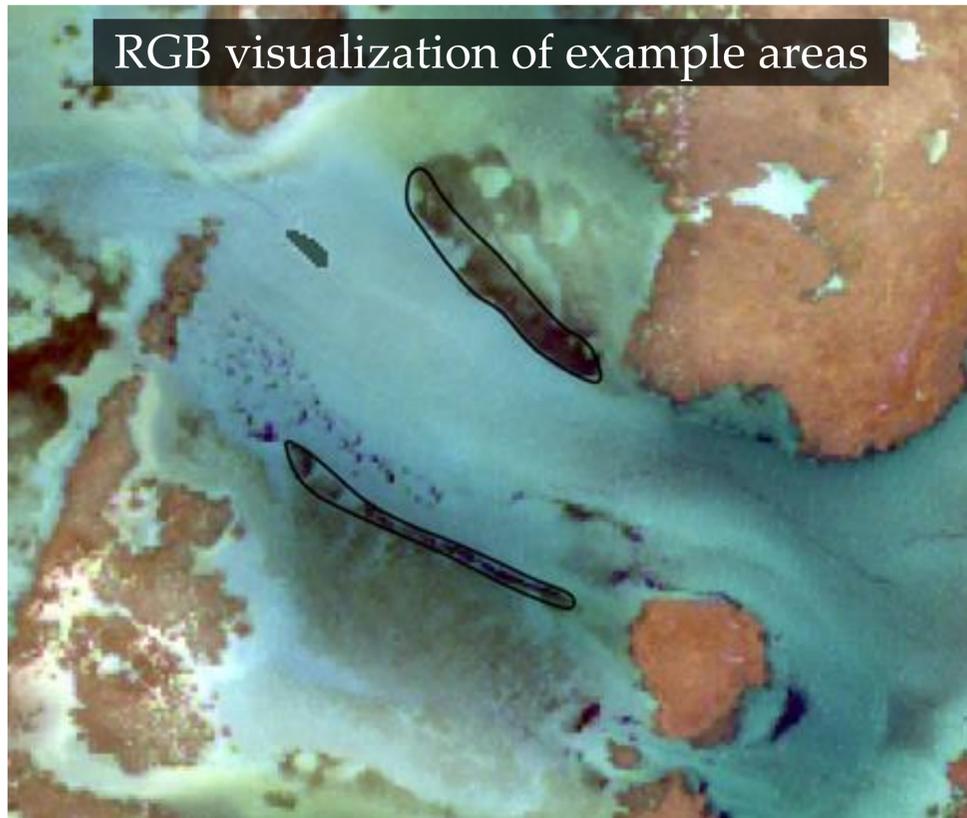


Fig S11 Class 8 – Macroalgae and Seagrass

Benthic Habitat: “Macroalgae and Seagrass”; Habitat Classification: Submerged vegetation; Reef Zones: Not associated with the reef structure. Usually associated with sand; Description/major covers: Areas of seagrass (*Halodule wrightii*) with associated macroalgae covering most of the substrate.

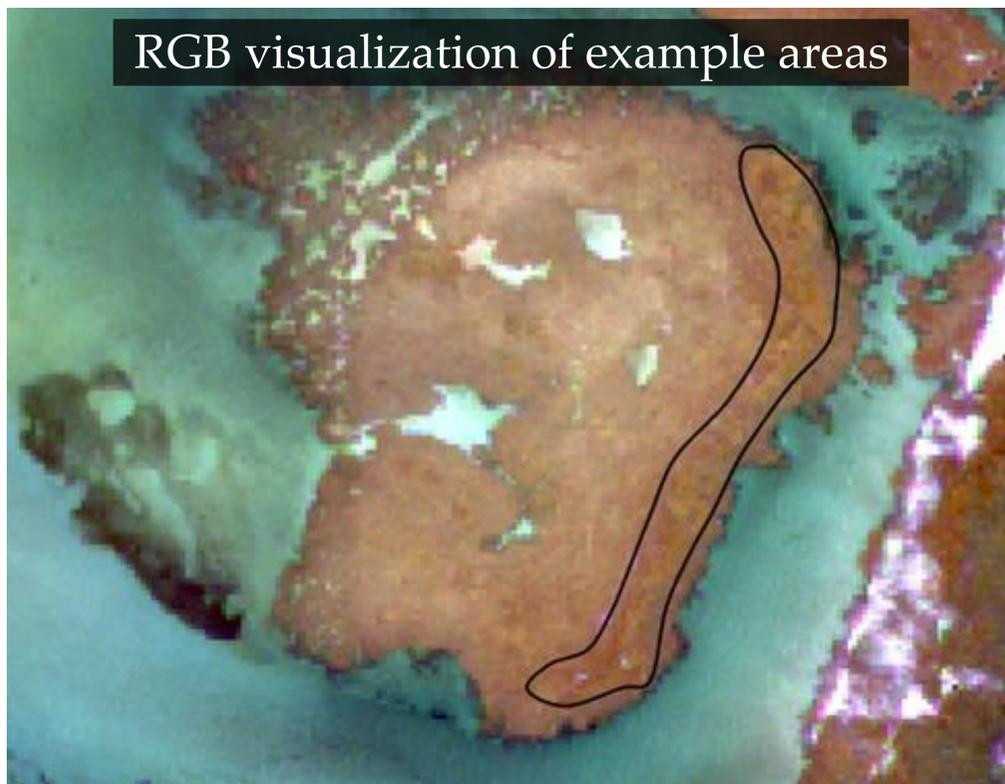


Example photos: Class 8 “Macroalgae and Seagrass”



Fig S12 Class 9 – *Palythoa caribaeorum*

Benthic Habitat: "*Palythoa caribaeorum*"; Habitat Classification: Coral reef and colonized hardbottom; Reef Zones: Reef flat, reef crests; Description/major covers: Consolidated substrate, mostly reef flats, covered by *Palythoa caribaeorum*



Example photos: Class 9 "*Palythoa caribaeorum*"

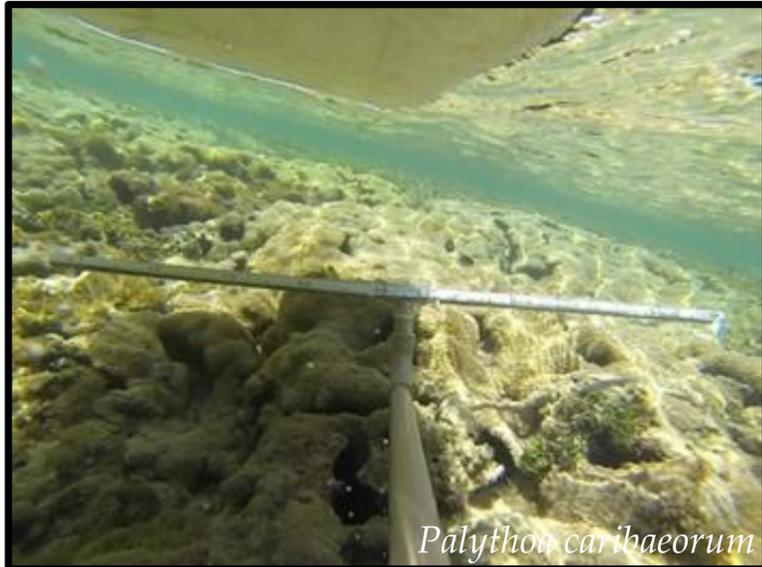
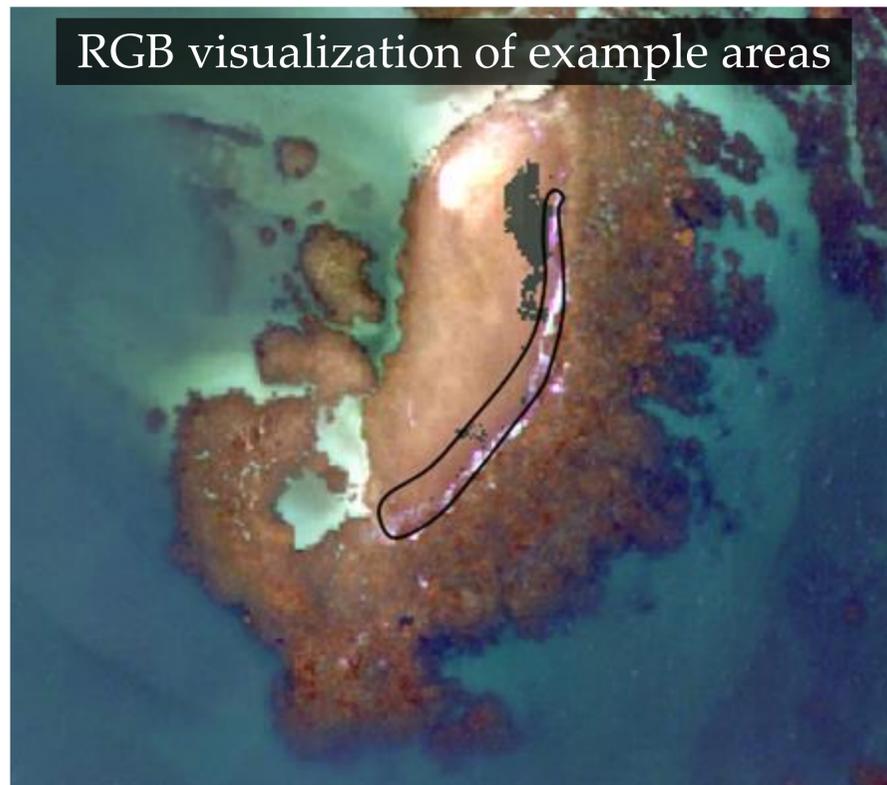


Fig S13 Class 10 – Reef flat (hard substratum)

Benthic Habitat: “Reef flat (hard substratum)”; Habitat Classification: Uncolonized hardbottom; Reef Zones: Reef flat; Description/major covers: Consolidated substrate (*i.e.* calcareous rock), mostly emerged reefs and eroded reef tops. Turf algae and *Palythoa caribaeorum* may also be observed covering parts of the substrate.

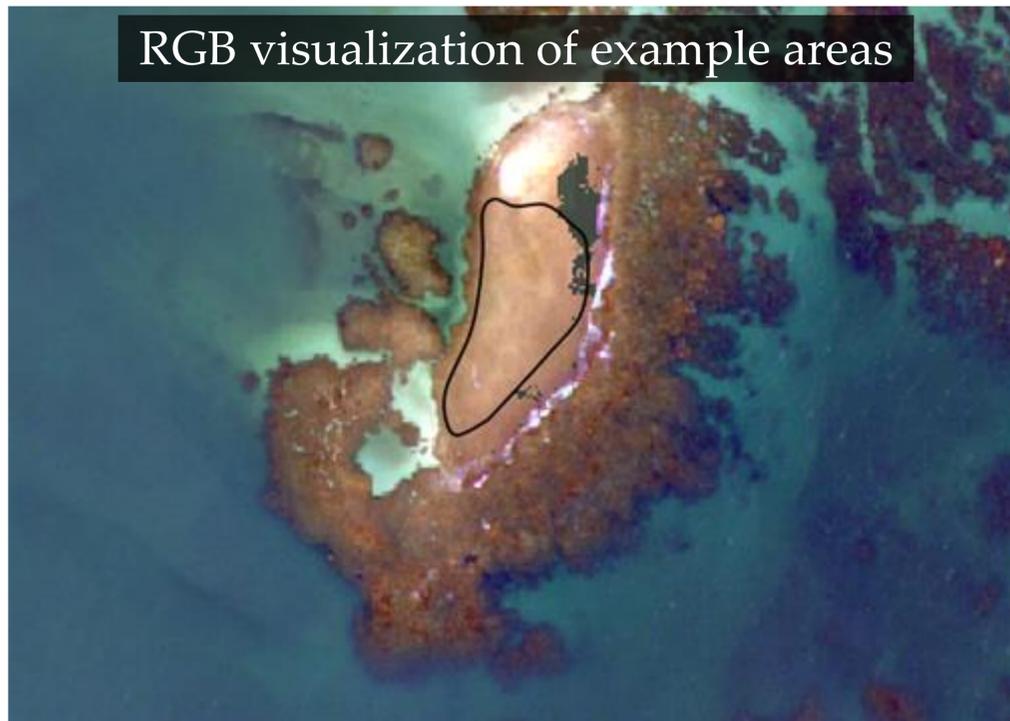


Example photos: Class 10 “Reef flat (hard substratum)”



Fig S14 Class 11 – Reef flat (algae)

Benthic Habitat: “Reef flat (algae)”; Habitat Classification: Colonized hardbottom; Reef Zones: Reef flat; Description/major covers: Consolidated substrate (*i.e.* calcareous rock), mostly emerged reefs and eroded tops mostly covered by turf and filamentous algae. *Palythoa caribaeorum* and small colonies of *Siderastrea* sp. were also observed in this region.

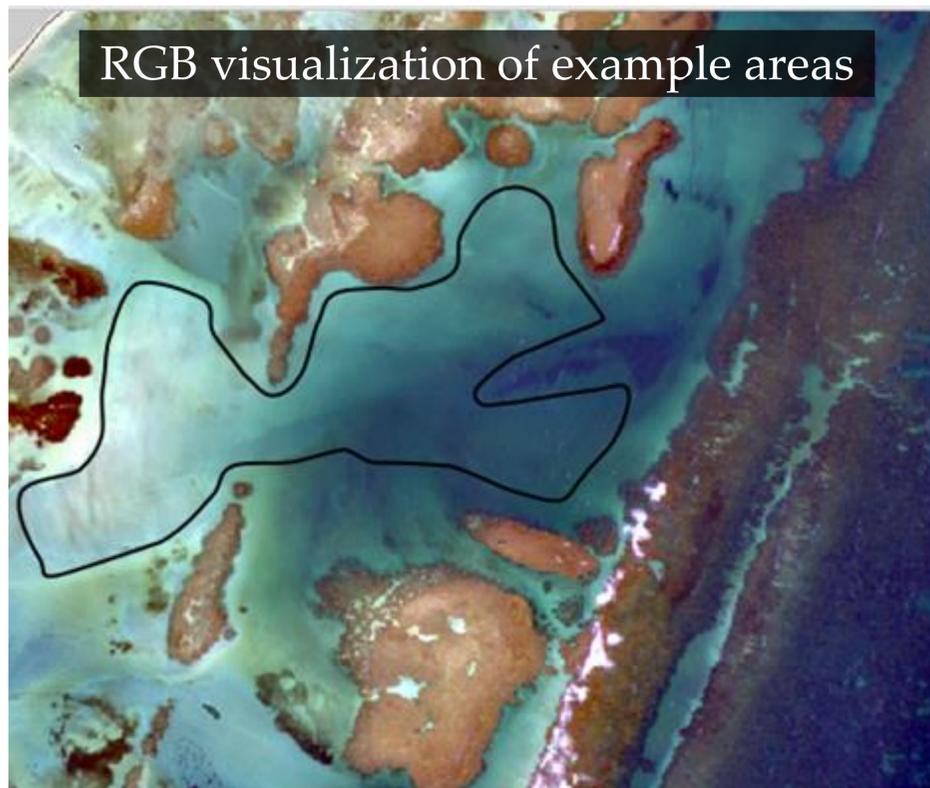


Example photos: Class 11 “Reef flat (algae)”



Fig S15 Class 12 – Sand

Habitat Classification: Unconsolidated sediments; Reef Zones: Reef lagoons / not associated with reef structures; Description/major covers: Sand, gravel, sparse macroalgae and/or rubble.



Example photos: Class 12 "Sand"

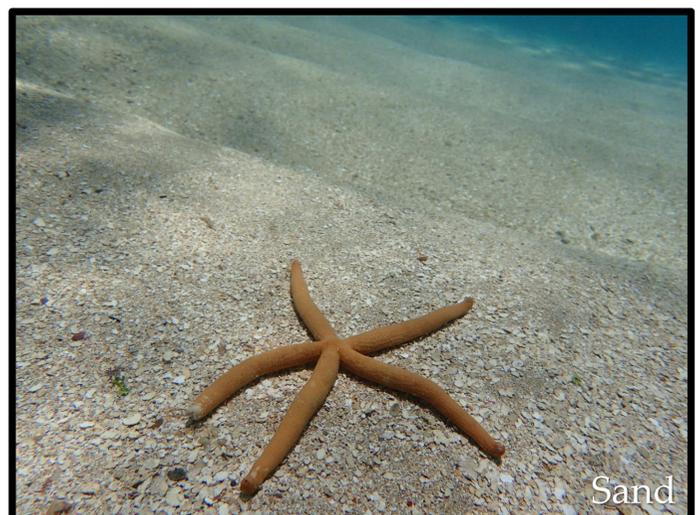
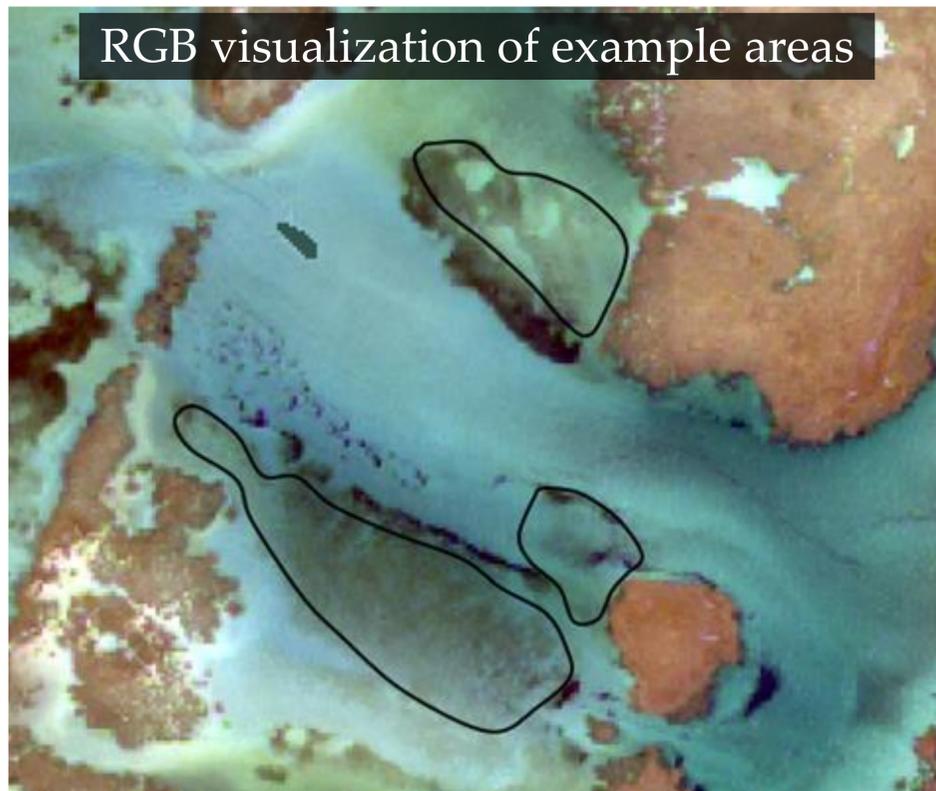


Fig S16 Class 13 – Seagrass

Benthic Habitat: "Seagrass"; Habitat Classification: Submerged vegetation; Reef Zones: Not associated with the reef structure. Usually associated with sand; Description/major covers: sand and in smaller proportions, gravel. Usually found surrounding some reef structure throughout the study area and in coastal areas. Two species were observed in the area: *Halodule wrightii* and *Halophila decipiens* (with a predominance of *H. wrightii*).

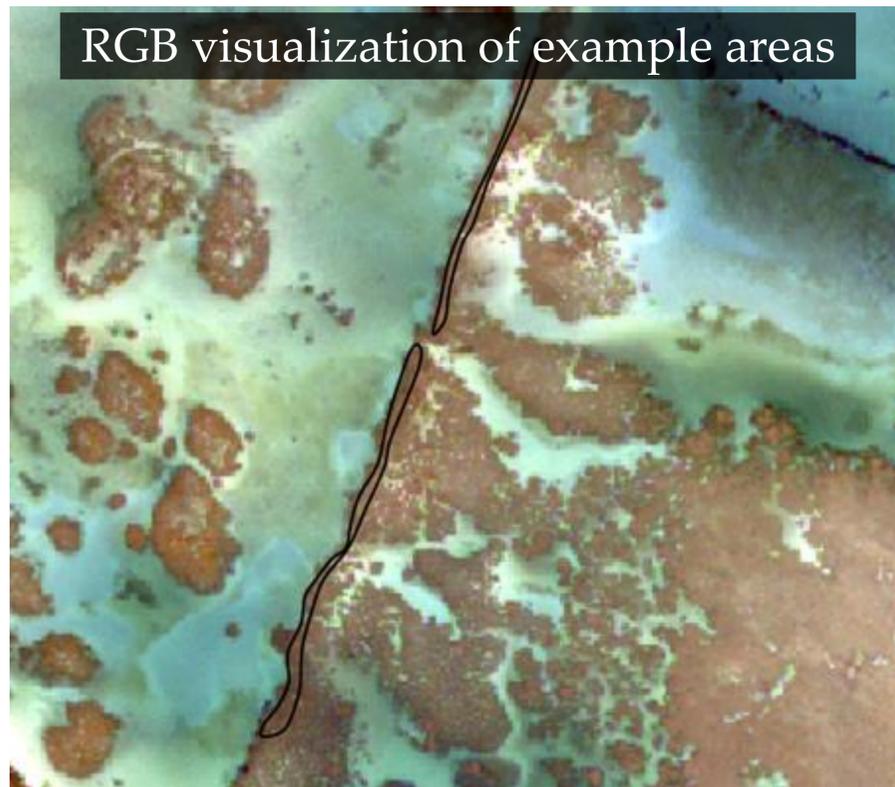


Example photos: Class 13 "Seagrass"



Fig S17 Class 15 – Calcareous Mat

Benthic Habitat: “Calcareous mat”; Habitat Classification: Coral reef and colonized hardbottom; Reef Zones: found covering most of the submerged parts of the reef structures, especially on the reef crests and back reef; Description/major covers: Multi-specific assemblage of articulated calcareous algae (e.g. *Jania* spp., *Amphiroa* spp.). It is a dominant substratum in many parts of the reefs, notably on the reef crests and back reefs.



Example photos: Class 15 “Calcareous Mat”

