Coral reef degradation at an atoll of the Western Colombian Caribbean

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Coral reef decline is an issue of concern around the globe. Remote and uninhabited coral areas are not exempt from facing changes in species composition and functionality due to global drivers. Quitasueño is a remote atoll within the Seaflower Biosphere Reserve, in the Southwestern Caribbean Sea. To evaluate the current status of the coral reefs in Quitasueño we sampled 120 stations through Rapid Ecological Assessment and evaluated four stations through Planar Point Intercept to compare the current percent cover of benthic groups with previous studies in the area. We found pronounced changes in coral and macroalgae covers in time, and great conspicuousness of multiple conditions of deterioration along Quitasueño, including diseases, coral predation, and aggression and invasion of coral colonies by macroalgae and sponges. The reef ecosystem seems to be facing a phase shift, in which the benthic cover previously dominated by hard corals is currently dominated by fleshy macroalgae. It is essential to evaluate the possible drivers of the extent of degradation of Quitasueño to understand the process of deterioration and mitigate the impacts.

CORAL REEF DEGRADATION AT AN ATOLL OF THE WESTERN COLOMBIAN CARIBBEAN

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Abstract

3 Coral reef decline is an issue of concern around the globe. Remote and uninhabited coral areas
4 are not exempt from facing changes in species composition and functionality due to global
5 drivers. Quitasueño is a remote atoll within the Seaflower Biosphere Reserve, in the
6 Southwestern Caribbean Sea. To evaluate the current status of the coral reefs in Quitasueño we
7 sampled 120 stations through Rapid Ecological Assessment and evaluated four stations through
8 Planar Point Intercept to compare the current percent cover of benthic groups with previous
9 studies in the area. We found pronounced changes in coral and macroalgae covers in time, and
10 great conspicuousness of multiple conditions of deterioration along Quitasueño, including
11 diseases, coral predation, and aggression and invasion of coral colonies by macroalgae and
12 sponges. The reef ecosystem seems to be facing a phase shift, in which the benthic cover
13 previously dominated by hard corals is currently dominated by fleshy macroalgae. It is essential
14 to evaluate the possible drivers of the extent of degradation of Quitasueño to understand the
15 process of deterioration and mitigate the impacts.

16 **Keywords**

17 Seaflower Biosphere Reserve, Marine Protected Area, Benthic Community, Phase Shift

Introduction

19   Coral reefs are facing multiple threats, which have caused great deterioration and loss of
20 ecosystem functionality worldwide for the last quarter-century (*Souter et al., 2020*). Some threats
21 work on a global scale related to climate change, such as coral bleaching due to increase in sea
22 surface temperature (*Brown et al., 2019*); others operate at the local or regional levels related to
23 local human activities, such as pollution, terrestrial runoff, and overfishing (*McLean et al.,*
24 *2016*). In that sense, lower levels of coral decline are usually expected in remote and uninhabited
25 areas due to the lesser direct influence of human activities, however, coral degradation in such
26 areas has also been reported (*Coelho & Manfrino, 2007*), with remarkable changes in the benthic
27 community composition as a common indicator.

29   Heavily degraded reefs typically exhibit low cover of reef-building corals, with fleshy
30 macroalgae dominating the bottom (*Perry et al., 2018*). In addition, shifts in the dominance of
31 those reef-building corals are also associated with degradation processes. In the western Atlantic,
32 the branching acroporids used to be the main reef builders and habitat providers on shallow
33 waters, however, due to their massive mortality in the 80s and 90s, *Orbicella* species became the
34 main reef-forming corals (*Estrada-Saldivar et al., 2019*). The remaining populations of *Acropora*
35 spp. and other reef-building species have decreased across the region due to emergent diseases
36 and other environmental stressors, which have favored fast growing non-framework coral species
37 such as *Porites astreoides* and *Agaricia agaricites* (*Green, Edmunds & Carpenter, 2008*;
38 *Estrada-Saldivar et al., 2019*). Therefore, the assessment and monitoring of coral reef
39 conditions and the drivers of its decline in continental and oceanic localities are crucial to
40 understand ecosystem dynamics, addressing possible ways to mitigate stressors, and designing
41 recovery strategies when necessary (S*anchez et al. 2019*).

43   In the Colombian Caribbean, the Archipelago of San Andrés, Providencia, and Santa
44 Catalina, nominated as the Seaflower Biosphere Reserve since 2000, comprises several remote
45 and oceanic islands, atolls, cays, and shoals with almost 80% of the coral reefs areas of the
46 country (*Abril-Howard et al., 2012*). The reserve includes the Marine Protected Area Seaflower
47 (MPA Seaflower) whose northern section (37 522 km^2) holds multiple submerged banks and the
48 three northern atolls of Roncador (13°34 N, 80°5 W), Serrana (14°17 N, 80° 21 W), and
49 Quitasueño (14◦ 20 N, 81◦ 11 W) (CORALINA-INVEMAR*, 2012*). The latter is a volcanic
50 basement atoll (*Geister, 1975*) with no inhabited land, and harbors the largest coral area in the
51 country with over 1300 km^2 (*Millán & Garcia-Valencia, 2021*). Within the types of uses
52 established inside the MPA Seaflower, Quitasueño is divided into non-take and artisanal fishing
53 zones (*Taylor et al., 2012*). Few studies have evaluated the benthic community of the area for its
54 remoteness.

56   Understanding vulnerability as the probability of detrimental effects due to the exposure
57 to degradation conditions, *Barrios* (*2000*) described a high vulnerability of Quitasueño not only
58 due to the high frequency of conditions but also to the great frequency of healthy coral colonies,
59 susceptible to be affected by those conditions. In general, the study reported that Quitasueño had
60 high frequency of current mortality, high levels of coral predation by mobile organisms (fish,
61 gastropods, and fire worms), high ratios of invasions (covering and smothering), and aggression
62 (contact) by macroalgae, sponges and other organisms like octocorals, zoanthids, and tunicates
63 including ascidians. In addition, Quitasueño displayed a high frequency of physical damage on
64 coral reefs such as overturns, scratches or scrapings, and sedimentation. Further, the seven
65 assessed diseases (yellow band, white band, black band, red band, white spots, dark spots, and
66 white patches) were reported in high frequency at the locality.
67
68   The great healthy coral cover was later confirmed by S*ánchez et al.* (*2005*), with data
69 collected using the Planar-Point Intercept (PPI). The evaluation of the benthic communities in
70 the three northern atolls of Serrana, Roncador, and Quitasueño, indicate that Quitasueño had the
71 greatest mean coral cover (33%) ranging between 18 to 50%, and of fleshy macroalgae between
72 4 to 39%. They also described spatially structured habitats in the atoll with differences between
73 North and South of the complex. The most recent information about the benthic community of
74 the area (*Abril & Arango, 2012*) confirms the ongoing decline indicating lower coral cover than
75 reported by *Sánchez et al. (2005)*, however, methods and benthic categories included in the
76 analysis were not comparable. This was also suggested in a study of macro-algae diversity of
77 Quitasueño, where a rather low coral cover was reported as well, but no quantitative data were
78 offered to support that assertion, instead extensive cyanobacterial mats were described as a
79 possible indicator of coral decline (*Gavio et al. 2015)*.
80
81   More than 20 years after the first quantitative assessments of coral reef degradation and
82 vulnerability in Quitasueño (*Barrios, 2000)* we surveyed the area as part of a scientific
83 expedition to five oceanic islands of the western Colombian Caribbean to update the maps of the
84 shallow marine ecosystems. Quitasueño was the last atoll evaluated in the expedition, and the
85 high level of deterioration of coral reefs was conspicuous. Here we present the results of a video-
86 transects based analysis and Rapid Ecological Assessment, and a brief description of several
87 signs of coral decline, as an update of the general health status of the coral ecosystems in the
88 atoll, but mainly as a warning on the urgent need for an in-deep ecosystem health assessment in
89 this and other remote coral areas of the Southern Caribbean.
90

91 ## Materials & Methods
92 **Study area and data collection**
93   Quitasueño is an elongated atoll of 63 km long and 23 km wide (*Millán & García-*
94 *Valencia*, 2021). The reef system has an extensive leeward pre-reef terrace dominated by
95 scleractinian corals towards the mid part, and large octocoral gardens and sponges dominating

96   reef bottoms towards the north and south segments of the complex (*Millán & García-Valencia*,
97   2021). Historically, the lagoon basin was dominated by ecological units of *Orbicella spp.* and
98   *Acropora palmata-Pseudodiploria strigosa,* with the former also dominating the pre-reef terrace
99   (INVEMAR-MINAMBIENTE, 2020).
100
101   During November 2021, we evaluated 120 sampling stations through Rapid Ecological
102   Assessment (REA) on coral-reef bottoms of Quitasueño Bank (14° 20 N, 81° 11 W) during the
103   Seaflower Plus scientific expedition, which was part of a governmental effort to update the
104   habitat maps and to identify priority areas for restoration and conservation in the Seaflower
105   Biosphere Reserve. To describe the current benthic community of Quitasueño we used two
106   complementary approaches. A spatial approach involved the visual assessment of the percent
107   cover of benthic groups, and a temporal approach aimed to identify changes in the current
108   benthic cover compared to previous studies. For the later approach, we selected *Sánchez et al.*
109   *(2005)* to produce comparable data in time, due to a more detailed description made by these
110   authors about the fieldwork and data analysis procedures they followed, allowing us to replicate
111   their methods to a certain extent.
112
113   **Spatial scale**.
114   We used REA to record information on the percent cover of shallow benthic communities
115   (<30 m) following similar methods used by *Díaz et al. (1995)*; *Garzón-Ferreira & Pinzón (1999)*
116   and *Andréfoüet & Guzmán (2005).* The benthic groups included hard corals (C; Scleractinia and
117   Milleporidae), fleshy macroalgae (MALG), calcareous macroalgae (CALG), encrusting algae
118   (EALG), Cyanophyta algae (CYAN), octocorals (OCTO), sponges (SPG), and zoanthids
119   (ZOAN). During REA, two researchers visually estimated the percent cover of the benthic
120   community and photographed the most conspicuous benthic organisms in a radius of 6 m around
121   a marking point. The estimated percentages made by each researcher were averaged and
122   registered per station. Surveys included sites in reef terraces, lagoon basins, back reefs, and fore
123   reef terraces, attempting to cover the largest possible area and geomorphological traits of the reef
124   complex. Each station was georeferenced with a GPS and stations were classified according to
125   depth as follows: shallow (<8m), medium (8-12m), and deep (>12m).
126
127   **Statistical analysis**
128   The estimated percentages of benthic organisms considered during the REAs were
129   standardized to 100% and transformed to arcsine root (*Gotelli & Ellison, 2004*). To ascertain
130   how stations grouped depending on the visual percentages estimated in the field and identify
131   structure in our data, we performed a CLUSTER analysis based on a Bray-Curtis similarity
132   matrix and SIMPROF test following *Somerfield & Clarke (2013)*. The groups of stations formed
133   in the CLUSTER analysis were considered as a new factor of the data, which was then used to
134   perform a non-metric multidimensional scaling ordination analysis (nMDS) and a SIMPER
135   analysis to establish which benthic groups contributed the most to the clustered stations (*Clarke,*
136   *1993*). Finally, to visually assess how the primary benthic groups were spatially arranged, we

137 generated three maps; one with georeferenced stations classified according to the cluster results,
138 and two bubble maps to spatially represent the percent cover of the fleshy macroalgae and hard
139 corals across the bank. All the statistical analysis and figures were performed in Primer 6
140 (v.6.1.1.4), ArcGIS (v. 10.8), and R i386 (v. 4.1.3).
141
142 **Temporal scale**
143   We surveyed four stations with video transects using the Planar-Point-Intercept method
144 (PPI) (*Dodge, 1982*). In the field, 10 meters transects were placed at each station and the same
145 diver recorded the benthic composition with a video camera. Transects were conducted in depths
146 between 3 to 19m and were located on the lagoon terrace, lagoon basin, and reef terrace. The
147 video processing consisted of creating quadrants at each meter of both sides of the transects
148 using the metric tape as a reference and a grid of points separated every 10 cm, trying to closely
149 replicate the methods described by *Sánchez et al. (2005)*. As a result, 6070 points were
150 evaluated, which was equivalent to 607 linear meters with benthic cover evaluated every 10cm,
151 in contrast to the 7413 linear meters evaluated by *Sánchez et al., (2005)* in the 48 stations
152 considered. In addition, we used the same benthic categories used by *Sanchez et al. (2005)*
153 including hard corals (Scleractinia and Milleporidae), fleshy macroalgae (Macroalgae),
154 calcareous macroalgae, encrusting calcareous algae, filamentous algae, octocorals, erect sponges,
155 and encrusting sponges. Unlike *Sánchez et al. (2005),* the category "Other fleshy invertebrates"
156 was not included in this study.
157
158   To compare the percent cover among benthic communities back in 2003 and the observed
159 in 2021, we generated a similar boxplot chart to the one produced by *Sánchez et al. (2005)*. Since
160 we only evaluated four stations with PPI, we made a similar graph with percentage data obtained
161 in the 120 stations evaluated through REAs to complement the results obtained through PPI.
162 Although it was a different method than PPI (e.g., *Sanchez et al. 2005*), we decided to include
163 the box plot with the data obtained through REA because we cover the same habitat types (reef
164 terrace, lagoon basin, back reefs, and fore-reefs terrace) and depths (0-30m) (refer to Figure 5A
165 in *Sanchez et al.* (*2005*) to see the stations surveyed). However, caution is required in the
166 interpretation of this data as methods and sampling efforts differ between both studies.
167
168 **Conditions of degradation**
169   We evaluated photographs taken at each station to semi-quantify the conditions of
170 degradation within the complex. Such conditions included: [1] Current mortality; considered
171 whenever the coral tissue had recently died but the coral skeleton was visible and identifiable to
172 species level, [2] old mortality; when coral structures were covered with non-easily removed
173 organisms like sponges and algae; predation by mobile organisms (gastropods), [3] invasions;
174 when corals were covered or smothered by spongers or algae, [4] aggression; when corals were
175 in contact with algae, [5] presence of diseases, and [6] physical damage (turnover, scratches, and
176 sedimentation). We warn about the possible underestimation of the condition of degradation as

177 they are dependent on whether they were observed and photographed by the field researchers at
178 each station.
179

Results

Spatial scale

182   Stations were clustered into 11 groups based on the benthic coverage estimated. The most
183 frequently observed coral species were *Siderastrea siderea* (82%), followed by *Porites*
184 *astreoides* (71%), *Agaricia agaricites* (67%), *O. annularis* (56%), and *O. faveolata* (53%).
185 Algae and hard corals were the dominant benthic organisms except for group I, with octocorals
186 as the dominant component (Fig. 1). This was supported by the nMDS, which showed hard
187 corals and fleshy macroalgae as the benthic groups largely involved in the ordination of stations
188 (Fig. S1). Furthermore, in the group with the highest number of stations (Group B=50) the
189 SIMPER analysis showed that fleshy macroalgae contributed to over 78% of the similarity
190 between stations (Fig. 1-3A, Table S1). Group A was second in the number of stations (22), with
191 fleshy macroalgae contributing mostly to the similarity among stations (58%), and a greater
192 contribution of coral cover (24.08%) setting them apart from group B. Nine more stations
193 showed the highest coral cover, contributing to over 84% of the similarity among stations (group
194 J, Fig. 1).
195

196   Once the stations were represented on the map according to the groups formed by the
197 CLUSTER analysis, the configurations of the benthic community composition did not show to
198 be spatially arranged along the reef complex (Fig. 2A). For example, stations from group B
199 extended through the reef complex, covering habitats from the reef terrace, lagoon basin, back
200 reefs, and fore-reefs terrace. Likewise, the nine stations with a high coral cover (group J)
201 stretched along the complex near the reef crest, inside the lagoon basin, and on the reef terrace.
202 Moreover, we did not find a spatial pattern once we independently plotted the percent coverages
203 of the hard corals and fleshy macroalgae (Fig. 2B-C). This indicates that there was not a specific
204 area of the complex with higher percentages of either one of the dominant benthic groups. In one
205 hand, a high percent cover of fleshy macroalgae was found throughout the sampled area
206 independently of the habitat type (i.e., exposed habitats in the fore reefs and protected habitats in
207 the lagoon basin), and the different depths evaluated. On the other hand, the few places where we
208 found a high percentage of hard corals, were spread throughout the area also distributed in
209 exposed and protected habitats, however, it only covered depths shallower than 12 m.
210

Temporal scale

212   The comparison among benthic covers in Quitasueño surveyed by *Sánchez et al. (2005)*
213 and those surveyed in the present study, suggest an ongoing shift in community composition
214 within the atoll in the last two decades. Previously, corals appeared as the dominant benthic
215 group with the greatest percent cover (median around 30%) above fleshy macroalgae (~20%)
216 (*Sánchez et al., 2005*; Fig. 3A). Our results showed that fleshy macroalgae increased up to ~65%

217 and was the benthic group with the greatest percent cover in 2021, high above the hard corals
218 with a percent coverage median of around 10% (Fig. 3B). We found similar results when
219 analyzing the percent cover of the benthic groups through REAs (Fig. 3C). Although, for
220 methodological reasons the categories differ from those considered in the four stations evaluated
221 through PPI, some general considerations can be made, such as hard corals and fleshy
222 macroalgae as the most common groups in the benthic community. Likewise, the distribution of
223 percentages in both groups was similar, with most macroalgae cover ranging between 40 to 80%,
224 including some stations with up to 100% coverage and some others with almost no fleshy
225 macroalgae. The median percentage of hard coral cover (~20%) did seem to differ with the
226 stations evaluated through the PPI (~10%). However, it is still 10% lower than what was
227 reported by *Sánchez et al. (2005)* (Fig. 3A).

228

229 Conditions of degradation

230 The semi-quantification of conditions of degradation showed that Old Mortality and
231 Aggression by macroalgae were the most frequently observed conditions with 95% of stations
232 presenting them. Physical Damage was present in 87.5% of stations with turnovers, scratches,
233 and holes that looked as if scoops of ice cream had been scooped out (Fig. 4). These conditions
234 were followed by Invasions (65.8%), Current Mortality (51.7%), and Diseases (33%), including
235 white plague, and dark spot diseases, among others (Fig. 5). Finally, Predation by Mobile
236 Organisms was observed in 10 stations (8.3%) as only predation by gastropods was included,
237 usually *Cyphoma gibbosum* in octocorals (Table 1).

238

239 Discussion

240 Quitasueño reef complex goes through a decay process, with a sharp decline in coral
241 cover compared to previous studies (e.g., *Barrios 2000*, *Sánchez et al. 2005*). More than 20
242 years after the study by *Barrios (2000)*, the steady decline in Quitasueño coral reefs seems
243 evident. According to our observations on 120 stations evaluated along the reef complex, we can
244 claim it is currently dominated by macroalgae since only nine stations (7.5%) had a higher coral
245 cover compared to the other benthic categories evaluated. Moreover, the lack of spatial
246 distribution patterns according to the benthic community composition and the percentages of
247 hard corals and fleshy macroalgae, leads us to the belief that the degradation process is
248 widespread throughout the complex and not something that is happening in a specific area or
249 habitat.

250

251 Few stations with no apparent spatial pattern of distribution remained healthy and
252 surrounded by areas with high percentages of fleshy macroalgae. It is very important to address
253 specific drivers of damage to understand why some coral reef patches can maintain the
254 dominance of coral cover while being surrounded by a highly degraded coral ecosystem,
255 although it is known that coral reef degradation and phase shift are multidimensional processes
256 involving multiple states (*McManus & Polsenberg, 2004; Bruno et al., 2009*). This apparent

257   patchiness of healthy coral cover throughout the complex, with no evident structure, suggest a
258   loss in the reef complexity with coral reefs tending towards homogenization and becoming a
259   habitat dominated by fleshy macroalgae. The most common species of fleshy macroalgae were
260   *Lobophora* and *Dictyota,* which were also the two species dominating the macroalgae group in
261   *Sánchez et al. (2005*). Both algae species have shown a negative effect on the fecundity of reef-
262   building corals such as *Orbicella annularis* (*Foster et al., 2008*), which was among the dominant
263   species of hard corals registered by this study and by *Sánchez et al. (2005*) along with the other
264   species of the genera.
265
266   In addition, as the initial objective of the scientific expedition was to update the shallow
267   ecosystems maps (>30m), we found that areas that were previously reported as *Acropora*
268   *palmata-Pseudodiploria strigosa* (*Díaz et al., 2000;* INVEMAR-MINAMBIENTE, 2020) were
269   replaced by *Pseudodiploria strigosa-Porites astreoides (*INVEMAR-MINAMBIENTE-DIMAR-
270   CCO, 2021). In those areas, the contribution of *A. palmata* to the overall coral cover was very
271   low whereas *P. astreoides* was always present and abundant. As shown by our results, *P.*
272   *astreoides* was one of the most common species of hard corals observed in the stations evaluated,
273   as well as *A. agaricites*, and *S. siderea.* These species are known to cope better with
274   environmental changes (*Estrada-Saldivar et al., 2019*) and stressful agents such as sedimentation
275   (*Cuevas et al., 2009*). For instance, in the Greater Caribbean, there are reports of an increase in
276   the percent cover of *P. astreoides*, usually driven by a cover decline of reef-building species
277   (*Green, Edmunds & Carpenter, 2008*). Therefore, it is important to analyze the community
278   structure composition over time to identify changes related to environmental shifts and
279   detrimental conditions of reefs, and the data provided by us can be replicable to serve as a
280   baseline of information.
281
282   Despite not being able to make precise statistical comparisons over time due to the
283   difference in sampling effort with respect to *Sánchez et al. (2005)*, the results obtained through
284   PPI in the four stations suggest relevant changes in the composition of the benthic community.
285   This was validated by the similarity in the percent cover of fleshy macroalgae and hard corals
286   between the two methods employed in the present study (PPI vs. REA) (Figs. 3B-C). Currently,
287   not only fleshy macroalgae are more abundant than hard corals, but differences in cover among
288   both studies are fairly contrasting; for example, we found double macroalgae cover and less than
289   half of the coral cover previously reported (*Sánchez et al. 2005*).
290
291   Multiple stressors are radically changing coral reef ecology and functionality,
292   reconfiguring benthic assemblages and populations of various habitat-building coral species. A
293   recent study comparing the nearby atolls of Roncador and Serrana *(Sánchez et al. 2019)*
294   indicated that coral cover demise in Roncador has been replaced with higher cover of octocorals,
295   with minor change in the abundance of fleshy macroalgae. Nevertheless, their results suggested a
296   generalized deterioration of the reef complex with a possible phase shift to octocorals and algae

297 in Roncador. This is particularly evident within the Caribbean Region in shallow and exposed
298 fore-reef zones, where the diversity and biomass of gorgonian octocorals is higher than
299 scleractinian corals, particularly increasing in the last two decades (*Sánchez et al. 1998;*
300 *McManus & Polsenberg, 2004; Villamizar et al. 2013; Ruzicka et al. 2013*). In Quitasueño the
301 coral reef deterioration process looks different and is probably moving faster than in the other
302 two northern atolls of the Seaflower Biosphere Reserve.

303

Conclusions

305 Overall, our paper serves as baseline for current information about isolated reefs in the
306 wider Caribbean. The Rapid Ecological Assessments methodology efficiently allowed us to
307 collect information on over a hundred stations within an extensive reef complex in a short period
308 of time, making this study replicable and comparable for future studies so the reefs can be
309 monitored in time. Coral reefs in Quitasueño seem to be facing a state of fleshy macroalgae
310 dominance, very different from the coral dominance reported 20 years ago. Opportunistic
311 macroalgae such as *Lobophora* and *Dyctiota* are common, and several drivers of coral cover
312 decline such as diseases, aggression, invasion by macroalgae and sponges, and coral tissue
313 predation, among others. We did not see a clear pattern of spatial distribution of stations
314 regarding the percent cover of benthic classes, suggesting that the phase shift is taking place over
315 the entire coral reef complex. In consequence, a significant extension of Quitasueño seems
316 currently just a remnant of the exuberant reefs of yore, which are suffering a gradual and perhaps
317 irreversible decline possibly caused not by a sudden disturbance (i.e. hurricanes) but most likely
318 by a series of chronic stressors. Efforts to understand the reason for the apparent phase shift of
319 Quitasueño should be urgently made, such that coral decline drivers can be mitigated.

320

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328

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Figure 1

Classification analysis of the benthic community of Quitasueño

CLUSTER of similarity (Bray-Curtis) of 120 sampling stations in Quitasueño Bank (the 65% similarity line between groups is shown). The stacked bar chart shows the average cover for every benthic class. Hard corals (C; Scleractinia and Milleporidae), fleshy macroalgae (MALG), calcareous macroalgae (CALG), encrusting algae (EALG), Cyanophyta algae (CYAN), octocorals (OCTO), sponges (SPG) and zoanthids (ZOAN).

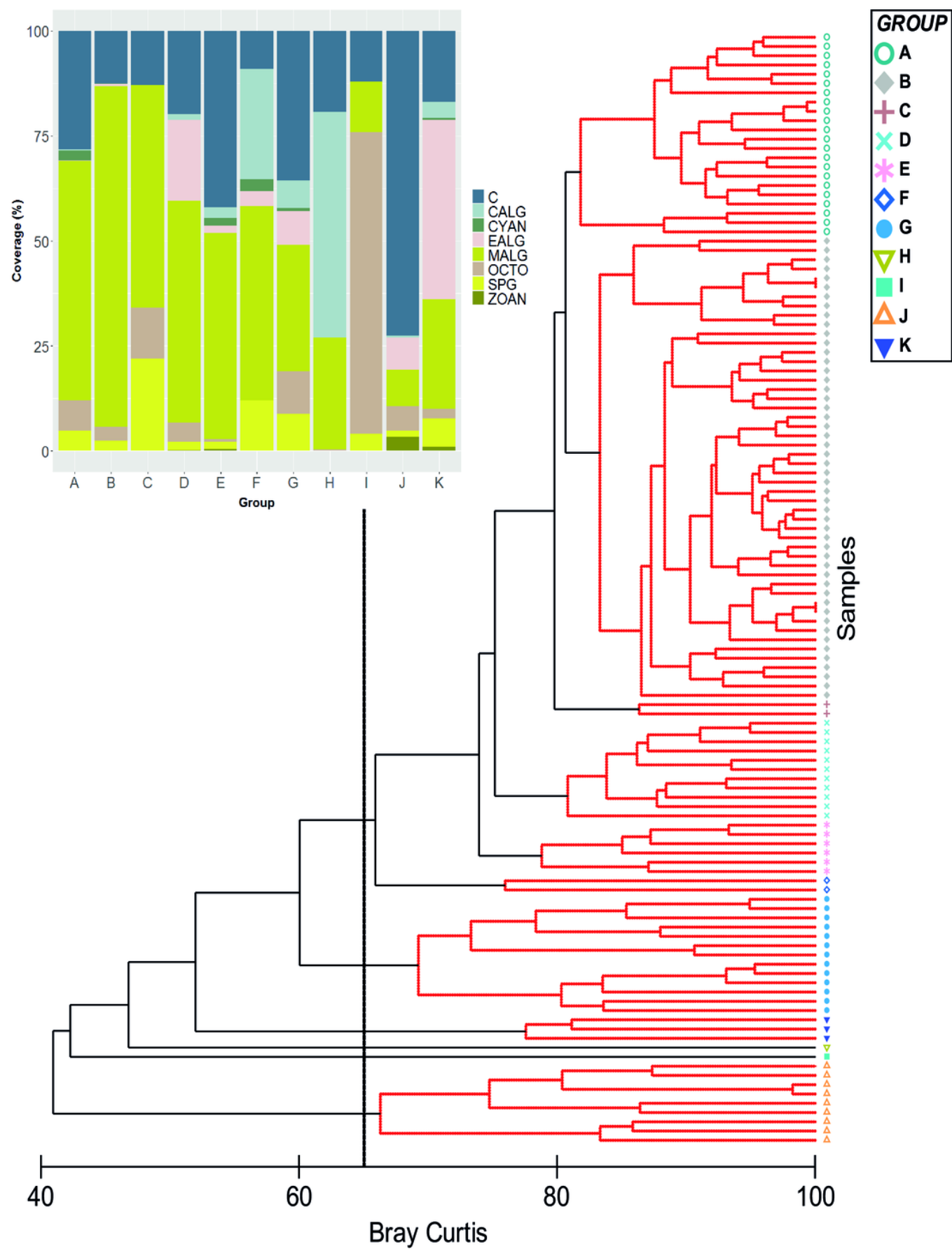



Figure 2

Spatialized data of the benthic community of Quitasueño.

(A) Georeferenced sampling stations evaluated by Rapid Ecological Assessment (REAs) in Quitasueño Bank. The stations are labeled according to the CLUSTER classification in Figure 1. The legend details the geomorphological units, and the four stations evaluated through Planar-Point-Intercept are highlighted with a star. (B-C) Bubble maps with the spatial location of the stations evaluated through REAs. Bubbles sizes represent the percentage of contribution of hard corals (B), and Macroalgae (C) and panel color shows the depths of the stations.

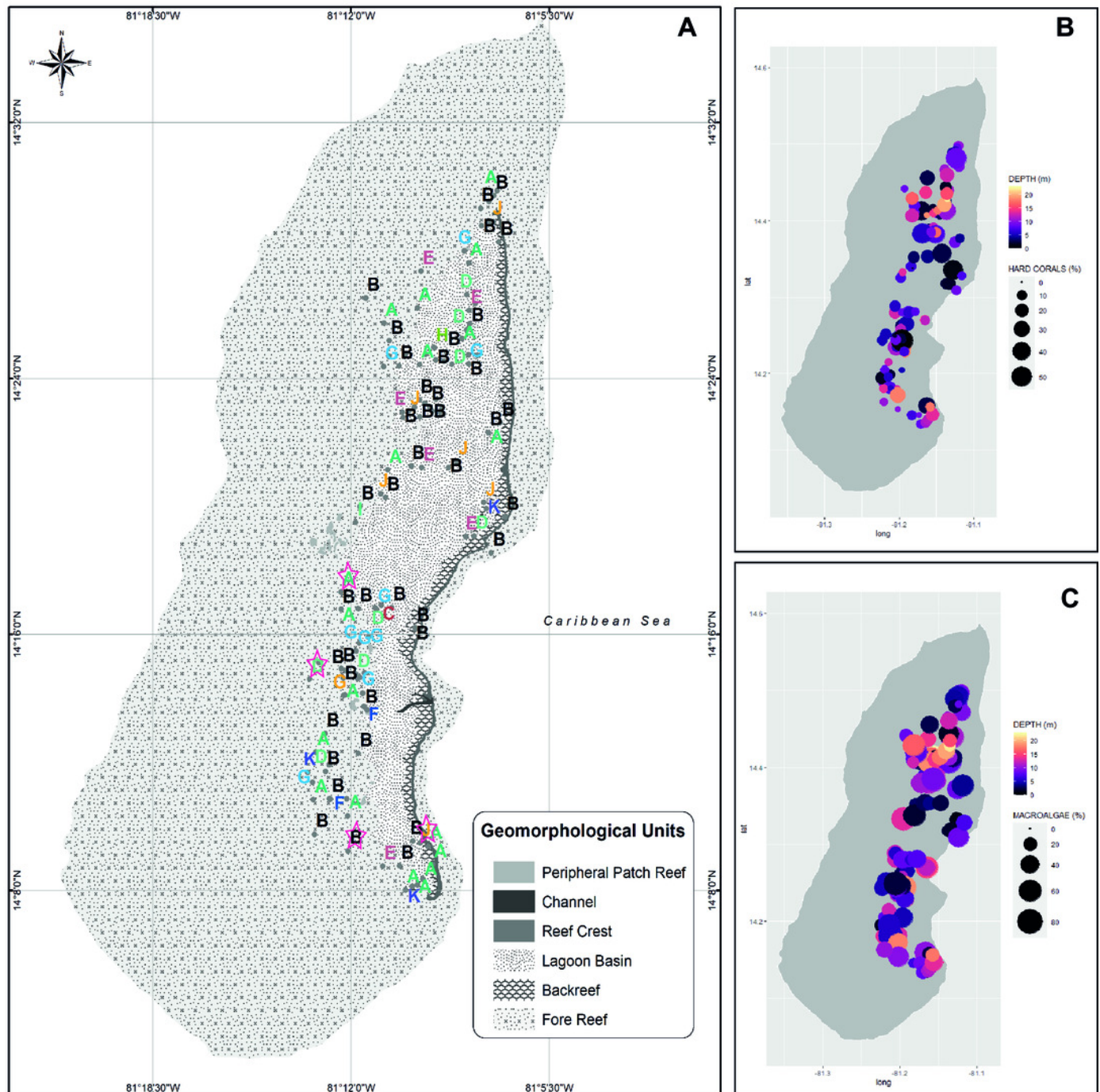
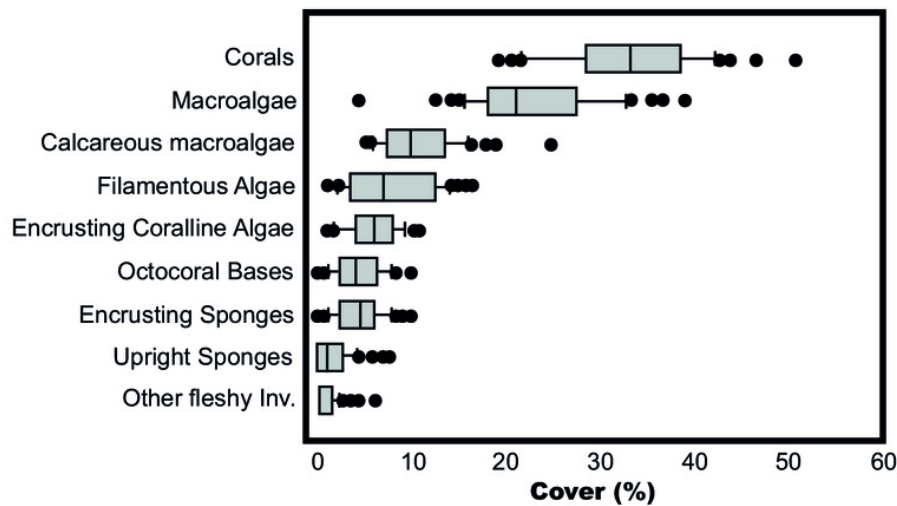
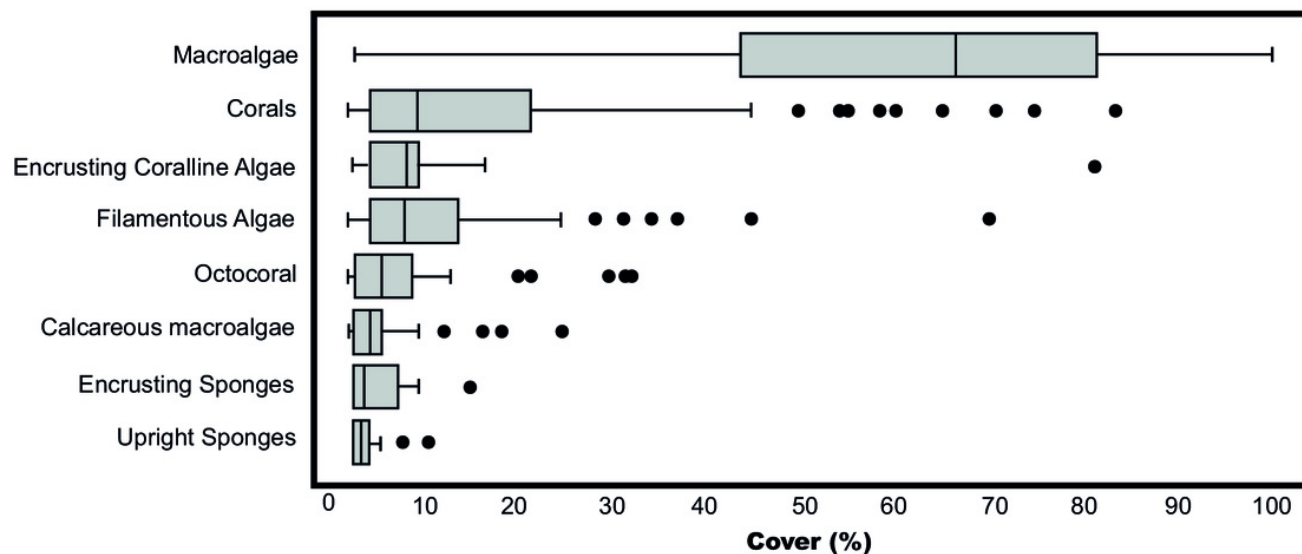



Figure 3

Cover percentage of the benthic groups of Quitasueño in 2000 and 2021.

(A) Boxplot adapted from Sánchez et al. (2005) (CC BY-NC 4.0). (B) Data from video-transects and Planar Point Intercept (PPI). (C) Data from Rapid Ecological Assessment (REA), both collected during the Seaflower Plus Scientific Expedition 2021.

A) 2000- Sánchez et al. (2005)

B) 2021-PPI

C) 2021-REA

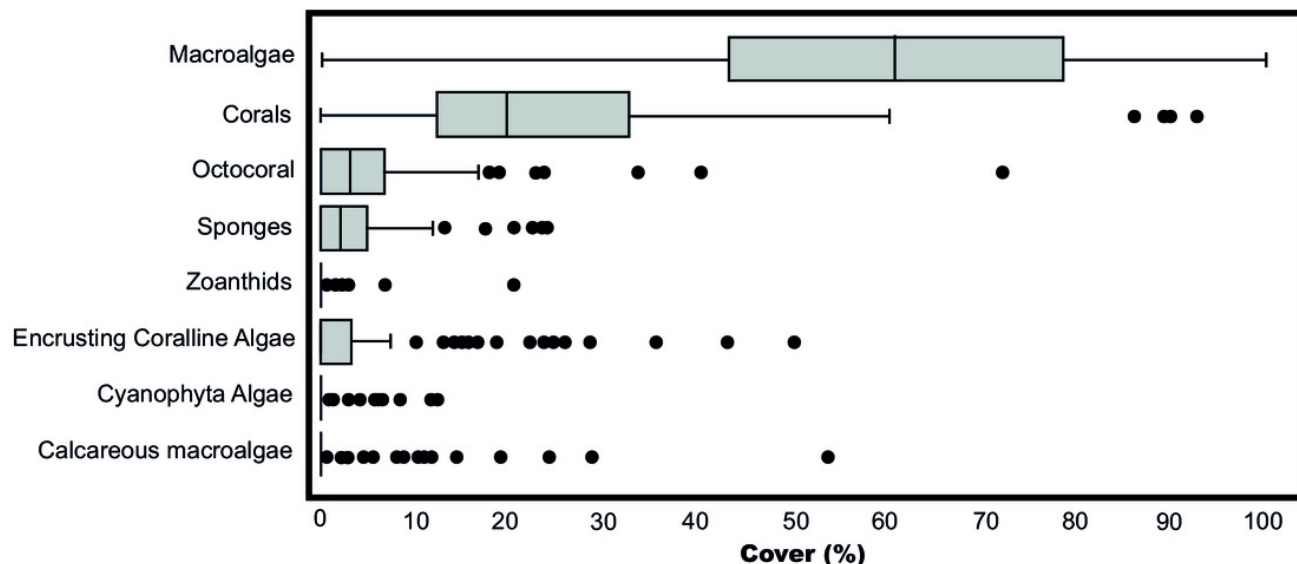



Figure 4

Evidence of conditions of degradation at coral reefs of Quitasueño

(A-B). Old Mortality, Current Mortality, and Aggression by macroalgae. (C-D). Physical Damage. (E) Invasions. (F) Predation. Photos were taken during the Seaflower Plus Scientific Expedition in November 2021.

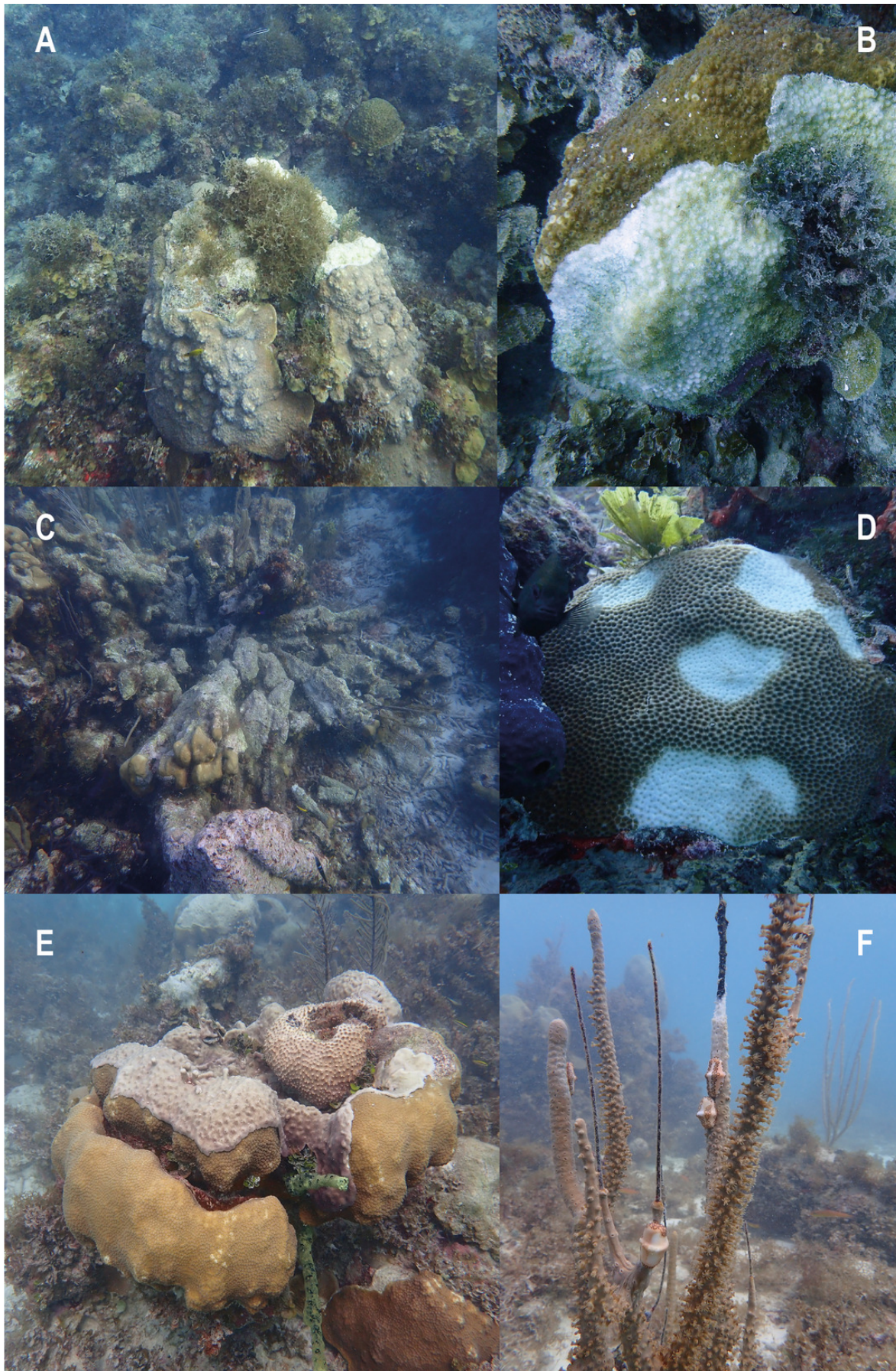
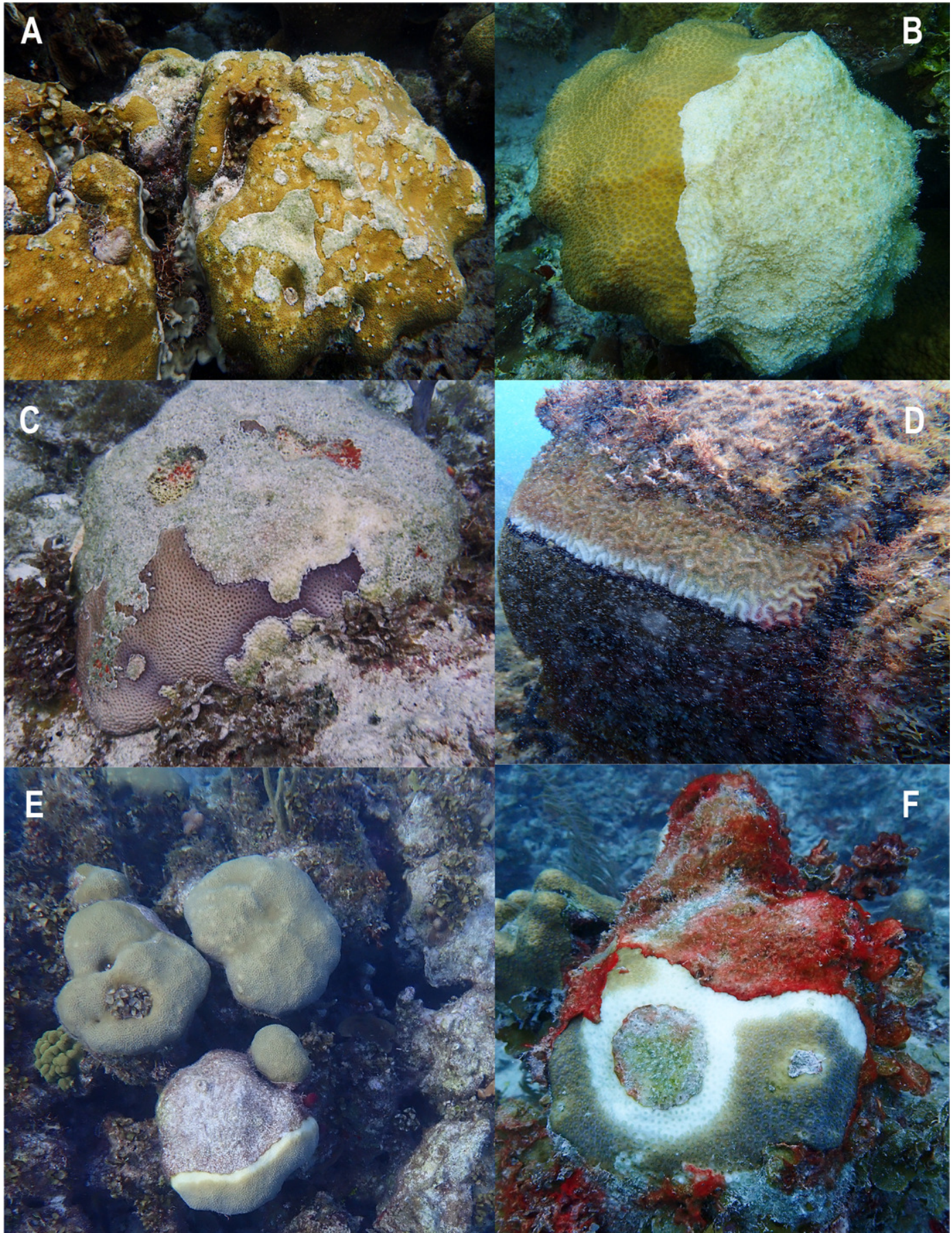



Figure 5

Evidence of Current Mortality and Diseases.

(A) The current mortality is possibly due to sediment damage. (B) The current mortality is possibly due to White Plage. (C) Black Band disease. (D) Dark Spot disease. (E-F) Caribbean Yellow Blotch disease.

Semi-quantification of conditions of degradations in Quitasueño

The number and percentage of stations presenting each condition are included.

1 **Table 1. Semi-quantification of conditions of degradations in Quitasueño.** The number and
2 percentage of stations presenting each condition are included.

Conditions of degradation	No. of stations	Percentage
Current Mortality	62	51.7
Old Mortality	115	95.3
Predation by Mobile Organisms	10	8.3
Invasions	79	65.8
Aggression	114	95
Diseases	33	27.5
Physical Damage	105	87.5