Supplemental Materials for Kim et al. 2022

1. Supplemental Tables

Table S1. An overview of coral disease prevalence from studies within the Coral Triangle. Few studies included compromised health states in the total 'health impacts' prevalence which were included where relevant. Disease and compromised health abbreviations are as follows: AA—algal abrasion; AtrN—Atramentous necrosis; BBD—Black band disease; BL—bleaching; BrB—Brown band disease; Gas—Growth anomalies; N—Necrotic syndrome; PR—Pigmentation Response; PUWS—Porites Ulcerative White Spot; SATL—Subacute tissue loss; SEB—Skeletal eroding band; SLT—silt damage; UWS—Ulcerative white spot; WP—White Plague; WS—White syndrome; YBD—Yellow band disease.

Location(s)	Diseases	Prevalence	Reference
Bali, Sulawesi, West Papua, Indonesia	BBD, BrB, GAs, SEB, WS	0.1 ± 0.09%–43.9 ± 5.1%	[166]
Spermonde Archipelago, Indonesia	BBD, BrB GAs, SEB, WS	1.6 ± 0.6%–5.9 ± 1.1%	[167]
Kepulauan Seribu Marine National Park, Indonesia	BBD, WS	<1% of each disease	[126]
Panjang Island, Indonesia	UWS, WP, YBD	UWS: 6.59 ± 0.08%; WP: 17.76 ± 8.6%; YBD: 2.88 ± 0.05%	[168]
Spermonde Archipelago, Indonesia	AtrN, BrB, GAs SEB, WS	<5% each disease	[127]
Wakatobi National Park, Indonesia	BBD, GAs, PUWS, WS	2005: 0.15% GAs, 0.42% WS 2007: 0.02% BBD, 0.05% GAs, 0.08% PUWS, 0.19% WS	[122,125]
Tubbataha Natural Marine Park, Philippines	BBD, BrB, GAs, SEB, UWS, WS	2.4 ± 0.1%–13.5 ± 5.4%	[169]
Cebu, Philippines	AA, BL, BBD, BrB, GA, PR, SATL, SLT, WS	12.5 ± 9.3%–34.4 ± 4.1%	[170]
Central Philippines	BBD, BrB, GAs, SEB, UWS, WS	0.25–7.9%	[31]
Philippines	Porites GAs, PUWS	GAs: 0–39.1% PUWS: 0–43.6%	[171]
Central Visayas, Lingayen Gulf, Philippines	GA, N, PR, PUWS, WS	8.3 ± 1.2%	[172]
Sumilon Island, Philippines	PUWS	0–72.6 ± 16.5%	[173]
Sabah, Borneo, Malaysia	AtrN, BBD, BrB, PR, WS	0–0.44 colonies per m^2	[174]

Table S2. Summary of Indo-Pacific studies assessing nutrients on reefs. DIN—dissolved inorganic nitrogen; TN—total nitrogen; TP—total phosphorus.

Location	Sampling Description	Nutrient	Concentration [μM]	Reference
West Hawaiʻi Island	Reef slope 12 m depth	NH_4^+	0.716 ± 0.22	[44]
		NO_3^-	0.38 ± 0.11	
		PO_4^{3-}	0.24 ± 0.07	
	Enriched experimentally	NH_4^+	148.80 ± 7.51	
		NO_3^-	94.35 ± 19.68	
		PO_4^{3-}	22.38 ± 2.06	
Florida Keys	5–6 m depth	DIN	1.15 ± 0.05	[37]
	Enriched experimentally	DIN	3.91 ± 1.34	
Kingman Atoll	10–12 m depth	DIN	1.3 ± 0.08	[42]
		PO_4^{3-}	0.1 ± 0.003	
Kiribati Atoll		DIN	3.6 ± 0.1	[42]
		PO_4^{3-}	0.3 ± 0.024	
Maui	Surface 0.25 m depth	DIN	0.1 ± 0.1–25.6 ± 17.8	[41]
		PO_4^{3-}	0.06 ± 0.06–0.43 ± 0.86	
	Coastal groundwater	DIN	1.6 ± 1.8–414.9 ± 37.8	
		PO_4^{3-}	1.01 ± 1.03–4.90 ± 1.06	
Philippines	1–3 m depth	TN	5.9–15	[171]
		TP	0.13–0.98	
Majuro Atoll	Reef flat	NH_4^+	0.34 ± 0.15	[43]
		NO_3^-	0.45 ± 0.45	
		PO_4^{3-}	0.34 ± 0.15	
	Ground water wells	NH_4^+	2.4–16.9	
		NO_3^-	49–1060	
		PO_4^{3-}	0.2–22.1	

Table S3. Description of coral diseases and compromised health found during surveys in Timor-Leste and references citing negative impacts to corals. Supplemental information to Figures 2 and A1.

Disease/Condition	Description
White Syndrome	A class of tissue loss disease-producing white symptoms in the Caribbean and the Indo-Pacific. White Syndrome (WS) describes corals with clearly defined lesion of exposed coral skeleton from the rapid sloughing of coral tissue ranging from 1.0 to 124.6 cm of tissue loss per day not associated with predation (*Drupella* spp. snails or crown-of-thorns sea stars [COTS]). In the Indo-Pacific, WS predominantly affects tabulate acroporids [26,29,132,175].
Growth Anomalies	Gross lesions of raised tissue with lighter pigmentation and enlarged variable polyps affecting several coral genera [176]. Energetically, GAs rely on resources from surrounding healthy tissue [177].
Trematodiasis	Pink, swollen nodules caused by infection of a larval trematode in *Porites* corals that can reduce colony growth [178,179].
Burrowing/Tube-dwelling Invertebrates	Invertebrates (polychaete worms [180,181], crustaceans [180], bivalves [182], gastropods [91], etc. [182]) that burrow into the surface of corals. Such interactions have been demonstrated to alter coral morphology (furrows) that could impact growth, fecundity, and morality [180]; and reduced skeletal strength in host corals [182].
Flatworm Infestation	An infestation of flatworms, typically *Waminoa* spp., on the surface of corals. Infestation has been associated with tissue loss [183], reduced heterotrophic feeding [139], light-shading [137,184], and experimentally shown to feed on coral mucus [138].
Predation	Scars or tissue loss from predation by *Drupella* spp. snails, COTS, and reef fishes [185]. Typically, invertebrate predators and reef fishes make distinctive lesions.
Tissue Loss	Unexplained tissue loss (absence of predator, shape of lesion, etc.) by infectious agents, physiologic disorders, or toxins [176,185].
Crustose Coralline Algae (CCA) Overgrowth	CCA in competition with living coral causing a reaction (pigmentation) or overgrowing the coral. Two species of CCA *(Pneophyllum conicum*, *Lithoamnion* spp.) have been identified to overgrow live coral in the Indo-Pacific [186,187].
Cyanobacteria and Turf Overgrowth	Cyanobacterial filaments or filamentous turf algae competing with or growing on living coral tissue. Cyanobacteria are often associated with increasing nutrients, smothering of corals [188], and reducing coral recruitment [189]. Decreased coral function such as decreased zooxanthellae density and tissue thickness have been associated with turf–coral interactions [190].
Sponge or Tunicate Overgrowth	Sponge overgrowth on live coral tissue can negatively affect corals [191] with some aggressive species such as *Terpios* spp. and *Cliona* spp. killing corals [192]. Colonial tunicates can also smothering live coral [193–195]. Although there are several bioeroding sponges (*Cliona* spp.), they are typically easy to visually identify on the surface of the coral colony compared to other burrowing invertebrates and have been classified separately.
Pigmentation response	Pigmented edge of a coral lesion which may be swollen, form bumps, or irregular shapes. Potentially caused by borers, competitors, breakage, cyanobacteria [196], polychaetes, and/or molluscs [26].

Table S4. Site and transect GPS points of coral surveys and seawater sampling at four sites in Timor-Leste. Coral surveys were conducted in Nov 2015 and Jul 2017 while seawater and macroalgae were only collected in 2015 for nutrient analysis.

		Transect 1	Transect 2	Transect 3
Rural-N	5 m	8°13′26.03″ S, 125°37′2.03″ E	8°13′27.56″ S, 125°36′59.53″ E	8°13′25.22″ S, 125°37′3.83″ E
	10 m	8°13′26.5″ S, 125°37′2.93″ E	8°13′28.51″ S, 125°36′59.52″ E	8°13′25.63″ S, 125°37′4.25″ E
Rural-E	5 m	8°28′30.77″ S, 125°53′17.01″ E	8°28′28.82″ S, 125°53′14.82″ E	8°28′29.23″ S, 125°53′15.67″ E
	10 m	8°28′31.08″ S, 125°53′17.36″ E	8°28′30.74″ S, 125°53′17.41″ E	8°28′29.71″ S, 125°53′17.46″ E
Urban-W	5 m	8°33′19.74″ S, 125°30′0.41″ E	8°33′18.72″ S, 125°29′59.46″ E	8°33′18.28″ S, 125°29′56.95″ E
	10 m	8°33′18.85″ S, 125°30′0.57″ E	8°33′17.04″ S, 125°29′57.27″ E	8°33′17.88″ S, 125°30′0.03″ E
Urban-E	5 m	8°31′28.68″ S, 125°36′29.00″ E	8°31′29.82″ S, 125°36′30.07″ E	8°31′31.87″ S, 125°36′30.76″ E
	10 m	8°31′28.26″ S, 125°36′28.33″ E	8°31′29.80″ S, 125°36′29.32″ E	8°28′27.94″ S, 125°53′15.49″ E

Table S5. Mean (±SE) percent coral cover, diseased corals, and corals exhibiting signs of compromised health, average number of genera, density of hard corals (colonies/m^2), total number of colonies surveyed on 15 × 2 m belt transects per site and depth. Abbreviations as follows: % Coral—percent live hard coral cover; % Disease—disease prevalence; % Comp—compromised health prevalence; # Genera—number of genera; Density col/m^2—density of hard coral colonies per square meter; # Colonies—total number of hard coral colonies. All values are meaned across survey years.

Site/ Depth	% Coral	% Disease	% Comp	# Genera	Density col/m^2	# Colonies
Rural-N 5 m	47.78 ± 5.84	1.22 ± 0.19	22.22 ± 1.49	30.5 ± 1.4	12.7	761 ± 88
10 m	49.71 ± 4.38	0.79 ± 0.37	21.33 ± 1.73	32.8 ± 1.7	10.8	647 ± 61
Rural-E 5 m	16.27 ± 3.13	0.09 ± 0.09	49.17 ± 2.70	29.7 ± 1.0	8.6	516 ± 50
10 m	32.37 ± 4.85	0.40 ± 0.20	31.31 ± 3.51	29.0 ± 1.5	7.7	460 ± 67
Urban-W 5 m	4.66 ± 1.05	0.44 ± 0.30	42.45 ± 2.70	24.7 ± 1.7	5.2	315 ± 10
10 m	32.67 ± 8.37	0.66 ± 0.32	30.52 ± 5.57	18.00 ± 2.2	8.1	488 ± 76
Urban-E 5 m	22.01 ± 5.28	0.46 ± 0.23	38.50 ± 1.16	26.5 ± 2.3	9.6	578 ± 39
10 m	9.08 ± 2.14	0.42 ± 0.09	34.24 ± 2.49	27.5 ± 2.2	7.9	472 ± 5

Table S6. Average seawater nutrient values from samples collected in triplicate from transects at four sites in Timor-Leste in 2015. DIN is the sum of NH_4^+, NO_2^-, and NO_3^-. All units are in μM.

Site	Depth	DIN	NH_4^+	NO_2^- + NO_3^-	PO_4^+
Rural-E	5 m	1.87 ± 0.31	0.00 ± 0.00	0.80 ± 0.17	0.00 ± 0.00
Rural-E	10 m	1.9 ± 0.49	1.35 ± 0.52	0.55 ± 0.06	0.09 ± 0.00
Rural-N	5 m	2.19 ± 0.51	1.69 ± 0.49	0.51 ± 0.07	0.10 ± 0.01
Rural-N	10 m	3.39 ± 0.62	2.34 ± 0.61	1.05 ± 0.07	0.15 ± 0.01
Urban-E	5 m	3.4 ± 0.78	2.69 ± 0.78	0.71 ± 0.07	0.11 ± 0.00
Urban-E	10 m	1.78 ± 0.16	1.32 ± 0.17	0.46 ± 0.09	0.10 ± 0.00
Urban-W	5 m	2.31 ± 0.66	1.81 ± 0.60	0.50 ± 0.08	0.10 ± 0.01
Urban-W	10 m	2.79 ± 0.62	2.41 ± 0.60	0.37 ± 0.05	0.09 ± 0.00

Table S7. N% and C:N ratio ANOVA results of two genera of algae sampled in replicates at the four sites (Urban-W, Urban-E, Rural-N, Rural-E), two depths (5 m and 10 m), and three transects per depth in Timor-Leste in 2015. Starred values are significant results with mean, standard error (SE), and post hoc groupings presented per site. No *Chlorodesmis* spp. was sampled at Rural-N or Rural-E at 10 m and the three samples collected from a single transect at Rural-E 5 m were removed for the ANOVAs. df—degrees of freedom.

***Halimeda* spp.**		**df**	**F-Value**	***p*-Value**		**Rural-E**	**Rural-N**	**Urban-E**	**Urban-W**
N%	Site	3	5.779	0.0011 *	mean	0.62%	0.82%	0.48%	0.76%
log10	Depth	1	0.2103	0.6475	SE	0.06	0.08	0.02	0.07
	Site × Depth	3	1.06	0.3698	groups	ab	b	a	b
C:N	Site	3	3.3989	0.0207 *	mean	28.24	24.77	31.56	25.02
	Depth	1	0.0687	0.7938	SE	1.96	1.98	1.30	1.62
	Site × Depth	3	1.2926	0.2811	groups	ab	b	a	b
***Chlorodesmis* spp.**									
N%	Site	1	6.0924	0.0261 *	mean	2.63%	-	3.31%	2.36%
	Depth	1	0.3489	0.5635	SE	0.18		0.18	0.29
	Site × Depth	1	0.3849	0.5443	groups			b	a
C:N	Site	1	4.2869	0.0561	mean	11.78	-	9.71	10.95
	Depth	1	6.0953	0.0261 *	SE	0.87		0.19	0.64
	Site × Depth	1	1.6411	0.2196	groups			a	b

2. Additional nutrient data

Nutrients measured in the Laclo river (Manatuto district east of Dili) in 2006 indicated low levels of pollution from sewage and fertilizer [22]. The report concluded that nutrient levels in Laclo were comparable to other tropical rivers [197–199] and tidal seawater samples were similar to unpolluted mangrove sampling in Australia [200]. Ammonium decreased from 4 μM approximately 10 km upstream from the mouth of the Laclo, to ~2 μM at the mouth, and then to <1 μM about 20 km west of the mouth in Metinaro. Combined nitrate and nitrite dropped from >8 μM to almost zero from the river mouth to Metinaro. There was a similar pattern with phosphate concentrations of 0.5 μM in the Laclo which dropped to 0.05 μM in Metinaro (Table S9). Located 12 km from the mouth of the Laclo, Rural-E at Manatuto was approximately half-way between the mouth of the Laclo River and Metinaro. Seawater nutrient samples at Rural-N 5 m were in-between values sampled at the Laclo River and Metinaro (Table S9). It is difficult to draw conclusions based on these limited nutrient measurements with 10 years between studies and different sampling locations (riverine and coastal versus 5 m depth on the reef). Additionally, the extent to which riverine outputs affect the downstream coast is not known. However, both surveys were taken during the dry season and though based on the limited evidence, it does not appear that nutrients on the reef at Rural-E are greatly elevated by anthropogenic inputs.

Table S8. Nutrients from water samples collected in the Laclo River and Metinaro in 2006 (adapted from [22], permission by Dr. Daniel Alongi) and from Rural-E at 5 m depth in 2015 which is approximately half-way between the mouth of the Laclo and Metinaro in Timor-Leste.

Site	**NH_4^+ μM**	**NO_2^- + NO_3^- μM**	**PO_4^{3-} μM**
Laclo River Upstream	4.04 ± 0.93	8.22 ± 0.38	0.49 ± 0.09
Laclo River Mouth	1.98 ± 1.03	8.65 ± 1.32	0.54 ± 0.01
Rural-E at 5 m (12 km from mouth)	1.20 ± 0.28	0.90 ± 0.16	0.11 ± 0.01
Metinaro (20 km from mouth)	0.80 ± 0.09	0.05 ± 0.00	0.05 ± 0.01

3. Supplemental Figures

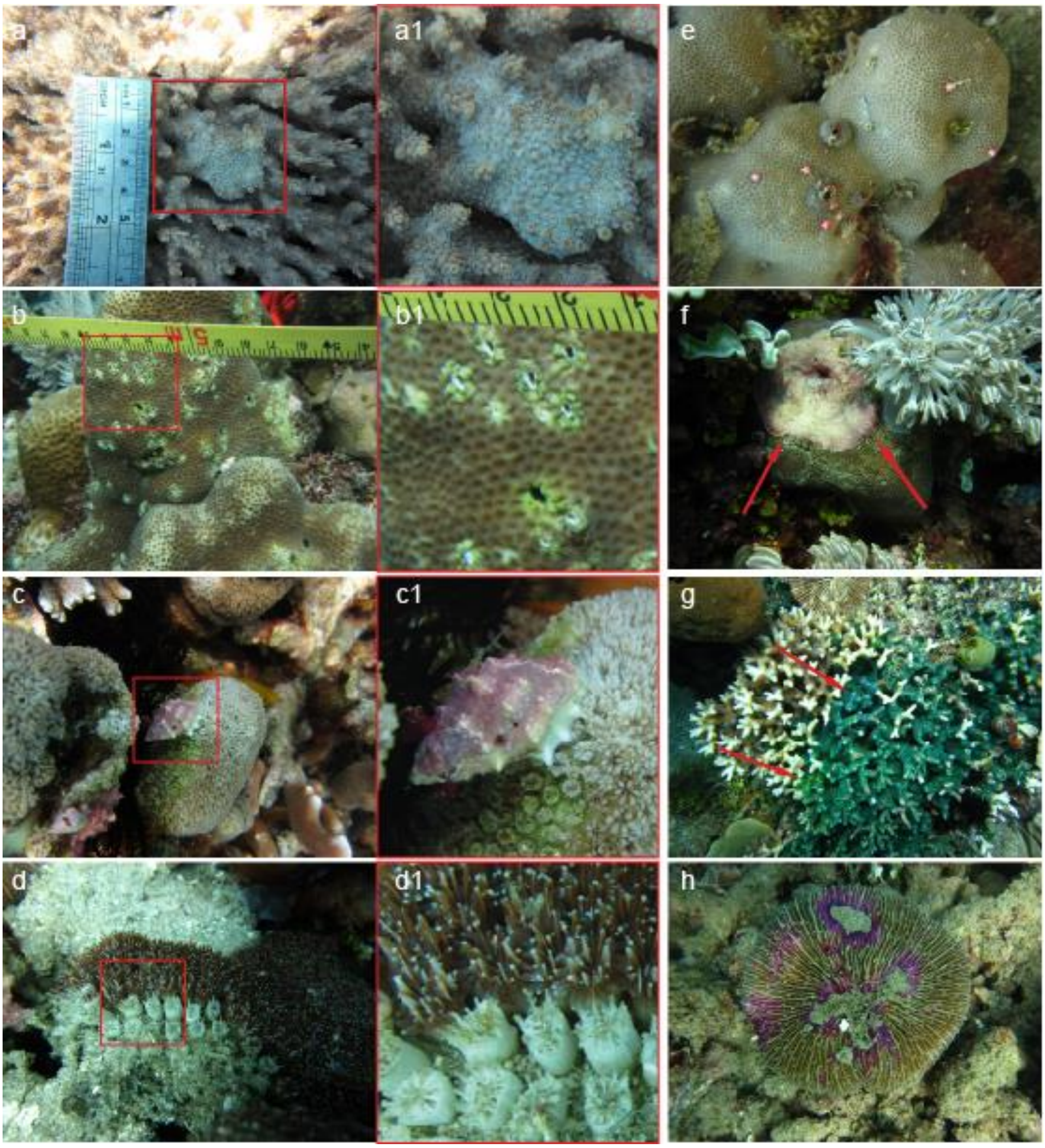

Figure S1. Disease and compromised health states found during 15 × 2 m belt transect surveys in Nov 2015 and Jul 2017 at four sites (Rural-N, Rural-E, Urban-W, Urban-E) in Timor-Leste. Red boxes indicate enlarged section of the corresponding picture (a1, b1, c1, and d1): (**a**) GA—growth anomalies; (**b**) burrowing invertebrates; (**c**) *Drupella* spp. snail predation; (**d**) TL-unexplained tissue loss; (**e**) potential Trematodiasis; (**f**) crustose coralline algae overgrowth; (**g**) tunicate overgrowth; and (**h**) pigmentation response.

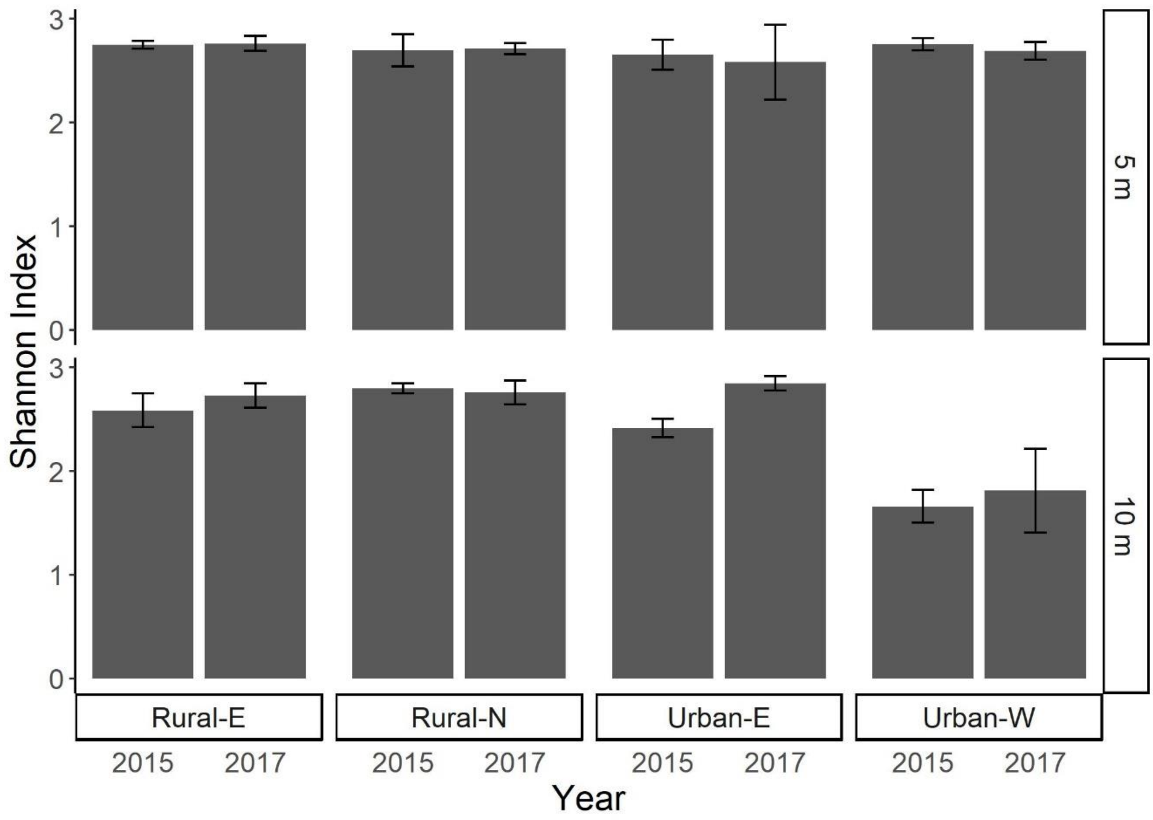

Figure S2. Shannon diversity index calculated per site (Rural-N, Rural-E, Urban-W, Urban-E) and depth (5 and 10 m) on genera present per belt transect in Timor-Leste. Sites on the *x*-axis are split into the 2015 and 2017 survey periods. Error bars represent standard error.

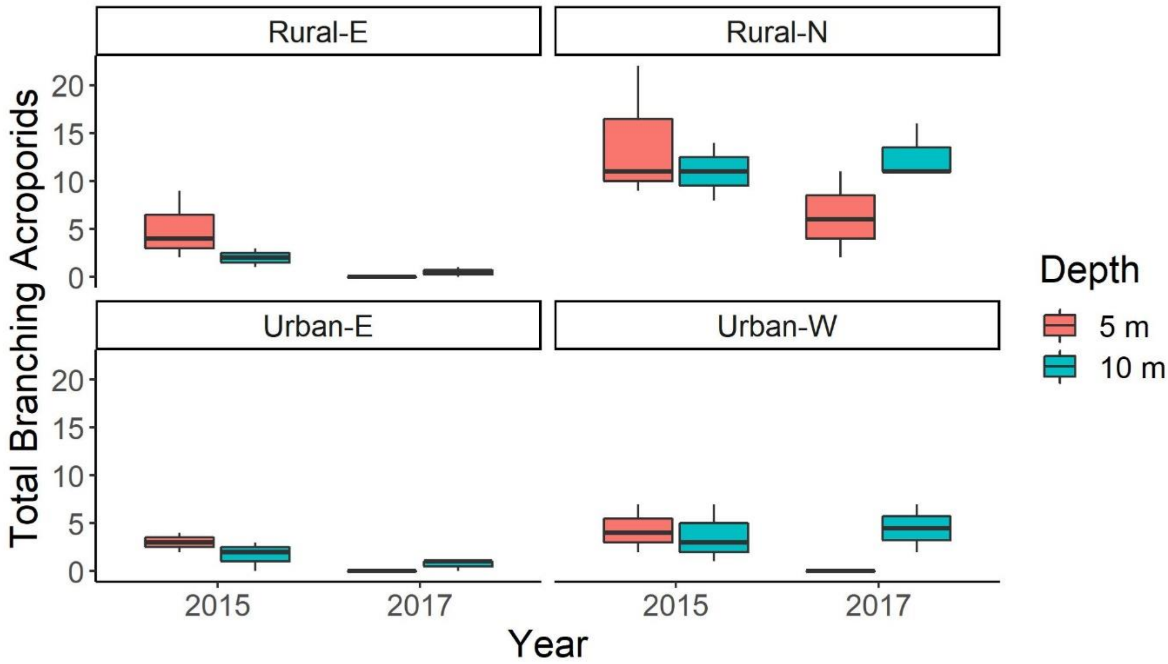

Figure S3. Boxplot of the count of branching Acroporids from the coral health 15 × 2 belt transects split by site, depth, and year. The bold black bar represents the median while the upper and lower hinge represents 75% and 25% quantiles, respectively.

Figure S4. Gleaning and recreational activity at Urban-W site in Timor-Leste during the 2015 surveys. Urban-W is in the Dom Alexio subdistrict of Dili which had a population density of 4993.0 people per km^2 in the 2015 Timor-Leste census. Comparatively, the national population density is 79.3 people per km^2. This beach was within walking distance to densely populated neighborhoods and very popular for swimming, fishing, and gleaning which likely has impacted the shallow-water coral reefs. Women can be seen in the foreground gleaning and children playing on the reef flat further offshore.

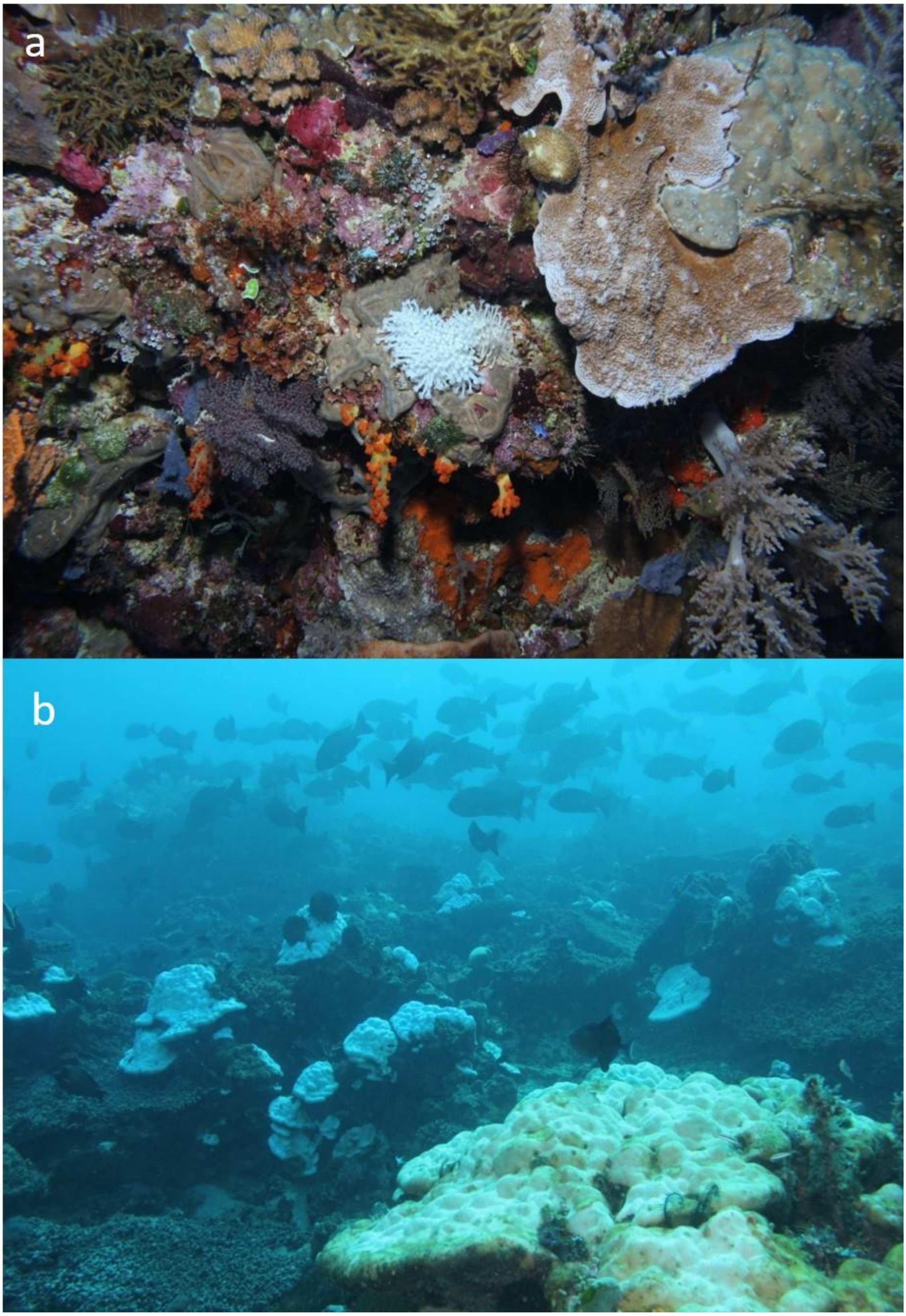

Figure S5. Photos by Tony Crean, a local dive operator, emailed on 31 May 2016. (**a**) Bleached *Goniopora* spp. at Adara on the west coast of Ataúro Island. An estimated 90% of *Goniopora* spp. were bleached with no other hard corals affected on Ataúro Island reefs. Depth of the photo unknown. (**b**) Image taken at Jaco Island, the easternmost point of Timor-Leste, showing bleached massive *Porites* spp. corals. The observer indicated that there was a similar percent of corals bleached from 5–18 m.