THE IMPACT OF TYPHOON URSULA ON THE REEFS OF DAANBANTAYAN (DEC 2019)

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EXECUTIVE SUMMARY

Early on the morning of Christmas Day 2019, Typhoon Ursula (or Phanfone) passed through the Philippines with wind speeds of up to 175 km/h, leaving a trail of destruction in its wake. The Visayas, and the north of the Province of Cebu in particular, were among the most impacted landscapes and communities. But typhoon Ursula did not only leave its mark on infrastructures on land, its affects were also felt by seascapes throughout the region.

A rapid assessment of the damages of Ursula on coral reefs surrounding Malapascua was conducted in January and February 2020 on 18 sites around Malapascua, Campatoc Shoal (north-east of the island of Cebu), and Carnaza. The objectives of these surveys were (*i*) to assess the extent and intensity of damages on the reefs; (*ii*) determine which coral forms and genus were the most affected; and (*iii*) draw implications regarding the potential of the reefs to recover from the damages.

A total of 72 surveys were conducted by People and the Sea scientific divers to record the intensity and extent of coral damages, using a methodology based on the Reef Health and Impact Survey (RHIS) protocol developed by the Great Barrier Reef Marine Park Authority (GBRMPA). Data on benthic cover, as well as coral growth forms and genus affected by the damages, were also recorded.

Observations showed evidences of typhoon damage on coral reefs up to 20 metres below the surface. The assessment results showed widespread damages on the shallow reefs surrounding Malapascua and Campatoc Shoal, and lowest damage levels around Carnaza, approximately 18km to the north. The level of destruction decreased with the depth, but was highly variable between reefs. Most shallow reefs displayed extensive damage to corals (especially branching, table and foliose growth forms), and the most affected sites also showed dislodgement of large coral colonies and structural damage to the reef framework, inducing an important decrease of coral cover and habitat complexity.

Recovery from such a strong natural disturbance is a slow process, with an estimated timeline of around ten years to get back to initial values of coral cover and biodiversity. Since the economy of Malapascua is heavily dependent on healthy reefs, both for tourism and fishing, it is necessary to maximise the resilience potential of coral reefs. Hence, it is particularly crucial to limit other human-induced coral stressors in order to allow reefs to heal from the damage inflicted by Ursula. Long-term monitoring should be continued to measure the recovery of the reefs and inform marine resource management. More than ever, a hand-in-hand collaboration is required between all stakeholders, from the community, tourism industry, government and science, to give the best possible chances to our coral reefs to recover.

INTRODUCTION

On the night of December 24th 2019, Typhoon Ursula (internationally called Phanfone) passed through the Visayas region of the Philippines (Figure 1), after making a first landfall in Eastern Samar. Initially classified as a tropical storm, Ursula intensified to typhoon status shortly before making its first landfall. Further intensification ensued until December 25th, peaking at 00:00 UTC with 175 km/h 1-minute sustained winds and a central pressure dropping to 970hPa (National Institute of Informatics 2020). These attributes classify Ursula as a Category 2 typhoon according to the Saffir-Simpson Hurricane Wind Scale (NOAA 2020).

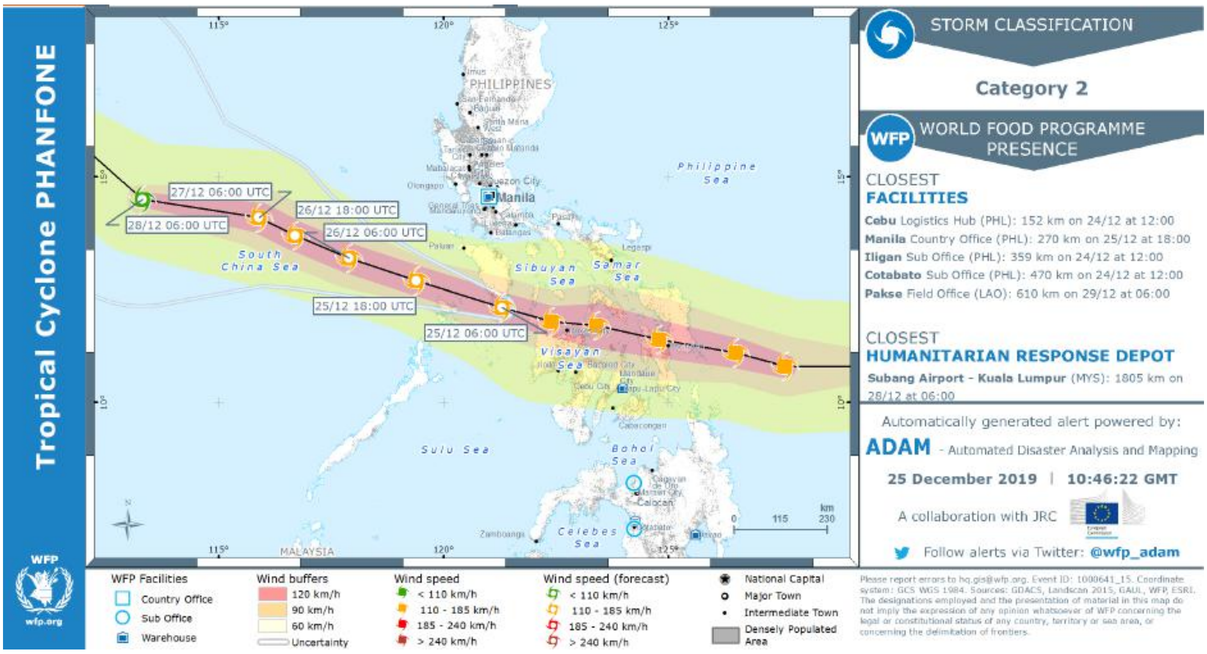


Figure 1. Map from the Global Disaster Alert and Coordination System showing the track of typhoon Ursula across the Philippines (GDACS 2020).

Ursula wreaked extensive damage to infrastructure and agriculture across the country, with an estimated cost of ₱3.43 billion (CNN Philippines 2020). According to the National Disaster Risk Reduction and Management Council (NDRRMC) the death toll was 50, and a total of 600,142 families (over 2.4 million individuals) were affected by the typhoon in five regions of the Philippines (CNN Philippines 2020).

Specifically, Cebu province estimated the cost of its damages at ₱300 million, and the Office of Civil Defense (OCD)-Central Visayas claimed that about 65,000 people across 14 local government units (LGUs) had been affected by the storm that toppled power lines, houses and trees (Cebu Daily News 2020). The fishing sector also felt the force of Ursula, with an estimated 255 fishermen from northern Cebu affected by the typhoon, according to BFAR-Central Visayas spokesperson Alma Saavedra (Sunstar Journal 2019).

Malapascua is part of the Municipality of Daanbantayan, located at the northern tip of Cebu. With the eye of the typhoon passed over that area at its peak (Figure 2), Daanbantayan was among the most affected zones, with losses estimated at ₱17 million, mostly related to crops and fishing industry losses (Cebu Daily News 2020).An ocular inspection conducted by Daanbantayan Mayor Sun Shimura, on December 27 (Cebu Daily News 2020) concluded that 6,000 homes across the Municipality were destroyed while another 9,765 were damaged. A special session of the Daanbantayan council declared a State of Calamity, allowing the LGU to access part of the Local Disaster Risk Reduction and Management (LDRRM) fund, in order to help reconstruction (Cebu Daily News 2020).

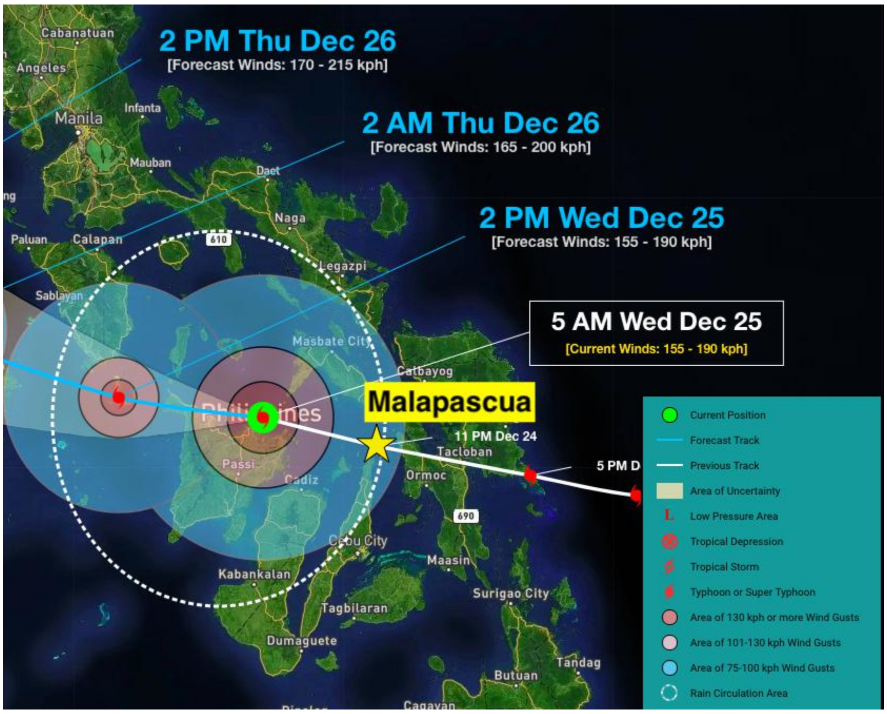


Figure 2. Map from Weather Philippines Foundation showing the position of Malapascua on the track of Ursula (Michael 2019).

The Philippines span an area prone to such dramatic weather events , with an average of 20 typhoons every year - five of which are destructive (ADRC 2019). In particular, Malapascua has been heavily impacted in the recent past by Super-Typhoons Yolanda and Ruby in 2013 and 2014 respectively. In addition to extensive terrestrial damage, typhoons cause broad damage to coral reefs. Indeed, the surge and currents generated by the winds can cause severe and widespread destruction of coral colonies, reductions in live coral cover, and impact reef organisms and underlying substrate (Beeden et al. 2015; Anticamara and Go 2017). However, damages are usually highly variable between reefs, due to differences in exposure to wind and surge, as well as differences in the sensitivity of the reef organisms and 3-D structures. Even in exposed areas, there are often reefs that suffer only minor damage (Puotinen 2007; Beeden et al. 2015).

As typhoons are expected to increase in magnitude and frequency in the future (Woolsey et al. 2012), understanding the impacts and implications of such events is essential to the development of management strategies supporting the resilience of the reef ecosystem and fishing industries in the face of climate change. This report presents the results of surveys conducted to assess the severity of physical damage caused by Ursula to the coral reefs surrounding Malapascua.

IMPACT ASSESSMENT METHODOLOGY

The rapid assessment of typhoon damage used a methodology based on the Reef Health and Impact Survey (RHIS) protocol developed by the Great Barrier Reef Marine Park Authority (GBRMPA) to collect 'standardized, quantifiable reef health data suitable for rapid assessment of the impact of events such as flooding, coral bleaching, disease, predation and tropical cyclones (e.g. event severity and extent) as well as human impacts such as anchor damage'. A similar methodology was used to assess the damages of Typhoons Yasi and Ingrid on the Great Barrier Reef (Great Barrier Reef Marine Park Authority 2011; Beeden et al. 2015; Fabricius et al. 2008).

Between 15 January and 14 February 2020 (less than seven weeks after Typhoon Ursula), 72 surveys were conducted on 18 reefs around Malapascua, Campatoc Shoal and Carnaza (Figure 3). All surveys have been conducted by the same four members of People and the Sea's marine biologist team in order to minimise observer bias. Reefs were selected to represent the range of wind exposure levels and various depths. Surveys also targeted sites that were part of People and the Sea's ongoing monitoring programme in order to use these data for the longer-term assessment of reef health and resilience.

For each site, divers completed four surveys assessing the extent and severity of typhoon damages to the reef. For each survey, a team of two surveyors recorded typhoon damage over randomly selected circle plots of five-metre radius (78.5 m^2). On the selected reef site, observers swam 20 fin kicks following a randomly selected compass bearing to select the plot. To delimit the survey area, two 10-metre tapes were laid down to form a cross. The two observers swam half of the circle each, while looking into the survey area to estimate the damages to corals. The average of the data collected by both observers was then calculated to provide an estimate of damage extent and severity per plot.

The extent of the damage was recorded as the proportion of coral cover affected within the survey area, while severity of the damage was evaluated using categories: Category 1 = colony tips / edges; Category 2 = colony parts / branches; Category 3 = whole colonies.

To integrate these extent and severity scores for each survey, we used the 'Damage Impact Matrix' (Table 1) developed by Beeden et al. (2015). Six 'Damage Level Indices (DLI)' are used to encapsulate both colony and structural damages. Level 0 indicates no damage, Levels 1 and 2 indicate damages to colony only, whereas Levels 3, 4 and 5 indicate an increasing extent of colony mortality and reef structural damage. These six levels are further detailed and represented with photographs in Figure 3 from Beeden et al. (2015).

Table 1. Damage matrix to calculate damage level from severity and extent of damages. From Beeden et al. (2015): coral damage extent (columns) represents the percentage of coral cover that was damaged, and severity categories (rows) represent the predominant type of colony damage observed in the survey area. Damage levels encapsulate both colony and structural damage. For example, DLI3 applies to either minor structural damage (e.g. 11-30% of colonies damaged) or high coral damage (31-50% branches or >75% tips).

	DAMAGE EXTENT						
SEVERITY	CATEGORY	0%	1-10%	11-30%	31-50%	51-75%	76-100%
None	0	0	0	0	0	0	0
Tips/Edges	1	0	1	1	2	2	3
Branches / Parts	2	0	1	2	3	4	4
Colonies	3	0	2	3	4	5	5

Damage Level Index (DLI):

Level 0: No damages
Level 1: Minor coral damages
Level 2: Moderate coral damages
Level 3: High coral damages / Minor reef damages
Level 4: Severe coral damages / Moderate reef damages
Level 5: Extreme coral damages / High reef damages

As part of the survey, observers also recorded the presence of reef framework or structural damage, which refers to impacts to the underlying substrate. Six features characterising reef structural damage were looked at: rubble fields with a mix of live and dead corals, soft corals torn, large rock/massive coral colonies dislodged, scarring by debris, sediment covering corals and dislodged giant clams.

In addition, the surveyors recorded which coral growth forms and genus were impacted by the damage.

Fortuitously, a monitoring survey had been conducted immediately before the typhoon (23rd December 2019) on the Coral Garden East site, as part of the People and the Sea long-term monitoring programme. The percentage cover of 30 different benthic categories were recorded (see Appendix) as well as coral damages and stressors (predation, disease, bleaching, physical damages and trash). That this survey had been conducted so recently presented an opportunity. In order to facilitate a comparative analysis, another survey was conducted at Coral Garden East site(just four weeks after the typhoon) on the exact same four permanent transects and using the same methodology (see Dalongeville, Jorcin, and Mills 2019 for detail on the reef monitoring methodology). These data sets would allow for a more detailed and quantitative assesment of Ursula’s impact on the benthic cover, and more specifically on the corals.

Damage Level 0 (No damage): Healthy reef.

Damage Level 1 (Minor damage): Some (1-30%) corals partially damaged; primarily broken tips and some branches or plate edges.

Damage Level 2 (Moderate damage): Many (31-75%) corals partially damaged; most fragile colonies have tips or edges broken, some branches missing or as large rubble fragments.

Damage Level 3 (High damage): Up to 30% of colonies removed, some scarring by debris, soft corals torn, coral rubble fragments from fragile and robust coral lifeforms.

Damage Level 4 (Severe damage): Many (31-50%) colonies dead or removed, extensive scarring by debris, rubble fields littered with small live coral fragments, soft corals severely damaged or removed and some large coral colonies dislodged.

Damage Level 5 (Extreme damage): Most (51-100%) corals broken or removed, soft corals removed and many large coral colonies dislodged.

Figure 3. Illustration of the six damage levels used in the impact assessment and analysis (Figure from Beeden et al., 2015).

OBSERVATIONS AND RESULTS

Damage Level Index (DLI)

Damages from Ursula ranged from very little damage affecting only the tips of the most fragile coral forms, to fracturing of the reef substrate and removal of sessile organisms (sponges, tunicates, soft corals). Figure 4 shows the Damage Level Index (DLI), calculated from damage matrix in Table 1, for the 18 assessed reefs. For each site, the level displayed is the average of the four surveys, rounded to the closest integer. None of the sites were completely free of damage, with most of the reefs being moderately affected with DLI 2 (10 sites) or DLI3 (4 sites). The most impacted sites were Coral Garden East and North, on the eastern side of Malapascua, with an average DLI 4 and 5 respectively. Tominjao 1, on Campatoc Shoal, was also strongly affected with an average DLI 4. These three sites were characterised by shallow depth (average of 2.3 and 2.5 metres for Coral Garden North and East, and 3.6 for Tominjao 1).

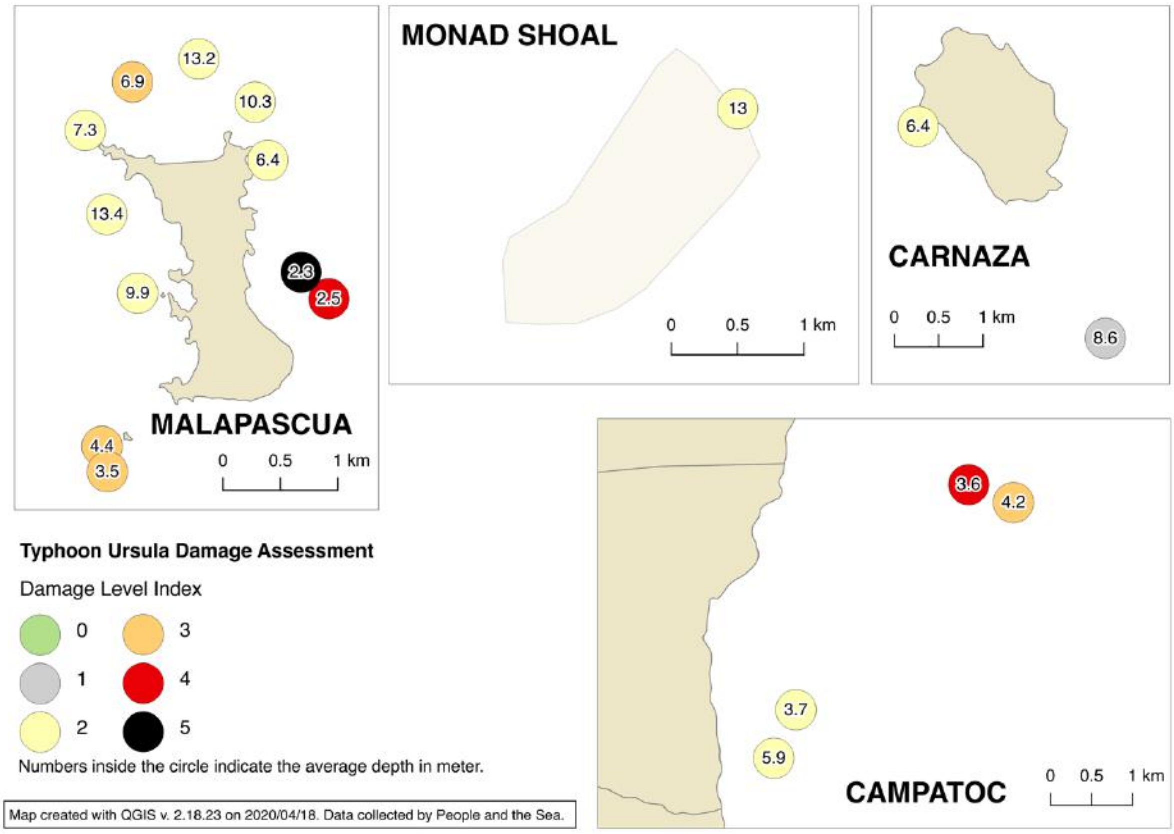


Figure 4. Damage Level Index (DLI) of typhoon Ursula in the 18 assessed sites in Daanbantayan Municipality. DLI was calculated from the extent and severity of damage on corals according to the damage matrix in Table 1. DLI displayed on the map represent the average of the DLI of the four plots surveyed for each site. The number within the circle indicates the average depth of the four plots in metres.

Figure 5 shows the DLI for each of the 72 surveys (four survey in 18 sites) in relation to the depth. Although sites display a high variability, the intensity of damages tends to decrease with depth. A notable exception is Lighthouse, on the western side of Malapascua, which exhibits a DLI of 4 for one survey despite being relatively deep (13.5m). Aside from this exception, severe structural damages (levels 4 or 5) were recorded in only 10% of the surveys, and affected only four sites that are very shallow: Coral Garden North and East, Two Rocks and Tominjao 1.

Most of the surveys (68%) show damages at the colony level only (DLI 1 or 2), but none of the surveyed area was completely exempt of damages. No survey was undertaken on sites deeper than 16 metres, but divers' observations reported evidence of typhoon damage up to at least 20 metres depth.

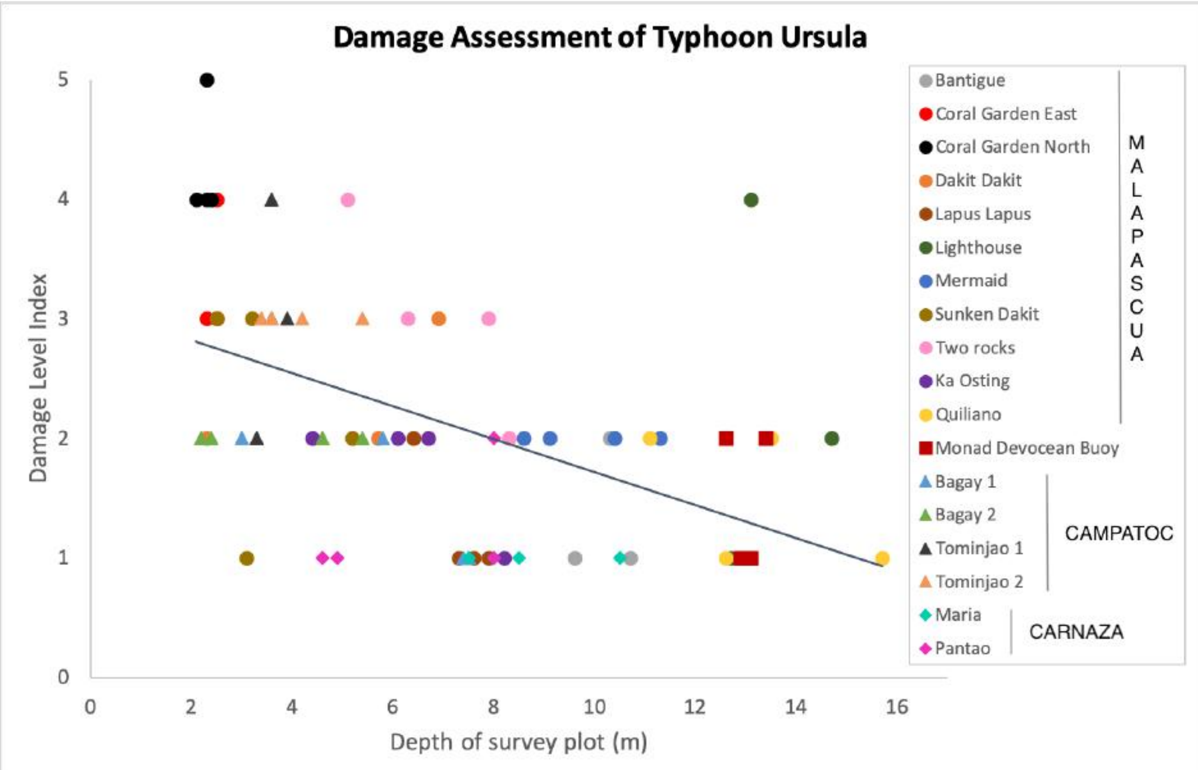


Figure 5. Plot showing the Damage Level Index (DLI) of each of the 72 surveys as a function of the depth. Each site is shown in a different color/symbol and comprises four surveys. The line represents the linear trend calculated from all data.

Affected Coral Forms

Across all sites, branching, table and foliose coral forms were the most frequently and severely damaged. This was not unexpected as they are the fastest growing but also more fragile forms. More robust, slow growing, coral forms such as massive, sub-massive, encrusting and columnar corals were affected by damages in only 10 of the 18 surveyed sites (55%). At sites with low damage levels (DLI 1 or 2), robust massive and sub-massive corals such as genus *Porites, Favites* and *Diploastrea,* and encrusting corals, such as genus *Pachyseris,* were mostly undamaged or only superficially damaged. The fragile branching and table corals of genus *Acropora*, *Seriatopora* (fine needle coral) and *Pocillopora* (pepper coral) and foliose forms such as *Millepora* (fire coral) and *Pachyseris*, suffered injuries to branch tips or plate edges with occasionally some branches/fragments missing (Figure 6a).

Reef framework/structural damage

At sites with high coral damage (DLI 3), signs of reef structural damages started to appear with coral colonies completely removed by the force of waves or marine debris, and with significant damages recorded on both fragile and robust corals (Figure 6b).

At severely affected sites (DLI 4 and 5) most corals exhibited substantial physical injury; many large massive colonies had been recently dislodged (Figure 6c), and many corals (including soft corals) suffered extreme damages with only their base remaining attached to the reef (Figure 6d).

The most commonly observed structural damage was the dislodgement of large coral colonies (Figure 6c) which was recorded in 61% of the surveys. Massive *Porites,* and large *Acropora* tables were commonly found upside-down and broken or scarred by impact with wave-born debris (e.g. boat pieces or tree branches). Evidence of scaring by debris (Figure 6e) were recorded in 25% of the surveys.

The second most common structural damage was the presence of rubble fields, recorded in 57% of the surveys. Extensive fields of freshly formed rubble, including a large proportion of live coral fragments and sessile animals such as sponge and tunicates (Figure 6f) were observed, indicating substantial breakage of corals and damages to other reef organisms.

Sediment (mostly sand) brought by waves action was observed covering corals (Figure 6g) in 25% of the surveys. Torn soft corals were recorded in 25% of the surveys, especially in sites located in the north of Malapascua, where soft coral cover is high. Large soft corals suffered substantial tissue loss (Figure 6h) or had been completely dislodged from the substrate.

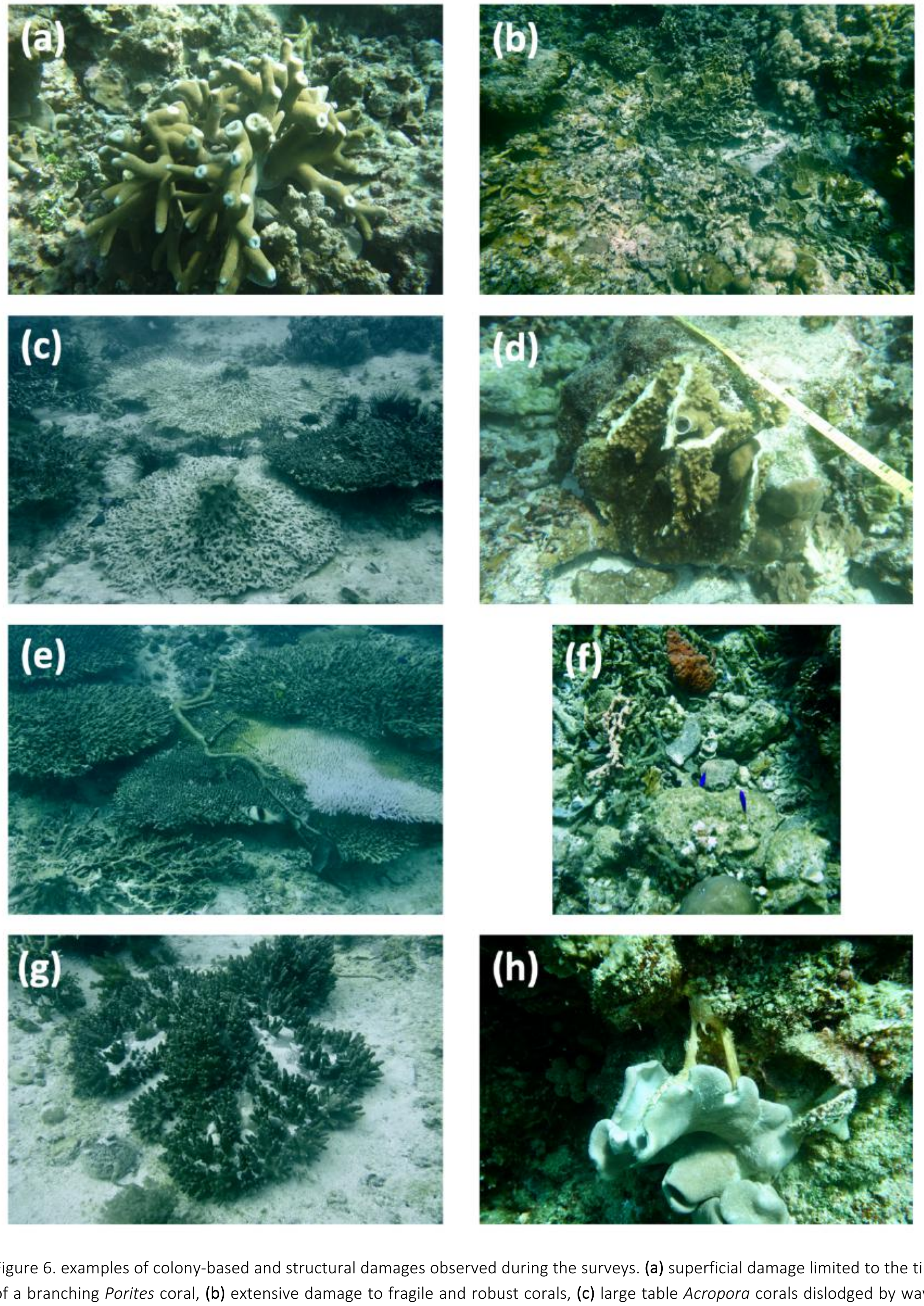
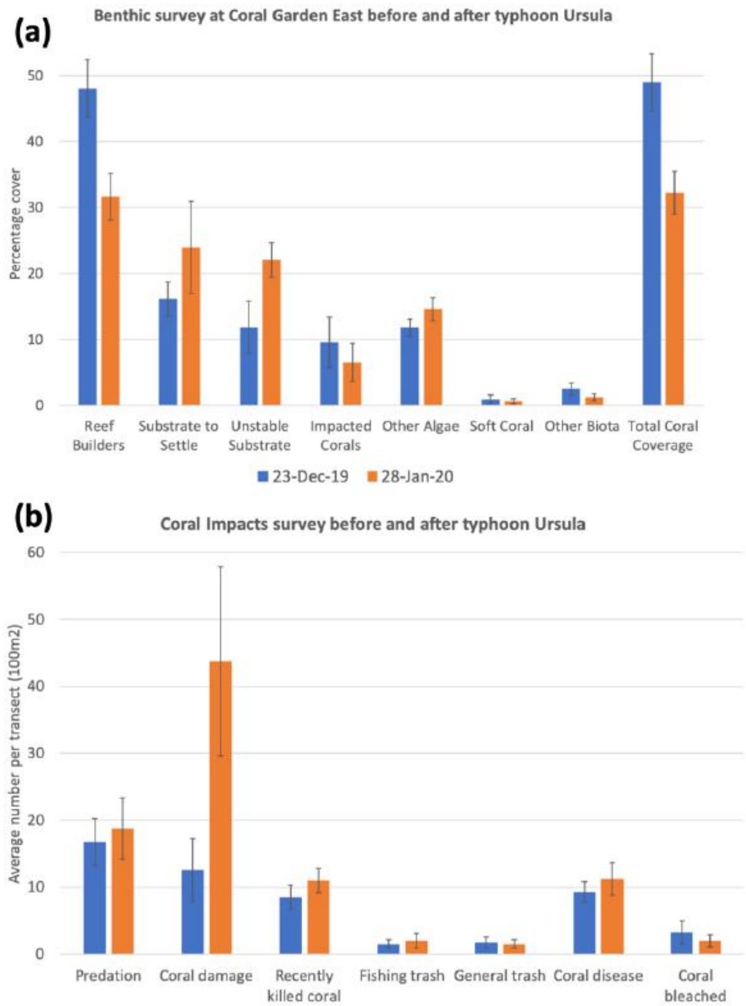


Figure 6. examples of colony-based and structural damages observed during the surveys. **(a)** superficial damage limited to the tips of a branching *Porites* coral, **(b)** extensive damage to fragile and robust corals, **(c)** large table *Acropora* corals dislodged by wave action, **(d)** severe damage to a fire coral colony leaving only its base, **(e)** scarring by marine debris, **(f)** rubble field including live coral fragments, sponges and tunicates, **(g)** sediment covering a soft coral, and **(d)** soft leather coral torn and partially dislodged.

Impact on benthic cover in Coral Garden East

Coral Garden East (CGE) is a site located on the eastern side of Malapascua, at a very shallow depth (2.4m in average over the four transects surveyed), where People and the Sea have conducted reef monitoring surveys since 2015. The following results are comparing the benthic cover and the coral impact data collected on four transects of 20m length immediately before Typhoon Ursula (23-Dec-19) and subsequently five weeks after (28-Jan-20).



The benthic survey data show a strong impact on reef builders (hard corals, fire coral *Millepora sp.* and blue coral *Heliopora sp.*), which decreased by 16.5% between the two survey periods (Figure 7a). These corals were replaced by stable substrates ('substrate to settle': rock and dead corals) and unstable substrates (sand and rubble), with an increase in cover of 7.8% and 10.2% respectively. Algae also started to colonise the empty space left by the corals, with an increase of 2.8% of algal cover between the two surveys.

Foliose and corymbose (very short and thick branches) coral forms were the most affected by the decrease, as they are the most abundant forms at the site. Their cover decreased of 4.0% and 8.7% respectively between the two survey periods. The percentage cover of submassive corals also decreased by 5.6%, showing that even robust coral forms were affected by the typhoon. Only encrusting forms did not show any decrease in their cover.

The coral impact survey data record the number of impacts/stressors within a 20x5m survey area (100m^2). The results show a strong increase in the abundance of coral physical damages (broken or displaced colonies), which increased from 12 damaged colonies/100m^2 before Ursula to 44 damaged colonies/100m^2 after the typhoon, on average over the four transects (Figure 7b). The amount of recently killed corals (colonies that have died within the last than six months, hence still appearing very white) also increased (+2.5 per 100m^2 between the two surveys). Other recorded stressors remained stable.

CONCLUSIONS

Typhoon Ursula has not only altered landscapes and communities, but coral reefs up to at least 20 metres have also been significantly damaged by the strong winds, waves and swell. Overall, our rapid damage assessment surveys show widespread damages on the shallow reefs surrounding both Malapascua, and Campatoc Shoal (further south). Damage appeared less significant around Carnaza, north of Malapascua, where the resulting swell might have been less. The level of destruction decreased with the depth but was highly variable between reefs. However, heavy damages were observed on reefs on all sides of Malapascua, demonstrating that the whole island must have been affected by a strong surge. Most shallow reefs displayed extensive damage to corals (especially branching, table and foliose growth forms), and the most affected sites also showed displacement of large coral colonies and structural damage to the reef framework.

Our reef monitoring data on Coral Garden East showed a drastic reduction of coral cover after Ursula (-16.5%). Such decrease reduces the extent and complexity of habitat, which has negative consequences for many reef associated organisms (fishes and invertebrates such as shrimps or crabs) that depend on corals for their reproduction, food or to hide from predators. For example, significant decreases in density and diversity of reef fishes were recorded in New Caledonia up to three years after Cyclone Erica (Guillemot, Chabanet, and Le Pape 2010).

Recovery of reefs from that type of physical damages requires a combination of regrowth of damaged colonies, and settlement of new coral larvae. Major threats that may compromise natural coral recovery are the overgrowth of macroalgae and the establishment of coral diseases or predators inducing mortality of the already damaged colonies (Hughes and Connell 1999). Larval recruitment plays a crucial role in the recovery process, but requires healthy unstressed corals to produce larvae that will colonise the damaged reefs. However, recovery is a slow process: at severely damaged sites, return to the pre-disturbance coral cover is likely to take 10 years or more, and it can be even longer for species diversity to recover (Osborne et al. 2011; Hughes and Connell 1999; Beeden et al. 2015).

Even though there is no data to quantitively estimate its damage, we know that typhoon Yolanda in 2013 (only six years before Ursula) had even stronger impacts on the coral reefs of Malapascua, as was the case for most of coral reefs in the Visayas region (Anticamara and Go 2017). Our long-term monitoring data showed that the recovery process from Yolanda was in progress, with a steady increase of coral cover from 2015 to 2019 (Dalongeville, Jorcin, and Mills 2019), but recurrent disturbances such as Ursula will obviously hinder the resilience of the reefs and render them more fragile.

Since the economy of Malapascua is strongly dependent on healthy reefs, both for tourism and fishing industry, it is necessary to maximise the chances to restore coral cover and the biomass and biodiversity supported by these corals. Compounding stresses on coral reefs, directly induced by human activities (e.g. pollution, overfishing) or linked to climate imbalance (e.g. Crown-of-Thorns outbreaks, coral bleaching) are known to hinder or slow recovery (Beeden et al. 2015). Hence, it is particularly crucial to protect reefs from such stressors in order to allow them to heal from the damages induced by Ursula. Actions should be taken to minimise coral stresses, especially in heavily impacted reefs, but also in undamaged areas, which may play a critical role in the recovery of adjacent impacted reefs by exporting larvae. Long-term monitoring should be continued to measure the recovery of the reefs, and more comprehensive assessments should be undertaken to determine the potential impact on local fisheries and inform marine resource management decisions. More than ever, a hand-in-hand collaboration is required between all stakeholders from the community, tourism industry, government and science, to give the best possible chances to our coral reefs to recover.

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APPENDIX

Benthic organisms and substrate types recorded in the PIT surveys

Type	Form recorded	Benthic category
Hard corals	Branching	Reef builders
	Columnar	Reef builders
	Corymbose	Reef builders
	Digitate coral	Reef builders
	Encrusting	Reef builders
	Foliose	Reef builders
	Massive	Reef builders
	Solitary	Reef builders
	Sub-massive	Reef builders
	Table	Reef builders
Impacted corals	Recently Killed Coral	Impacted corals
	Dead Coral with Algae	Impacted corals
	Bleached hard coral	Impacted corals
Octo-corals	Soft coral	Soft corals
	Blue coral	Reef builders
Algae	Halimeda	Other algae
	Crustose	Other algae
	Nutrient Indicator Algae	Other algae
	Coralline Algae	Substrate to settle
Substrates	Rock	Substrate to settle
	Rubble	Unstable substrate
	Sand	Unstable substrate
	Silt	Unstable substrate
Other organisms	Anemone	Other biota
	Corallimorph	Other biota
	Fire coral	Reef builders
	Hydroid	Other biota
	Sponge	Other biota
	Tunicate	Other biota
	Zoanthid	Other biota