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Resiliency of seagrass beds in shallow waters of Tacloban City, Philippines after super Typhoon Yolanda

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Abstract

Seagrasses have high ecological services as a promoter of biological productivity and biodiversity. When Super Typhoon Yolanda (Haiyan) devastated Tacloban City in 2013, two years after, seagrass beds started to emerge in the shallow waters of Cancabato Bay, Anibong Bay, and San Juanico Straight. Five species of seagrass were identified: *Cymodocea rotundata*, *Cymodocea serrulata*, *Enhalus acoroides*, *Halodule uninervis* and *Thalassia hemprichii*. Pooled resiliency attributes from literature to describe the acclimatization of the emerging seagrass beds and patches, anchoring on the resiliency model of Unsworth *et al.* 2015, suggesting three intervening factors: biological, biophysical, and support ecosystem. In the dearth of literature and studies of seagrass beds after Super Typhoon Haiyan, four stations were established in the shallow waters of Tacloban City to depict some resiliency characteristics. Biological indicators such as canopy height, shoot density, and; biomass were computed, showing recuperation values for seagrass health. Some physical environmental factors such as total suspended solids (TSS), pH, dissolved oxygen (DO), salinity, turbidity, and water movement were also identified. In a separate study, nitrates and phosphates levels (mgL-1) of sediments and seawater in Cancabato Bay and Anibong Bay showed ambient levels suitable for seagrass growth. Residents also amassed seagrass-associated epifaunal macroinvertebrates communities, such as mollusks and gastropods, for commercial and domestic utilities. Mangrove patches, complimentary with seagrass beds, are also showing recovery after the inundation. Though the analysis is just based on minimal inquiry and needs more in-depth investigations, seagrass in the shallow waters of Tacloban City is manifesting recovery and showing attributes of resilience.

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Introduction

When Super Typhoon Yolanda (Haiyan) devastated Tacloban City, Philippines, in 2013, it brought massive destruction, wiping anything along its path with a sustained wind of 315km/hr. It was considered the strongest and deadliest typhoon recorded on landfall (NEDA, 2014), which generated surges reaching 5.2 meters, equivalent to the height of a second-story building (PAGASA, 2013).

Typhoons and other climatological events cause large-scale disturbances to the coastal aquatic ecosystem (Paerl *et al.*, 2001, 2006), causing associated surges and swell to cause seagrass loss (Orth *et al.*, 2006). As the surge receded, bringing debris materials, wastes, and particulates, the sea beds became a catch basin for all the sediments brought forth by the killer surge.

Extensive rainfall induces floodwaters that reduce salinity and increase organic matter and nutrients (Zhang *et al.*, 2009); exacerbated by extreme wind velocities, storm surges, and flooding cause intense mixing, alterations to circulation, and even geomorphological changes (Conner *et al.*, 1989). In the case of Super Typhoon Yolanda, with collective factors that could rescind the integrity of the ecosystem beyond what had been experienced, Tacloban City's shallow waters were a picture of devastation. Despite the catastrophe, seagrasses survived in the shallow waters of Tacloban City, particularly in Cancabato Bay, Anibong Bay, and San Juanico Straight.

The emergence of seagrass indicated the resilience of the coastal systems despite the obliteration of the super typhoon. Not only emergence but thriving in very murky and thick sediment accretion, *Enhalus acoroides* bloomed in this harsh environment.

They started to propagate sexually through hydrophilous pollination (Fig. 1). This manifestation of resilience must be established in contextualization among existing ecosystem theoretical models to ascertain attributes favorable for seagrass regrowth. Few works of literature have evaluated seagrass ecosystem resiliency after a large-scale disturbance.

Fig. 1. *Enhalus acoroides* thrived and even bloomed after Super Typhoon Yolanda in the shallow waters of Cancabato Bay (Gibeon Consultancy Services, 2014).

In the context of resilience, this paper attempted to depict the seagrass beds of Tacloban City, albeit what had happened after Super Typhoon Yolanda and previous disturbances that had confronted it. Three properties can characterize resilience: (a) the amount of alteration the system can withhold and remain within a similar domain, (b) the degree to of the system is capable of self-reorganization, and (c) the degree of the system can build the capacity to adapt (Gunderson, 2000).

Since 1983, San Pedro Bay (in which Cancabato Bay is embedded) has reported episodic algal blooms of 20 potentially harmful phytoplanktons (Yap-Dejeto & Batula, 2016; Yap-Dejeto *et al.*, 2013; Yap-Dejeto *et al.*, 2013).

This enduring episodic bloom may be accounted for eutrophication as human-induced activities such as aquaculture, perpetual drainage catch basin of wastewater, and input of run-off water through precipitation (Martins *et al.*, 2001). Transport of nutrients into the seawater accounted for the episodic algal blooms. Eutrophication has been a significant cause of seagrass disappearance (Burkholder *et al.*, 2007), which would significantly impair growth, morphology, density, and biomass (Short *et al.*, 1995). Time Magazine emphasized that, on average, the Philippines is confronted with eight or nine tropical storms, where Eastern Visayas is the most frequently hit. Before Super Typhoon Yolanda, these alterations had constantly perturbed Tacloban City's seagrass beds. As time passed, this ecosystem withstood its domain under conditions and became an ecosystem source.

An ecosystem model of San Pedro Bay shows a trophic structure composed of 16 ecological groups comprised of 13 consumers, two producers, and one detritus (Campos, 2003). Seagrass was highlighted as a producer, with phytoplankton accounting for primary production based on biomass. This ecosystem had been productive and maintained energy flows with high turnover rates (Campos, 2003), attributed to the acclimatization after disturbances. Species found within this ecosystem that was reported first time in the Philippines, such as Padina spp. (Geraldino *et al.*, 2005) and marine diatoms (Yap-Dejeto *et al.*, 2013).

Another property of resilience is the ability of trophic reorganization after the disturbance. Gibeon Consultancy Services, commissioned by GIZ, assessed the marine and coastal resources one year after Super Typhoon Yolanda. Seagrass species found were *Cymodocea rotundata*, *Enhalus acoroides*, *Halodule uninervis* and *Thalassia hemprichii*. In a separate study of Payo *et al.*, 2018, additional seagrass; *Cymodocea serrulata* was included in the list. *E. acoroides* and *T. hemprichii* flourished in shallow waters in areas, where not part of the prior studies (Matillano, 2017). Though the seagrass beds were very poor (Gibeon Consultancy Services, 2014), diversity surveys showed escalating recovery even without restoration (Matillano, 2017). Associated marine macromolluscan gastropods and bivalves were also found (Matillano, 2016; Alvarez *et al.*, 2019) as gleaners were starting to amass economically significant seashells. Blue crabs usually inhabit seagrass beds, and other macroinvertebrates such as sea cucumbers, sea stars, and sea urchins were also noted. This emergence was also observed among fishes with 20 species from 14 families (Gibeon Consultancy Services, 2014). Though ecological studies of San Pedro Bay after Super Typhoon Yolanda were so scarce, this stressed condition was also the identical make-up even before the Super Typhoon happened.

The third property of resilience is the ability to adapt. Adaptation to environmental change is a primal issue to system resilience (Nelson *et al.*, 2007), adherent to three reasons: (a) response actions to multiple stresses and stimuli, (b) endurance to risks for future perturbations and (c) ability to lessen vulnerabilities.

Abiotic or biotic stressors that exceed the range of normal variations adversely affect individual physiology or population performance significantly (Barrett *et al.*, 1976; Auerbach, 1981), reducing adaptation toward environmental change (Scheffer *et al.*, 2001). Stressors do not occur singly but synergistically, complimenting one stressor to another. However, biodiversity tolerates stressor co-tolerance (Vinebrook *et al.*, 2004). The stress resistance was usually attributed to compensatory species dynamics of co-tolerant species, surviving in existing synergistic stressors, and the ability to resist upcoming stressors (Fischer *et al.*, 2001), resulting in increased survival. In the case of Tacloban City, the persistence of the emerging seagrass beds may be accounted for positive co-tolerance.

This persistence was accounted for in the studies of Yap-Dejeto & Batula (2016), Yap-Dejeto *et al.*, (2013), and Yap-Dejeto *et al.*, (2013) that despite episodic harmful algal bloom, seagrasses remain as top producer to the energy flow of the ecosystem functions (Campos, 2003).

Perpetually, as Eastern Visayas is located on the eastern seaboard of the Philippines facing the Pacific Ocean, incessantly heavy precipitations brought about by atmospheric conditions and periodic storms increase organic matter and nutrients loads (Zhang *et al.*, 2009), which may be accounted for the episodic algal blooms and maybe eutrophication even before Super Typhoon Yolanda.

The ability of seagrasses to emerge may be due to the persistence of the rhizomes that were buried upon the deposition of sediments (Marba & Duarte, 1997). The accretion of sediments due to the surge, as it receded, bringing debris materials, wastes, and sediments, both organic and inorganic. The sea beds became a catch basin of all the sediments brought forth by the killer surge. On the other hand, seagrasses may emerge on the availability of seed banks present (Erftemeijer & Lewis, 2006) th*at al*lows propagules to recover, though the survival and longevity of seeds were less known. As there were no studies about the emergence of seagrass beds after the super typhoon, the persistence of rhizomes or the availability of seed banks may cause the emergence even without restoration.

Since the seagrass beds were sessile organisms and could not evade or even reduce the effects of future perturbations, mitigation through policymaking could compensate for the impacts. Exposure and sensitivity could determine the susceptibility of the ecosystems' possibility for future disturbances (Nelson *et al.*, 2007). This concern remained a main thrust of the Local Government Units. Before Super Typhoon Yolanda, Tacloban City was a member of the Alliance of Local Fishery and Aquatic Resources Management and Development Council (ALFARMDC), institutionalizing LGUs to implement local marine protected areas and integrating coastal management (Gibeon Consultancy Services, 2014).

Materials and methods

Resilience research primarily focused on the socio-ecological perspective in general. Only Unsworth *et al.* (2015) suggested a resiliency model, particularly on seagrasses, based on (a) biological features, (b) the biophysical environment, and (c) features of supporting ecosystems.

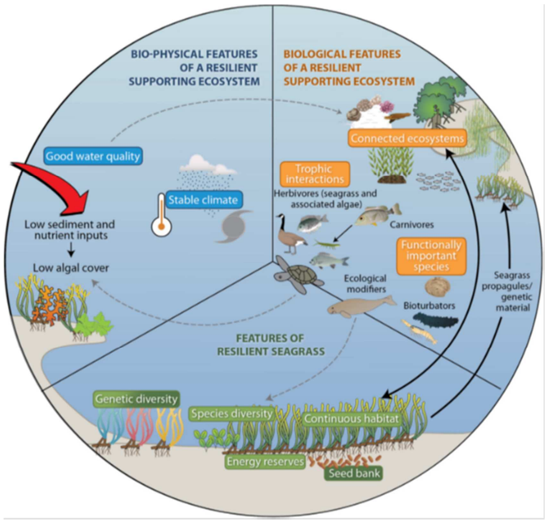

Fig. 2. The resiliency model by Unsworth *et al.*, (2015) suggests three intervening factors such as biological, biophysical, and support ecosystem.

In order to depict resilience based on Unsworth *et al.* 2015, permanent stations were established for each shallow water body within Tacloban City. Stations 1 and 2 were both in Cancabato Bay (11°12.741'N 125°1.004'E) and (11°14.796'N 125°0.604'E). Station 3 was in Anibong Bay (11°15.435'N 124°59.252'E and Station 4 was located in San Juanico Straight (11°15.775'N 124°58.34'E). A permanent 50-meter transect line was established for each station perpendicular to the coastline with a 1m² quadrat in the 10-meter interval. Seagrasses were identified, and biological conditions such as shoot density, biomass, and canopy height were computed. Environmental parameters such as turbidity, total suspended solids (TSS), salinity, pH, temperature, dissolved oxygen (DO), and water movement were also characterized for biophysical attributions. For the support ecosystem, secondary data were incorporated into the analysis.

Results and discussion

Biological Features

Though biological features referred to the three levels of diversity: genetic, species, and ecosystem (Campbell *et al.*, 2006; Reusch *et al.*, 2005), this study was exclusive to the species level. Seagrass species identified were *E. acoroides* and *T. hemprichii*.

In separate studies, other species found were *C. rotundata* and *H. uninervis* (Gibeon Consultancy Services, 2014) and *C. serrulata* (Payo *et al.*, 2018). Despite the inundation, seagrass species displayed regrowth as shoot density, biomass, and canopy height illustrated features of regrowth after the super typhoon. Species richness alone was not appropriate to conclude seagrass resiliency (Unsworth *et al.*, 2015); it needs phenotypic plasticity studies that could create diversity within the species level and ascertain resiliency attributes. Responses toward perturbations depend upon specific endowments of the organism, which could be manifested upon adaptations from continuous exposure to different adverse conditions. Biological parameters such as shoot density, canopy height, and biomass were measured to indicate seagrass health or adaptive significance. Station 1 manifested the highest canopy height and biomass compared to other stations, but shoot density was more extensive in Station 2 compared to others. Both Station 1 and 2 were located in Cancabato Bay, indicating growth among seagrasses. Stations 3 and 4 also showed progress, indicating shoot density, canopy height, and biomass values.

Table 1. Biological parameters of seagrass in the shallow waters of Tacloban City showing shoot density, biomass, and canopy height (Unpublished Boco & Matillano, 2016).

Stations	Shoot Density (m^2)	Canopy Height (cm)	Biomass (g=dw m^2)
1	8.2	165	20
2	9.2	160	13.8
3	4.8	97	8
4	5	79	7

Physical Environment

The biophysical environment has a wide range of factors that may influence resiliency. Although exposure to some environmental stress may enable individuals or communities to adapt and improve their resistance (Olds *et al.*, 2014), seagrasses are sensitive to environmental change and may influence seagrass health. Though this inquiry is descriptive, all stations in their turbidity, total dissolved solids, salinity, temperature, pH, water movement and dissolved oxygen values were close and proximate to each other. This proximation of value showed correspondence among bodies of water and the interconnection of physical properties. Stations 1 and 2 were within one embayment, but stations 3 and 4 were located in other coastal systems but connected. Turbidity and total suspended solids, on the other hand, showed disparity among stations. Stations 1 and 2 have higher turbidity and TSS values than other stations. These values show that seagrasses can tolerate a wide range of physical-environmental factors. Despite higher turbidity and TSS, Stations 1 and 2 have the highest biological seagrass parameters (Table 1). Higher turbidity and TSS values are attributed to the sediments' accretion after the super typhoon.

Table 2. Physical parameters generated from permanent transect lines in the shallow waters of Tacloban City (Unpublished Boco & Matillano, 2016).

Stations	Turbidity (cm)	Tss (mgl)	Salinity (psu)	Temperature (°c)	Ph	Water movement (m/s)	Do (mgl)
1	39	900	29.1	30.3	8.23	.06	8.3
2	36	1800	29	29.9	8.03	.07	8
3	29	400	29.6	29.7	8.27	.05	8.4
4	21	350	29.8	29.9	8.14	.06	7.8

Environmental parameters have a participatory influence on the resilience of the ecosystem, example, water turbidity can influence ecosystems' structure and function. Highly turbid water can restrict light transmission (Thrush *et al.*, 2004) as seagrasses require more sunlight for photosynthesis (Duarte, 1991; Markager & Sand-Jensen, 1992). Some synergistic factors may influence one from the other, like DO and pH; if pH decreases, DO also decreases (Frieder *et al.*, 2012). In the Philippines, physicochemical properties have been studied and their influence on seagrass distribution (Vinzon *et al.*, 2016; Hamisain *et al.*, 2020) but not in contexts of resiliency and stress tolerance. Our seagrass beds have been perpetually confronted with stressors induced by both natural and man-made, thus; frameworks of monitoring, conservation, and concepts should be patterned on this outlook.

Seagrasses required two essential nutrients: nitrogen and phosphorus, for growth, though they required different kinds of inorganic nutrients- nitrogen and phosphorous were the most quantitatively important (Greve & Binzer, 2004). Identifying the phosphate and nitrate levels in the substrate and the seawater was essential in the analysis. Nutrient availability may also depend on sediment quality, which is crucial for growth and persistence (McKenzie, 2008). Though the data differed from previous presentations, nitrates and phosphates in seawater and sediments were identified from Cancabato Bay and Anibong Bay. Stations 1 and 2 were from Cancabato Bay, while Station 3 was from Anibong Bay (Matillano, 2016). Anibong Bay had lower nitrates and phosphates in seawater but was recorded with higher nitrates in sediments. In Cancabato Bay, nitrates and phosphates have higher values in seawater and sediments. Both areas have seagrass beds, with more extensive in Cancabato Bay, implying tolerance of seagrass in different levels of nitrates and phosphates.

Table 3. Nitrates and Phosphates levels (mgL-1) of sediments and seawater in Cancabato Bay and Anibong Bay during July 2015 (Matillano, 2016).

Area	Nitrates in Seawater	Nitrates in Sediments	Phosphates in seawater	Phosphates in sediments
Anibong Bay	0.16	0.16	0.03	0.05
Cancabato Bay	0.53	0.10	0.14	0.056

Support Ecosystem

The importance of seagrasses in the economic and ecological viewpoints has been extensively studied both from the diurnal and diel perspectives (Matillano & Rosada, 2022; Alvarez *et al.*, 2023). Linkages between support ecosystems require understanding how neighboring ecosystems, such as mangroves and coral reefs, help confer resilience to the seagrass beds. In Tacloban City, mangroves recover after the storm surge as some patches regenerate. *Rhizopora apiculata*, *Rhizophora mucronata*, *Sonneratia alba*, and *Avecinnia marina* were the most common mangroves on the coastlines of Tacloban City (Matillano *et al.*, 2020; Matillano *et al.*, 2020). On the other hand, on Dio Island, a fringing reef survived after Super Typhoon Yolanda, but no coral reef was found within the embayment.

Local gleaners already amassed seagrass-associated gastropods and bivalves for commercial and domestic utilities, composed of 12 gastropods and five bivalve species, indicating a community structure in seagrasses and bare patches microcosms. A higher abundance of gastropods was sampled in bare sediment patches, while in seagrass beds, it indicated evenness and more abundance of both bivalves and gastropods (Matillano *et al.*, 2018). As complementary ecosystem support, seagrasses in the shallow waters of Tacloban City have shown sustenance to other community assemblages and provide resources for residents.

Conclusion

Seagrass-associated literature and studies were scarce in Tacloban City, especially after Super Typhoon Yolanda or even before it. The recovering seagrass beds had shown recuperation based on the seagrass resiliency model of Unsworth *et al.* (2015), highlighting attributes of the biological and biophysical environment and supporting ecosystem features. Seagrass shoot density, biomass, and canopy height indicated growth. Environmental parameters were also suited for seagrass growth, such as TSS, pH, DO, salinity, turbidity, and water movement. Complimentary ecosystems such as mangroves, bare sediment patches, and coral reef fringe were also recuperating. Though the approach was based on a limited inquiry, seagrasses of Tacloban City's shallow waters show attributes of resiliency.

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