The bloom of Chlorophyte *Ulva* in Lutoban Bay and the distribution of algae in The Central Visayas, Philippines

Abstract

Study was undertaken at four different sites on Negros Oriental, Philippines to establish species present, their abundance and depth distribution of algae. A local chlorophyte, *Ulva reticulata* and *Ulva intestinalis* at Lutoban was also monitored for changes in algal percent cover. To track the bloom eleven quadrats were measured over 50m of continuous reef at six different depths for Lutoban Pier and South. To quantify the species of algae present at Lutoban, Dauin and KooKoos, similar methods were conducted using a quadrat at five and ten metre depth. Results show that algal percent cover decreased on the reef at Lutoban Pier and South over the study period. Dauin shows the lowest number of algal species present while Lutoban has the highest number. More phaeophytes were observed at 5m and more rhodophytes were situated at 10m. Algal blooms pose a threat to many ecosystems, similar chlorophyte blooms have occurred in other Islands of the Philippines. Mostly as a result of eutrophication, these blooms occur in waters with untreated sewage or occur seasonally. The distribution of other algae across the three sites is a direct relationship of available light, herbivory, competition and growth form.

Introduction

The Philippines is an archipelago of more than 7000 islands with extensive coastline located in the centre of the coral triangle, this makes for an ideal study site. The coral reefs of the Philippines have a complex habitat with a very specific balance between algae and corals. This balance determines the health and success of the ecosystem.

Eutrophication is the enrichment of an environment with chemical nutrients, specifically nitrogen and phosphorus. Eutrophication results in an imbalance in the ratio of algae to coral. When these nutrients occur in excess it provides the algae with sufficient conditions to thrive. Algal blooms can occur as a result of a combination of factors such as eutrophication, temperature, sunlight, disturbance, hydrology and water chemistry (CEES, 2017.)

Eutrophication enhances the growth of one species while inhibiting the natural functioning of the ecosystem. Algal blooms are damaging to the environment as they deplete surface waters of oxygen (Garrison, 2010) and shade corals and other photosynthetic organisms by reducing the available light for other species. In another way they are beneficial as they remove excess nutrients and pollutants as they grow.

Ulva reticulata is the main species observed in Lutoban Bay and *Ulva intestinalis* to a lesser extent. *Ulva reticulata* is a light to dark green algae with holes of differing shapes and sizes and smooth margins. This chlorophyte found throughout the Indo-West Pacific region is more commonly known throughout the world as ribbon sea lettuce and more locally in the Philippines as lumot. *Ulva reticulata* normally grows attached while mature thalli is free-living and the primary contributor to green tides. *Ulva intestinalis* on the other hand has a green thallus with tubular branches originating from a single small stipe and disc-shaped holdfast.

Study was carried out at four different locations in the provinces of Dauin, Zamboanguita and Siaton on Negros Oriental, Philippines. During the months of April and May, research was conducted into the different species of algae present at three different sites on Negros Oriental. Additionally an Algal bloom was monitored for growth in Lutoban Bay, its affects on the reef and likely causes.

Research was primarily undertaken at Lutoban Bay, this location has two different sites, South and Pier. Each site is subjected to differing currents, siltation, land run-off and freshwater river inputs despite their close proximity. Dauin and Kookoos on the other hand do not neighbour as intensive land use, there are no rivers therefore the sites are exposed to a different combination of environmental stressors.

Bays such as Lutoban will be exposed to less currents than what may be experienced at KooKoos and Dauin. KooKoos and Dauin do not have rivers that feed into them therefore visibility and light penetration will be further than experienced at Lutoban and will in turn affect algal growth. Rivers affect light penetration by transporting upstream sediments from land run-off and erosion into the bay. Pier will have more freshwater influence, siltation and land run-off compared to South as South is located in the centre of the bay while Pier is closer to the shoreline.

Methods and Materials

An exploratory dive was made to collect samples of blooming specimens and identify to species level based on colour, morphology and presence of a holdfast. Using fresh samples alongside photo documentation of the fresh sample, online articles and resources were used to verify previous assumptions.

A: Monitoring Algal Bloom

At Lutoban Pier and South using a 100m transect reel and a 0.5m² quadrat, transects were reeled out to 50m at 15, 12, 10, 7, 5 and 3 metres depth haphazardly along 50m of continuous reef. Compass headings were not used, instead a Mares Nemo Wide dive computer was used to try maintain constant depth and account for depressions in the reef. Every 5m (0,5,10,15,20...50m) the quadrat was placed on the side of the transect going towards the descending slope, the deepest side. Percent cover was determined inside of the quadrat for *Ulva spp* in situ for 11 quadrats along each of 6 transect depths. Type of *Ulva* species present was also noted. 3 depths were completed in each dive with 2 dives required to complete a site. A minimum of three repetitions were made at each depth for per site for consistency, each repetition about 1 week apart.

Seagrass in front of Lutoban South reef location, was also monitored for algal cover. A total of three transects of 50m each were completed. Each start of the transect was marked by a floater and 50m was reeled out using a heading of 180 degrees. Every 5m on the side furthest from shore was surveyed for percent cover. Percent cover was taken for 11 quadrats per transect with each floater located parallel approximately 20m from each other.

B: Measuring presence/absence and abundance of species
At Dauin Marine Reserve, Lutoban Bay and KooKoos, the presence of different algae were observed haphazardly at 10 and 5 metres depth along 50 metres of continuous reef. Using a reel to reel out to 50m, both sides of the transect were sampled every 5 metres, identifying all algal species inside of a 0.5m² quadrat. All species were noted down, with samples and photos taken for species that could not be identified in situ. Greatest abundance was given a rating of 1 and lowest abundance a rating of 5.

Results and Observations

Image 1: Ulva reticulata

Image 2: Ulva intestinalis

A. There is a decrease in abundance of *Ulva* observed at all depths for Lutoban Pier over four separate weeks (Figure 1.) The deeper depths had a lower percent cover of algae with the mid depths of 10 and 7m showing the highest abundance.

Algal percent cover at Lutoban South was low to begin but still showed a further decrease in abundance over the two weeks it was monitored (Figure 2.)

U. reticulata is the dominant algae contributing to the bloom with *U. intestinalis* only being observed at the Pier at shallower depths of 3 and 5m. No *U. intestinalis* was observed at Lutoban South on the reef however lining the waters shoreline it can be observed attached to large rubble. Lutoban Bay experiences large tidal ranges where much of the seagrass beds become fully exposed therefore the *U. intestinalis* at the shoreline consequently undergoes periodic drying and saturation.

While not actually surveyed, during the surface swims *U. reticulata* was observed in its highest density in Lutoban Bay between the seagrass bed site and the South reef at about 1 to 2 metres depth. This location is the transitioning point between a macroalgal state and a fully functioning coral reef. The *Ulva* is developing attached to the substrate amongst macroalgae such as *Sargassum spp.* with an estimated percent cover in the high 70-90% range.

With the majority of *Ulva* located in the centre of the bay showing a rich green colour, the algae on the reef is free-living in a density less than 5%. Most algae observed was more yellow in colour indicating the length of time it had spent there. While carrying out the transects at both South and Pier most algae was seen to catch on the sand compared to the reef.

At the Pier, the algae is seen to smother some of the reef, most of this algae is smothered by silt. A large proportion of the algae you would not realise was present due to the magnitude of siltation occurring.

Amongst the seagrass in front of Lutoban South reef, the floater attached to Rock 3 (furthest transect from the shore) shows a gradual decrease in percent cover of algae (Fig. 3.) This is not a significant decrease, only about 1%. The other two transects show an overall increase in algal percent cover over the 3 weeks, of only about 2%, this is not a worrying proportion as all quadrats showed an average percent cover less than 10%. The presence of collector urchins in the seagrass affects percent cover in the quadrat as the urchins collect the free-living algae and attach it to their spines accumulating the algae in patches.

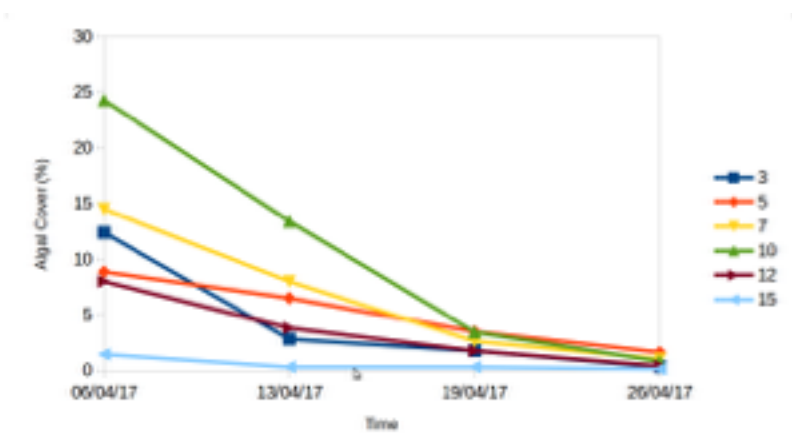

Figure 1: Algal Percent Cover at Lutoban Pier for depths: 3, 5, 7, 10, 12, 15m over 21 days

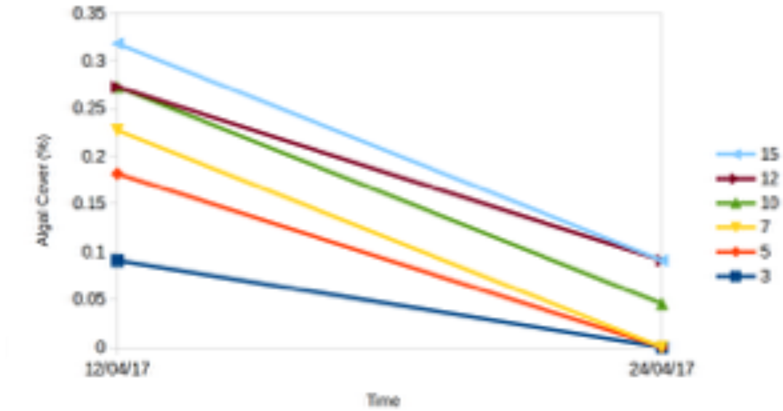

Figure 2: Algal Percent Cover at Lutoban South for depths: 3, 5, 7, 10, 12, 15m over 13 days

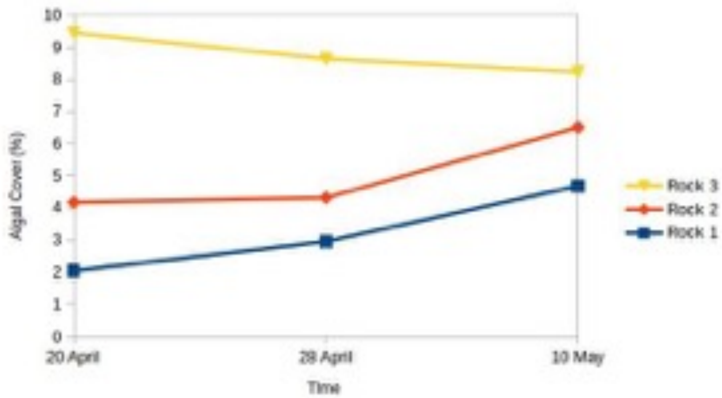

Figure 3: Algal Percent Cover at Lutoban South infront of reef at Rocks 1, 2 and 3 over 21 days

B. Dauin has the lowest number of algal species of any site surveyed (Table 1.) Lutoban Bay has the highest proportion while KooKoos is intermediate in its number of algal species. At all sites *Sargassum spp, Turbanaria spp* and usually *Padina spp* are never observed at depth, only in the shallows of 5m or less. The least abundant species in the table indicates only those that are found, with the least area covered. Coralline algae is the most abundant encrusting calcerous algae found at all sites while R3 and *Dictyota spp* are both found is the lowest proportions.

Bleaching of calcerous algae species *Halimeda* was observed across all sites. More species of red algae are observed at 10m over 5m depth. Lutoban 10m transect is the deepest site where *Valonia spp* was seen, *Valonia* was only observed at 5m depth at all other locations.

	Most Abundant	Least Abundant	Species absent at depth	Species present at depth	Species not present at site
Dauin 5m	Turfing Algae	R3	R2	Turfing algae, Coralline algae, R3, C1, *Halimeda*, P1, *Turbinaria, Dictyota, Valonia, Padina*	R4, *U. reticulata,* C4, C3, R6, R5, *Sargassum spp,* C2
Dauin 10m	Coralline algae	Turfing Algae	*Padina spp, Turbinaria spp,* P1, R3, *Valonia spp*	Coralline algae, turfing algae, *Dictyota*, R1, C1, R2, *Halimeda*	
KooKoos 5m	Coralline algae	R3	R4, *U. reticulata*	*Halimeda*, R3, R2, Coralline algae, Turfing algae, *Dictyota*, C1, P1, *Turbinaria*, C3, C4, *Valonia*	C2, R1, R6, R5, *Sargassum spp.*
KooKoos 10m	Coralline algae	*Halimeda spp.*	C4, *Turbinaria spp, Valonia spp*	*Padina, Halimeda*, R3, R2, Coralline algae, Turfing algae, *Dictyota*, C1, P1, R4, *U. reticulata,* C3	
Lutoban 5m	Coralline algae	*Dictyota spp.*	C3, R5, R6	Turfing algae, *Dictyota, Halimeda,* Coralline algae, C4, P1, *Turbinaria, Valonia, Sargassum,* R3, C2, C1, *Padina*	R2, R1, R4

Lutoban 10m	Coralline algae	*Dictyota spp.*	*Padina, Turbinaria spp, Sargassum,* C2	Coralline algae, *Halimeda, Dictyota,* turfing algae, R3, R6, P1, *Valonia*, C1, R5, C4, C3	

Table1: Showing findings for Algal ID at Dauin, KooKoos and Lutoban.

Discussion

Ulva reticulata makes up majority of the biomass of the bloom in Lutoban Bay. This species is one of 140 other species in the family of Ulva with its distribution expanding into Southeast and Southwest Asia, the Eastern, Western and Northern Indian Ocean, East Asia, the mid Pacific Ocean and Oceania (Largo, 2012.)

U. reticulata is most commonly found in its mature free-living form, entangled in seaweeds, seagrass, rocks and coral (Largo, 2012.) This holds true for Lutoban South where it is observed among the seagrass and seaweeds however little to no algae was observed on the reef at South or Pier, instead algae were seen to catch on the silty slopes of Pier.

This lack of presence on the coral reef is a relief, while *U. reticulata* is a native, non-invasive species to the Philippines, the blooming nature of this species can pose a threat to the coral reefs. Both animals and plants of the coral reefs can be affected through competition for space, light and their ability to move due to overcrowding specifically benthic communities.

Blooms of *Ulva* can disturb water and sediment quality through organic breakdown of the algae itself. It can also affect water flow over the boundary layer increasing the rate of sedimentation and affecting benthic community structure. Anoxia can become prevalent where detrital matter accumulates to the point it becomes mud. In Mactan, Cebu, rotting *Ulva* and the anoxic sediments below it has led to the dispersal of some fish and invertebrates out of the area and ultimately a decrease in the biodiversity of the region (Largo, 2012.)

The conditions required for this species to thrive includes a temperature between 25 and 30 degrees Celsius with a salinity between 34 and 35ppt, these conditions can only be found between the latitudes of 25ºN and 16ºS. Temperature being the main growth factor, clear shallow water and a protected habitat like a bay or lagoon is favoured also. Lutoban Bay is a very sheltered bay with the majority of the algal biomass occurring in only 1-1.5m of water coming into dry season in the Philippines the water temperature lies between 27 and 28 degrees currently. It is possible that this bloom is a result of seasonal change, the same species has been spotted in low quantities at KooKoos and Malatapay which indicates the issue is not localised but its presence is abundant throughout the Philippines.

Light is also a growth factor, optimal growth occurs when the algae is exposed to intermittent light rather than intense constant light conditions. This specific alga is able to adapt to low light conditions present in turbid environments when other algal species cannot. Growing algae can also create turbid conditions often seen in Lutoban which often experiences low visibility (CEES, 2017.)

U. reticulata is efficient at nutrient uptake, specifically nitrogen in the form of ammonia and phosphorus. These nutrients can occur in high concentrations in waterways due to anthropogenic behaviour. Run-off and soil erosion from agricultural land is known to contribute to eutrophication of neighbouring waterways from the use of fertilisers and live-stock feeds. Sewage effluent and deforestation are also potential causes. Lutoban has a small river that feeds into the Bay, it is likely that this waterway may play a part in linking what is happening upstream to the downstream environment.

On observation of the land use surrounding this river, it is mostly housing with some non-intensive farming. Possible inputs of excess nutrients may be via leaching of rubbish piles –full plastic waste bags which border the coast, in combination with some stock effluent located nearby the shoreline and subjected to tidal influence. Directly opposite Lutoban Pier lies a main road which underwent construction in late 2016/early 2017, this may be responsible for the levels of silt and high sedimentation about the pier. Sewage effluent is another factor that has been known to cause algal blooms, in Lutoban, human waste is processed in an underground concrete tank which in the centre is open to the external environment. This allows for percolation of waste liquids through the sediment – possible entry into ground waters.

A case study whereby green tides have previously occurred includes Mactan, Cebu in the Central Philippines. It demonstrates a use for *Ulva* as a biofilter in the removal of excess nitrogen and phosphate pollutants. The presence of this algae can act a gauge for pollution in the natural environment. Blooms of *Ulva* are not uncommon in areas of high population density where effluents from household and industry sources release directly to rivers and streams (Largo et al, 2004.) Water analysis of rivers that flow into Metro Cebu showed polluted levels of heavy metals, coliform bacteria, BOD and dissolved oxygen. In this case the Ulva was of benefit to the environment as it acts to remove toxicants and other pollutants from the water without any detrimental effects on neighbouring habitats. Highest density of Ulva was observed in the month of March, with an increase in biomass between December and March, exploratory dives in Lutoban Bay indicated a higher density of algae prior to the start of monitoring in April. This paper indicates that regardless of tidal flushing and how sheltered the Bay might be, algae can dominate areas that are relatively open to sea (Largo et al, 2004.)

Another example is Boracay in the Philippines. The white sandy beaches of Boracay act as an increasingly attractive location for tourists, however with this comes the requirement to support a greater population. The current sewage system is no longer fit to process such levels of sewage showing untreated sewage levels have reached a new maximum on the eastern side of the island. Historically locals have observed the presence of the algae for many years as a precursor to the arrival of summer. The alga is only present in the warmer months and does not occur year round, instead it is occurring later in the year around March/April instead of January/February (Rodriguez, 2017.)

Northern Mindanao, Philippines is again another location where green tides have developed in response to high nutrient availability. Mindanao is an example of how coastal waters respond to unregulated agro-industrial development along the waters edge (Villaluz et at, 2016.) Algal cover is not all bad, Romano et al, 2003 showed in a laboratory study that *Ulva* reduced erosion in sediments with increasing algal cover. *U. reticulata* is also shown experimentally to reduce effluents and increase levels of dissolved oxygen as growth is doubled and pH reduced (Villaluz et al, 2016.)

B.

Different coloured algae are distributed differently due to light. Light is a key component required for growth alongside phosphorus, nitrogen, water and carbon dioxide as in terrestrial plants. Macroalgae are categorised based on their accessory pigments, these compounds absorb light similarly to chlorophyll, and enhance photosynthesis of the algae under dim blue light. The colour of the accessory pigment gives rise to the colour of the macroalgae itself, with red, brown and green algae being the most commonly recognised seaweeds (Garrison, 2010.) The extent by which light can penetrate is not only determined by depth but a combination of variables. Seasonality and the strength of the irradiance, the angle of the incident light with the water, the optical properties of the water and the amount of suspended particulate matter in the water column all contribute (Talarico et al, 1998.)

A greater proportion of red algae are found at depth compared with other high light algae. The reason these species can thrive at depth is a result of either larger sized chloroplasts, more chloroplasts or a higher number of thylakoids per chloroplast. Red algae have an ability to adapt to changing light conditions on a molecular and cellular level (Talarico et al, 1998.) Algae can only use light in the visible spectrum, infrared is not strong enough and ultra-violet will cause damage to the DNA in the cells. Red light is absorbed at the surface while blue light can penetrate further, this affect how much light of specific wavelength can be attained by the algae (Garrison, 2010.)

Pigments are colour compounds that absorb light at a specific wavelength. Green algae or chlorophytes have Chlorophyll b while brown phaeophytes have fucoxanthin and red rhodophytes have phycoerythrin and phycocyanin pigments. According to chromatic adaptation red algae should be found the deepest. This is because green light which penetrates the deepest in coastal waters is absorbed by rhodophyte pigments. Chlorophyte pigments absorb in blue and red light; red light is only present in shallow waters therefore green algae should be found relatively shallow. Consequently, phaeophyte pigments absorb intermediate wavelengths of light so should therefore be located in intermediate depths. This is not always the case, pigments in combination with herbivory, competition and growth forms determine the depth distribution of different coloured algae (Karleskint et al, 2006.)

In conclusion, it is likely that the algal bloom in Lutoban is a combination of some untreated sewage alongside seasonal warmer ocean temperatures providing the right conditions for such a bloom to occur. The depth distribution of these algae across three sites can be attributed to light penetration however further research into the topic would offer a more definite conclusion.

There are many limitations to my study that prevented further conclusions to be made. Future opportunities for study in the Philippines would be to identify species found to family and even species level, lack of appropriate literature and online resources and access to them alongside an electron light microscope prevented this. Probes for measuring water temperature, salinity, DO2, pH, phosphorus and nitrogen levels would back up assumptions for causes of the bloom. The time and ability to monitor the algal cover year round would rule out the idea of seasonality or account the bloom solely to a seasonal phenomenon. The ability to measure light levels and penetration at depth, perhaps using secchi discs, would give a basis of knowledge to understanding the distribution of specific algae along the reef. The use of organic dyes to track currents from the river and in the bay can help determine whether the source of eutrophication is from the mouth of the river. The issue surrounding the siltation at Lutoban Pier is more topical than the algal bloom, while the algae may smother the reef to a small extent the silt smothers the algae and the reef further. Research into quantifying the extent of siltation at the Pier would be a good direction for study at this site.

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Appendix

Table 2: Algal species found at sites: Dauin, Lutoban and Kookoos