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Bioecology of the corallivorous *Acanthaster planci* (crown-of-thorns seastar) in the coastal areas of Dimataling, Zamboanga del Sur, Mindanao, Philippines

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ABSTRACT

Coral reef degradation is the major consequence posed by the massive infestation of *Acanthaster planci* (crown of thorns), a corallivorous sea star. This present study assessed the bioecological aspects of *A. planci* in terms of its morphology, coral type preference, gut analysis and physico-chemical parameter preferences on the coastal areas of Saloagan, Dimataling, Zamboanga del Sur. Two color morphs were exhibited by *A. planci* among the 90 individuals collected. The largest body size in diameter was 270mm, weighing 365g and with 7-16 number of arms. There were 14 identified coral species foraged by *A. planci* where *Porites* is the most preferred coral genus preyed by 23.33% of the *A. planci* studied. Gut analysis revealed fragments of coral species such as *Pocillopora spp., Acropora spp.*, five algae species, one sea grass species and unidentified species of crabs, gastropods and bivalves were found in the stomach of *A. planci*. All of the physico-chemical parameters obtained in Saloagan, Dimataling are within the same range compared to other areas where outbreaks of *A. planci* have been reported which indicate that the conditions in this local habitat are suitable for the growth of *A. planci*. This study may be significant in establishing management strategies to predict or possibly inhibit the outbreaks of *A. planci* on the coral communities.

Keywords: corallivorous, crown of thorns, gut analysis, Dimataling

INTRODUCTION

Coral reefs are one of the most biologically diverse and productive ecosystems on Earth (Grossman, 2014). They played a significant role in marine ecosystems as habitat and nursery grounds for 10% to 20% of the world's fisheries and protect coastlines from waves, storm damage and erosion. However, they are regarded as one of the world's most threatened ecosystems (Pratchett *et al.*, 2014). According to Uthicke *et al.*, (2015), these ecosystems are declining worldwide due to anthropogenic and natural causes such as overfishing, land-based pollution, sedimentation, climate change and outbreaks of certain corallivorous sea stars commonly known as crown of thorns (*Acanthaster planci*) (Thummasan *et al*., 2015).

A. planci is a species of sea star belonging to Phylum Echinodermata, Class Asteroidea (Lee *et al*., 2013). It feeds extra-orally by everting its stomach and wrapping it around the surface of its prey and then secretes digestive enzymes that break down the coral tissues (Vogler, 2010) where bleach white feeding scars are all that remains once a coral species has been foraged upon by *A. planci* (Clark & Weitzman, 2006).

Accordingly, if *A. planci* population reaches densities of greater than (>) 1,500 specimens per km^2, it is referred to as an outbreak (Haines, 2015) where it can be extremely detrimental to the coral reef ecosystem (Clark & Weitzman, 2006). Outbreaks of *A. planci* can lead to increase in benthic algae, loss of coral-feeding assemblages, collapse of coral reef structural complexity and a decline in biodiversity and productivity (Posada *et al.* 2014). As a corallivorous species, it can consume approximately 6-10 m^2 of living coral reef per year primarily upon Scleractinian or reef building corals such as *Acropora* and *Pocillopora* (Pratchett, 2001). This feeding behavior could be a major contributing factor making it as the second major cause of the decline of the world's coral cover specifically in Indo-Pacific region (De'ath *et al*., 2012).

The Great Barrier Reef of Australia, the largest coral reef in the world has lost approximately half of its initial cover over a period of 22 years (1985-2012) with 42% of this loss were caused by an outbreak of crown of thorns sea stars (Wilmes *et al.*, 2016). Studies by Australian Institute of Marine Science showed that with the absence of this sea star, coral cover would increase at 0.89% per year. In the Philippines, outbreaks have been documented in Sogod Bay, Southern Leyte (de Dios *et al*., 2014), Samal Island, Davao Gulf (Bos *et al*., 2013) and Tubbataha Reef of Sulu Sea (Bos *et al*., 2009).

Different methods that have been used to control the outbreaks of crown of thorns such as; (1) cutting of *A. planci* into pieces but was discouraged because of its regeneration capacity (Barker & Scheibling, 2008); (2) manual removing from reefs with hooks and stick and burying them at a nearby beach (Sato *et al.*, 2008); and (3) by injecting them with ammonia (Bos *et al*., 2013), copper sulfate and bisulfate (Bos *et al*., 2013). These studies, among others, focused on discovering potential mitigation against them. However, their proliferation remains one of the major threats in the coral reef ecosystem (Posada *et al*., 2014).

Barangay Saloagan in Dimataling, Zamboanga del Sur hosts a number of corals along its coastal areas. Fishing is the major source of livelihood in the locality. However, injury cases with these sea stars lead to some complaints by the interviewed fishermen in terms of their proliferation in the site. In terms of the effect of these sea stars to coral degradation, there has been no scientific documentation from the local government. Thus, this study was conceptualized to assess *A. planci* populations in terms of its bioecological aspects which are significant for early warning and pragmatic management to prevent coral loss in Barangay Saloagan, Municipality Dimataling, Zamboanga del Sur Province.

METHODOLOGY

Research Site
This study was conducted at the coastal areas of Barangay Saloagan, Municipality of Dimataling, Zamboanga del Sur Province. Figure 1 shows the map of Barangay Saloagan, Dimataling and the actual three sampling stations.

Research Design
Ten percent (10%) of the total land area of study site was sampled for the study. A 500m line was established along the shoreline. This was then divided into three (3) sampling stations with a distance of 100 m from one station to another. Belt Transect Method was employed in this study, with belt measuring 50m seawards, 50 m to the left and 50 m to the right of the belt station.

Research Procedure
Collection of Samples
A total of 30 *A. planci* individuals were collected per sampling stations. Collection of *A. planci* sea stars was based on the works of Bruckner (2013) where wooden stick was used for the collection and removal of sea

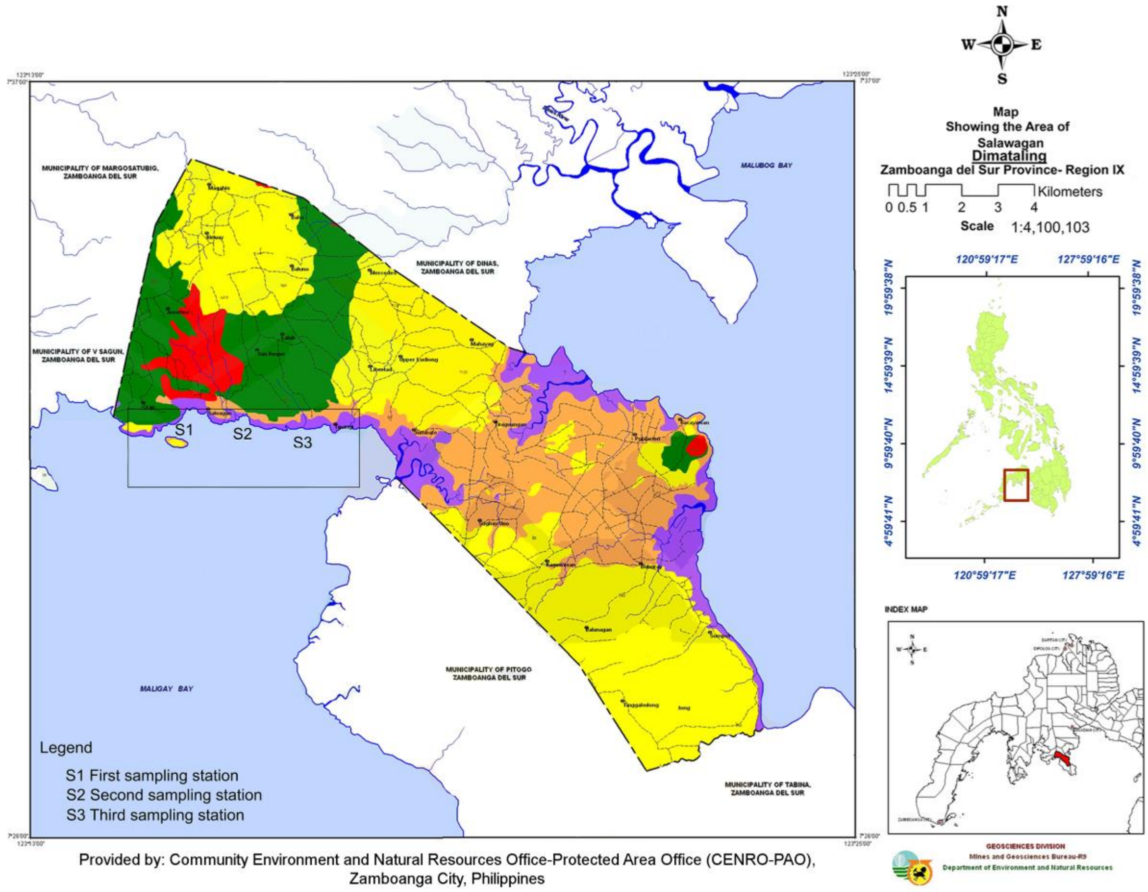

Figure 1. Map showing the geographical location of Barangay Saloagan, Dimataling, Zamboanga del Sur and the location of the three sampling stations.

stars. Divers used hand gloves for protection against the spines of *A. planci*. The collected sea stars were placed in large rice bags and were brought to the boat up to the shore.

Assessment of Behavior of A. planci

In assessing the behavior of *A. planci,* it was based on the works of Haines (2015) where individual that was spotted on a coral was marked as feeding and the complete taxonomic rank of the corals was identified. On other substrate such as rock and sediment, the individual was marked as non-feeding. For the computation of the percentage of non-feeding *A. planci* and the percentage of the preferred coral genus, the following formulae by Haines (2015) were used:

$$Percent\ of\ non-feeding = \frac{Number\ of\ non-feeding\ A.planci}{Total\ number\ of\ A.planci} x\ 100$$

$$Percent\ of\ preyed\ coral\ genus = \frac{Number\ of\ A.planci\ preying\ a\ specific\ coral\ genus}{Total\ number\ of\ A.planci} x\ 100$$

Identification of Foraged Corals

During the collection of *A. planci*, corals that are foraged by *A. planci* were identified to further better understand its coral type preference. In a 1x1 frame, corals foraged by *A. planci* were documented *in situ* using an underwater camera. The distance between the camera and the corals must be enough to fit the whole structure of corals into one photographed. On the other hand, the corals were photographed showing the entire close-up structure of single species for identification.

Morphometrics Approach

Sizes of *A. planci* were measured in terms of its diameter. A ruler was used to measure the distance between the farthest tips of the arm on the aboral side of the body and readings were obtained in millimeters (mm). Sizes of *A. planci* were categorized into different life stages. Accordingly, juveniles ranged between 1-19 cm; adults measured between 20-35 cm and senile adults are those with diameter of over 36 cm (Haines, 2015).

Total body weight was measured using a weighing scale. Samples were placed into the scale and readings were obtained in grams (g). The number of arms of *A. planci* was determined by simply counting the arms present in *A. planci*.

Gut Analysis

To further assess the feeding habits of *A. planci,* gut analysis was done in the ten (10) representative samples in each station. Thirty (30) *A. planci* individuals were preserved in a 70 % ethyl alcohol and were properly labeled in a container. All of the samples were brought in the laboratory of the College of Science and Mathematics, Western Mindanao State University, Zamboanga City.

Samples were then dissected to analyze the stomach content of *A. planci*. Since the stomach is the easiest part to dissect, gut analysis was focused on the stomach part located in the oral disk of the specimen. Just like any other sea stars, the oral portion of *A. planci* contains numerous tube feet for locomotion (Fig 2).

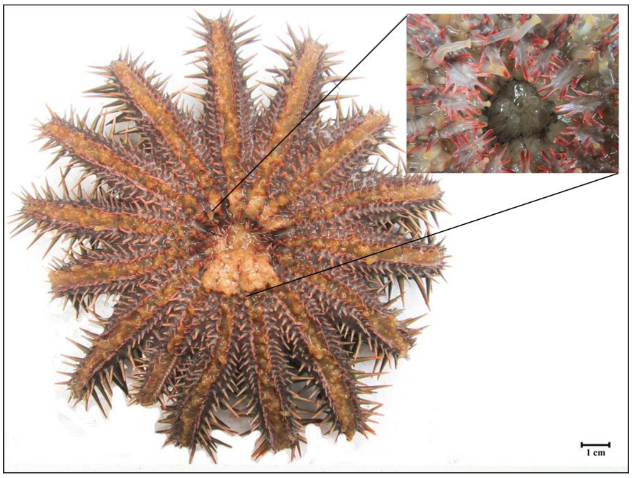

Figure 2. Oral part of the *A. planci* showing its stomach as part of the gut.

The stomach was cut with a scissor through incision and it was transferred in petri dish for microscopic examination with the use of stereomicroscope. Preyed item was identified to the lowest possible taxonomic level. Percent of occurrence was calculated using this formula by Loh and Todd (2011):

$$Percent\ of\ occurrence = \frac{Number\ of\ occurrence}{Total\ preyed\ item} x\ 100$$

Determination of Physico-Chemical Parameters

Water temperature was determined using a digital thermometer by placing the end of thermometer into the sea water for 2-3 minutes and readings were obtained in degree Celsius (°C). The water pH was determined with the use of a pH meter. The pH electrode was rinsed with distilled water and the power button was pressed. The pH electrode was dipped into the water sample. The pH level was recorded after 2-3 minutes when the pH reading is stable. The depth of the water where *A. planci* found was measured using a rope with a stone tied to one end of it and dropped it in the sea, when the stone hit the bottom it was pulled back up and the distance from the surface to the bottom was marked and calibrated using a meter stick for proper measurement. Water salinity was measured using a refractometer by dropping a 1 ml water sample in the refractometer's prism. The daylight plate was closed and pressed to spread the water evenly across the prism and the front of the refractometer was pointed towards a light source. A circular field containing the index used for measuring salinity level can be seen inside the eyepiece. The line created by light passing through the liquid and prism was delineated by a blue color in the top of the circular view and a white color in the bottom of the view. The point on the index at which the line falls was recorded.

On the other hand, water samples were brought at the Department of Science and Technology (DOST) laboratory, Zamboanga City and tested for the determination of phosphate content through Vanadomolybdophosphoric Acid Colorimetric Method. Fifty membrane filters were soaked in two (2) L distilled water for one (1) hour. Distilled water was then replaced and filters were soaked for an additional three (3) hour-period. A drop of phenolphthalein indicator (about 0.05 mL) was added to 50.0 mL sample and the red color with 1+1 HCl was discharged before diluting to 100ml 35 mL or less of sample, containing 0.05 was placed to 1.0 mg P, in a 50-mL volumetric flask. Ten (10) mL vanadate-molybdate reagent was added and diluted to the mark with distilled water. After ten (10) minutes or more, absorbance of sample versus a blank at a wavelength of 400 to 490 nm was measured. A calibration curve was prepared by using suitable volumes of standard phosphate solution using this formula:

$$mg\ \frac{P}{L} = \frac{mg\ \ P\ (IN\ 50\ mL\ final\ volume)}{mL\ Sample} x\ 100$$

For the water potassium (K) content, water samples were also brought to DOST laboratory. Using Direct Flame Atomic Absorption Method, a 0.1907g potassium chloride KCL (dried at 110 °C) was dissolved in water and make up to 1000 mL: 1.00ug K. A hollow cathode lamp was installed and let it warmed up until energy source stabilizes about 10-20 minutes. Acetylene flow rate was turned on and adjusted to give maximum sensitivity for the metal being measured. Absorbance of this standard was recorded through a calibration curve by plotting on linear graph paper absorbance of standards versus their concentration. Concentration of each metal ion was calculated in milligrams per liter.

In the case of Total Suspended Solids (TSS), one thousand (1000) ml water samples were collected from the three stations of the study site and were brought at the laboratory of Bureau of Fisheries and Aquatic Resources (BFAR), Zamboanga City. Water samples were filtered using a Whatman paper. The filter paper was pre-weighed and oven dried. The residue in the filter paper was rinsed with hot water and transferred to an inert aluminum weighing dish and dried in an oven at 103-105 °C. Sample volume to yield between 2.5 and 200 mg dried residue was chosen. Suspended solids were calculated in terms of mg/l using the formula:

$$mg\ TSS/L = \frac{\text{weight of filter + dried residue (mg) - weight of filter (mg)}}{\text{volume of sample (mL)}} \times 100$$

For the determination of Dissolved Oxygen (DO), one thousand (1000) ml water samples were collected from the three stations of the study site and were also brought at the BFAR laboratory. Two (2) ml of $MnSO_4$ (manganese sulfate) and two (2) ml of alkaline iodide-azide were added into the BOD bottle containing the water sample. Two (2) ml of concentrated H_2SO_4 (sulfuric acid) was added in the solution and the bottle inverted for several times until the precipitate dissolved producing orange color solution. The sample was titrated with 0.025 M $Na_2S_2O_3$ (Sodium thiosulfate) solution to pale yellow color. Two (2) ml of starch indicator was added into the solution and continued the titration until a color transition from blue to colorless was observed. The dispensed volume of 0.025 M $Na_2S_2O_3$ was used to calculate the dissolved oxygen in the sample using this formula:

$$D.O.\ in\ mg/L = \text{mL of Sodium thiosulfate (0.025N) consumed}$$

One hundred (100) grams of substrate samples were collected from the three stations of the study site and were brought at the Department of Agriculture, Regional Soils Laboratory, Zamboanga City for the characterization of substrate class through Bouyoucos Hydrometer Method. The soil samples were placed into an oven-safe jar and oven dried at 105 C° for 24 h. In a volumetric flask, sodium hexametaphosphate (HMP) and distilled water were combined for a total volume of 2000ml. Oven-dry soil samples were placed into a 600-mL beaker. A 250 mL distilled water and 100 ml HMP were added and soaked overnight. Soil-HMP mixture was transferred to a dispersing cup and was mixed for five (5) minutes with an electric mixer. In a sedimentation cylinder, 100 mL HMP to 900 mL room temperature distilled water was added to make 1L total volume solution and mixed with plunger and temperature was recorded. Gently, the hydrometer was placed lower into the cylinder. Upward strokes were used to remove sediment from bottom and finished with five or six smooth strokes. When mixing was complete, hydrometer was gently placed into the suspension. Readings were taken at 30s and lastly, hydrometer was removed, rinsed and dried.

RESULTS AND DISCUSSION

Outbreaks of *A. planci* populations have become a serious threat to ecologically important coral species in Indo-Pacific region in the last decades (Clark & Weitzman, 2006). This present study assessed the bioecological aspects of *A. planci* on the corals of Saloagan, Dimataling, including its feeding behaviour and preference that can cause considerable amounts of damage to coral communities which could lead to creating effective management to control the *A. planci* populations (Haines, 2015).

This study revealed that two different morphs of *A. planci*; the purple with orange spines *A. planci* (color morph #1) and the purple with red spines *A. planci* (color morph #2) were found to be the dominant color morphs in some coral communities on the coastal of Saloagan, Dimataling (Fig 3). The aboral portion of *A. planci* contains numerous spines which functions for protection. The color combinations can vary from gray with green spines to gray with purple spines color morphs which were observed in the Pacific Ocean, purplish blue with red spines and green with yellow spines in the Great Barrier Reef and blue to pale red spines in the Indian Ocean (Vogler, 2010). The actual images were taken on a broad daytime and *A. planci* was spotted in a stony coral type (Scleractinia).

The occurrence of *A. planci* may also be affected with the abundance of coral species (Pratchett, 2007). In terms of the corals species foraged by the *A. planci* in Saloagan, Dimataling, there were 14 identified coral species (Fig 5) belonging to six (6) families namely Acroporidae, Faviidae, Fungiidae, Musiidae, Pocilloporidae and Poritidae.

A total of 27 *A. planci* (30%) are observed as non-feeding and 63 *A. planci* (70%) are observed as feeding during the sampling periods. *Porites* is the most preferred genus of coral found during this study in all stations (23.33%) while the least preyed coral genera are *Fungia* (2%) and *Lobophyllia* (2%). According to De'ath et al. (2012), their feeding behavior is believed to be cryptic by nature, however, when it does not feed, *A. planci* will just hide to avoid predation. This non-feeding *A. planci* might have been migrating between coral colonies (Haines, 2015). Figure 4 shows the preyed coral genera of *A. planci* as observed on the corals of Saloagan, Dimataling using a pie graph.

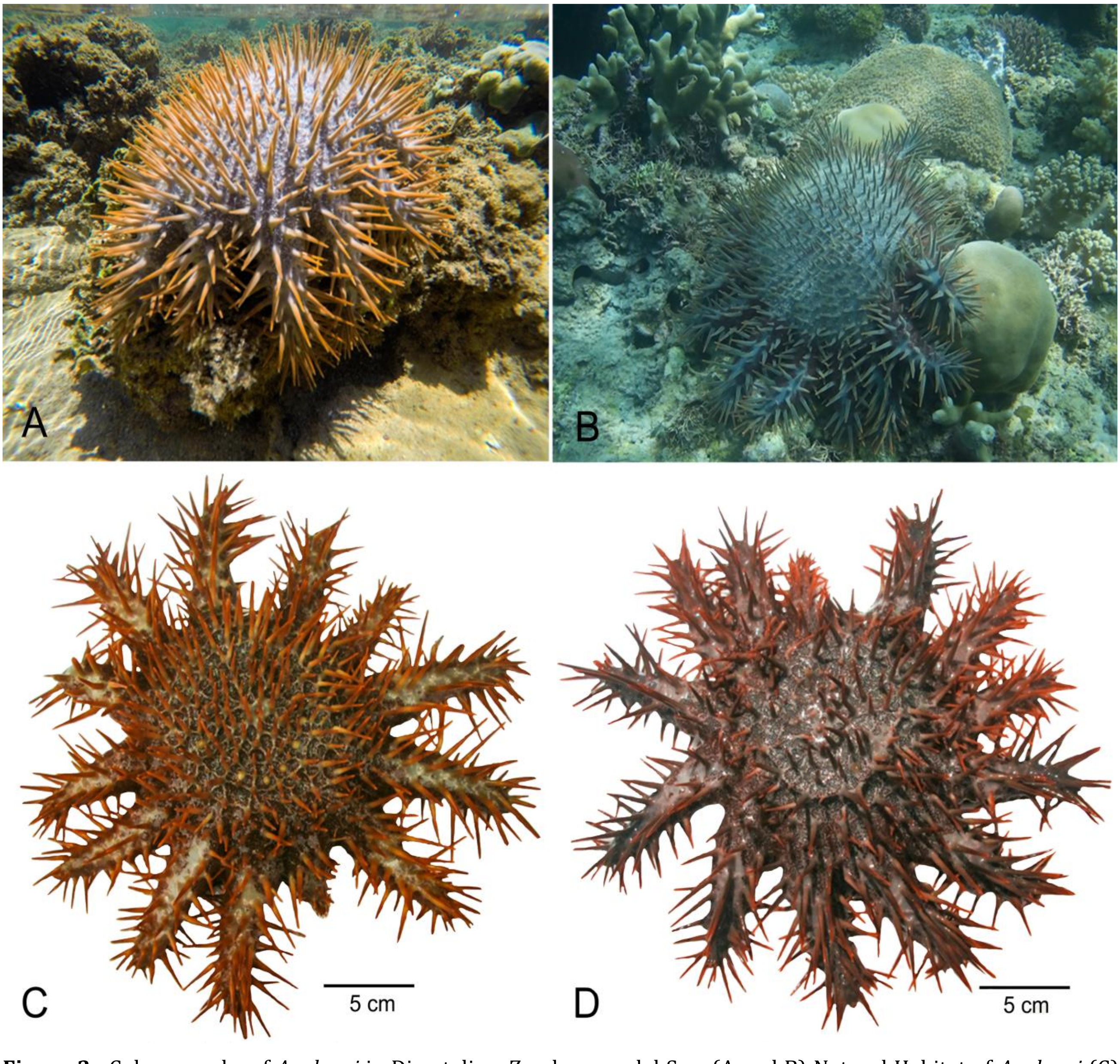

Figure 3. Color morphs of *A. planci* in Dimataling, Zamboanga del Sur; (A and B) Natural Habitat of *A. planci* (C) with orange spines covering its aboral surface and (D) with red spines covering its aboral surface.

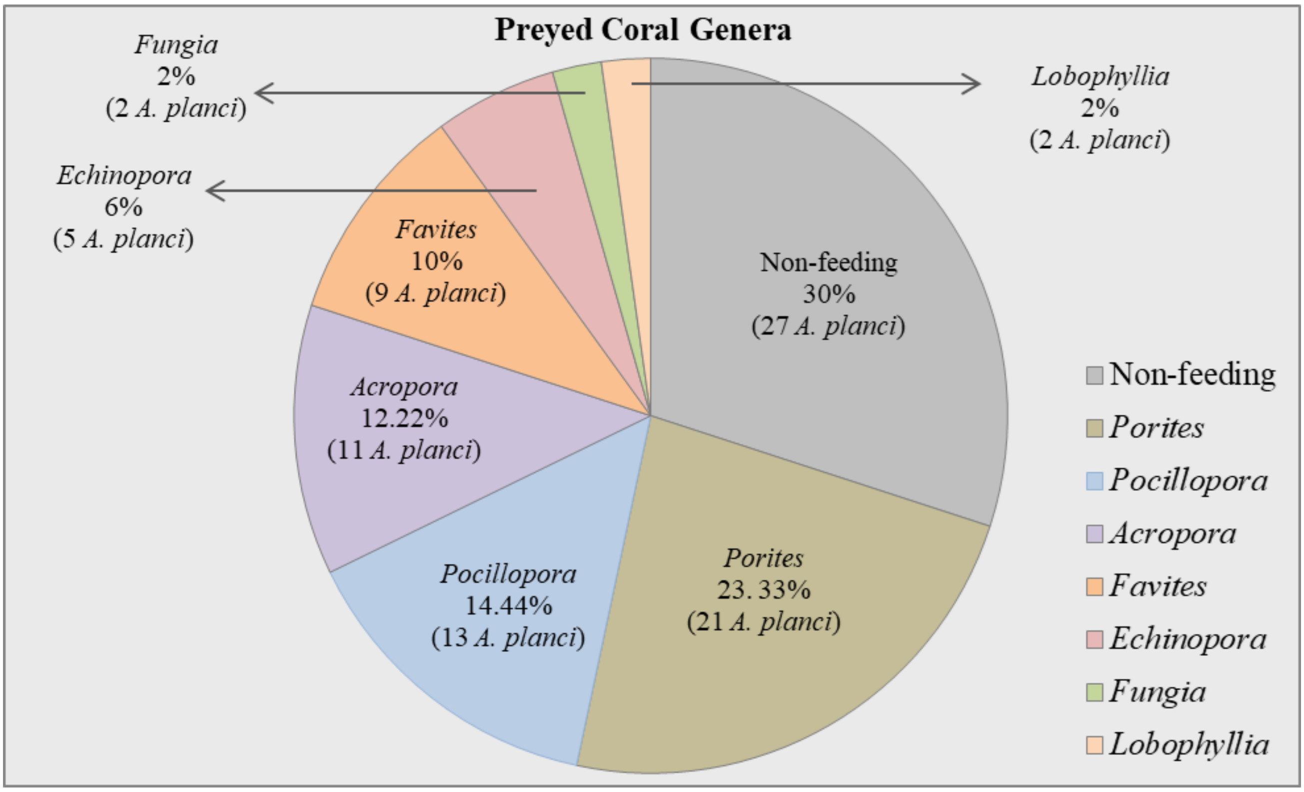

Figure 4. Pie graph showing the preyed coral genera of *A. planci* in Saloagan, Dimataling

In contrary to the coral reefs of Koh Tao, Thailand, the preferred genera for *A. planci* are *Fungia* which was found to be the prey of 17% of *A. planci*, *Pavona* was preferred by 15%, *Porites* 14%, *Acropora* and *Favia* 9% and *Favites* 8% (Haines, 2015). These proved that *A. planci* worldwide tend to have different preference in preyed corals. These preferences may be caused by a variety of different attributes and might be more related to morphological and physiological characteristics of corals that influence feeding efficiency such as the growth form, skeletal structure and tissue depth (Keesing, 1990).

In terms of the morphological features of corals, coral genera of *Porites*, *Pocillopora*, *Acropora* and *Favites* are characterized by having stony and branching structures, respectively, which suggest that these types of corals have a greater morphological surfaces and could be the contributing factors making them as the most preferred genera in Saloagan, Dimataling by *A. planci*. Although, abundance of coral species in the study site were not directly counted but based on field scientific observation during the sampling period, *Porites* was found to be the most abundant coral genus and might be the reason why it is the most preferred prey, this observation is supported by Pratchett *et al.* (2017) who stated that the most abundant coral genus in the local habitat would be the strongest selection to be foraged by *A. planci* and this is commonly termed as ingestive conditioning. Accordingly, during this condition, the *A. planci* would accept normally non-preferred genera over its preferred prey after this sea star had been conditioned to forage the most common coral species in its local habitat (Keesing, 1990).

In terms of morphometrics among the 90 sampled *A. planci* in the three (3) sampling sites, the largest body size in diameter was 270mm, weighing 631g and with 16 number of arms. On the other hand, the minimum body size of *A. planci* was 120 mm, weighing 50g with 7 number of arms. These morphometrics in terms of its sizes were further categorized in different life stages. The sizes of *A. planci* in terms of the diameter of whole body is an important factor to be considered in studying this species as it is related to the reproductive capacity of *A. planci* (Pratchett *et al.*, 2014; Haines, 2015). The mean average size of *A. planci* found in Saloagan, Dimataling ranged from 185.17 mm to 190.5 mm. These sizes are within the range that Pratchett *et al*. (2014) found in the Great

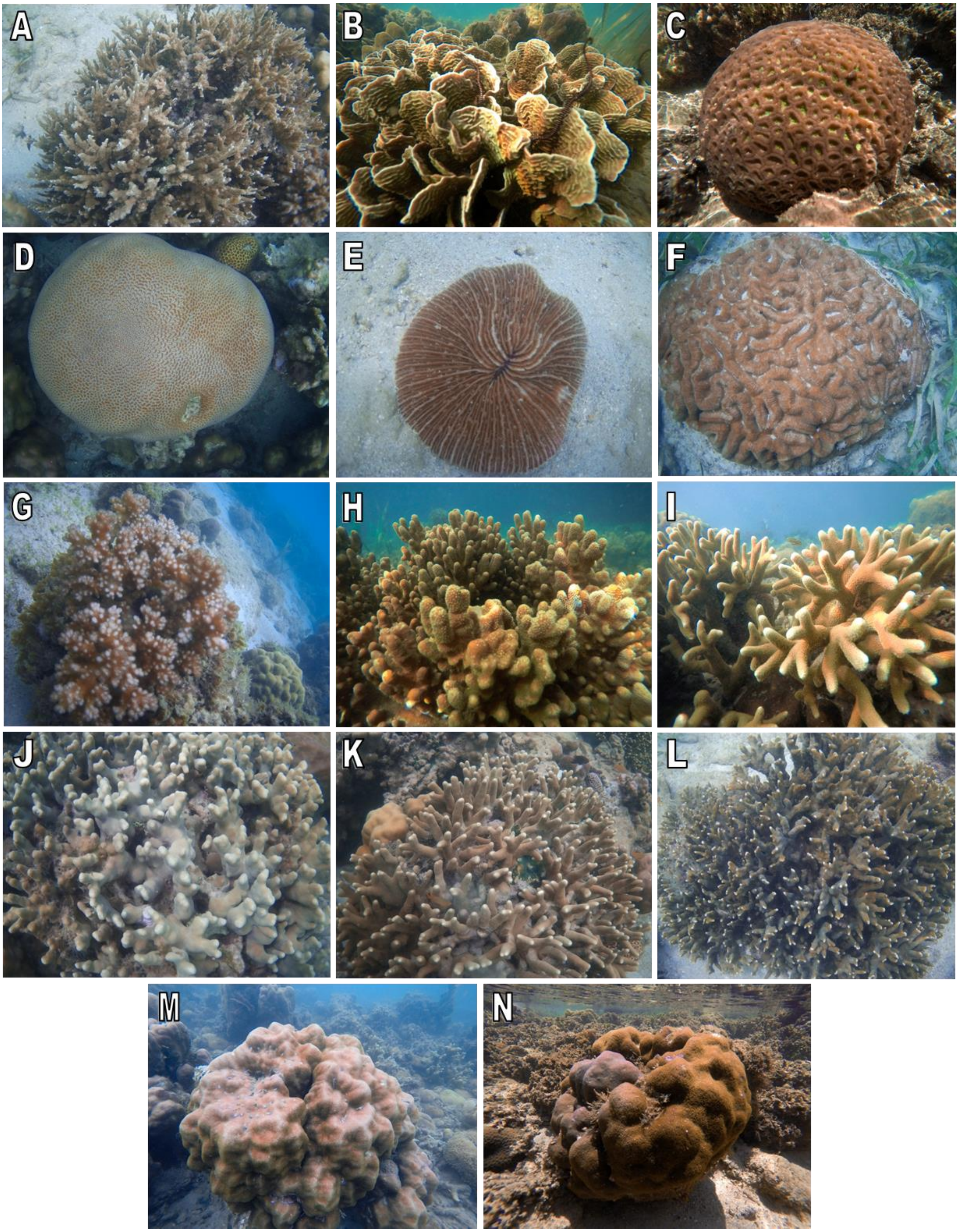

Figure 5. Coral species foraged by *A. planci* in Saloagan, Dimataling. A- *Acropora caroliniana.* B- *Echinopora pacificus.* C- *Favites abdita.* D- *Favites flexuosa.* E- *Fungia paumotensis.* F- *Lobophyllia hemprichii.* G- *Pocillopora damicornis.* H- *Porites annae.* I- *Porites attenuate.* J- *Porites compressa.* K- *Porites cylindrical.* L- *Porites divaricate.* M- *Porites lutea.* N- *Porites mayeri*

Barrier Reef in Australia where 110 mm was found as the minimum size and 620 mm was found as the maximum. Keesing (1990) found an average of 375 mm on the Great Barrier Reef, which is larger in diameter than what was observed in this study. With these findings, it supports that the body sizes of *A. planci* found in Saloagan, Dimataling are the most common size range of *A. planci* encountered. The presence of different size classes signifies that there might be a progressive accumulation of different cohorts in the specific coral communities (Posada *et al.,* 2014) and the different sizes of *A. planci* could be attributed on the availability of food in its habitat.

Moreover, the minimum body weight of *A. planci* found in all stations was 30g and the maximum weight was 365g and the mean average body weight of *A. planci* ranged from 163.97 -178.97g. In the Great Barrier Reef of Australia, body weight of *A. planci* ranged from 280 g to 300 g (Keesing, 1990) which is heavier than what was collected in this study. The increase or decrease of the body weight of *A. planci* can be attributed to the shrinkage of individuals that might be due to the loss of gametes, starvation and elevated skeletal contents.

The number of arms of *A. planci* found in Saloagan, Dimataling varies from 7-16 arms and the mean average number of arms ranged from 12-13 arms as observed in all stations which falls within the typical range of the number of arms of *A. planci* for about 7 to 23 arms worldwide (Haines, 2015). Differences in number of arms of *A. planci* between geographic areas have been documented in the Great Barrier Reef in Australia, Thailand (Haines, 2015), and Sogod Bay in the Philippines (de Dios *et al.,* 2014). As observed during the collection in the study site, some *A planci* are with missing and regenerating arms from the three stations. This is the most commonly regarded as the outcome of sublethal predation event that can be used as an index of predation intensity. The observed damaged arm of *A. planci* in the study site indicates that predation intensity might be high among sampled populations (Posada *et al.,* 2014). However, in the study of Messmer *et al.* (2013), it was found out that *A. planci* can regenerate from extensive tissue loss, but survivorship depends on maintaining at least part of the central disc.

Figure 6 shows the categorization of the life stages of *A. planci* (n=90) found in all stations in Saloagan, Dimataling based on the obtained morphometrics using a column graph.

Fifty-eight *A. planci* were categorized as juveniles, 32 individuals were categorized as adults and no senile adult *A. planci* was recorded during the sampling. This suggests that the juvenile *A. planci* are found out to be more cyptic, with an age ranged of 0.5 year to 2 years while the coral feeding adults the age ranged from 2 years to 5 years (Pratchett *et al.,* 2014).

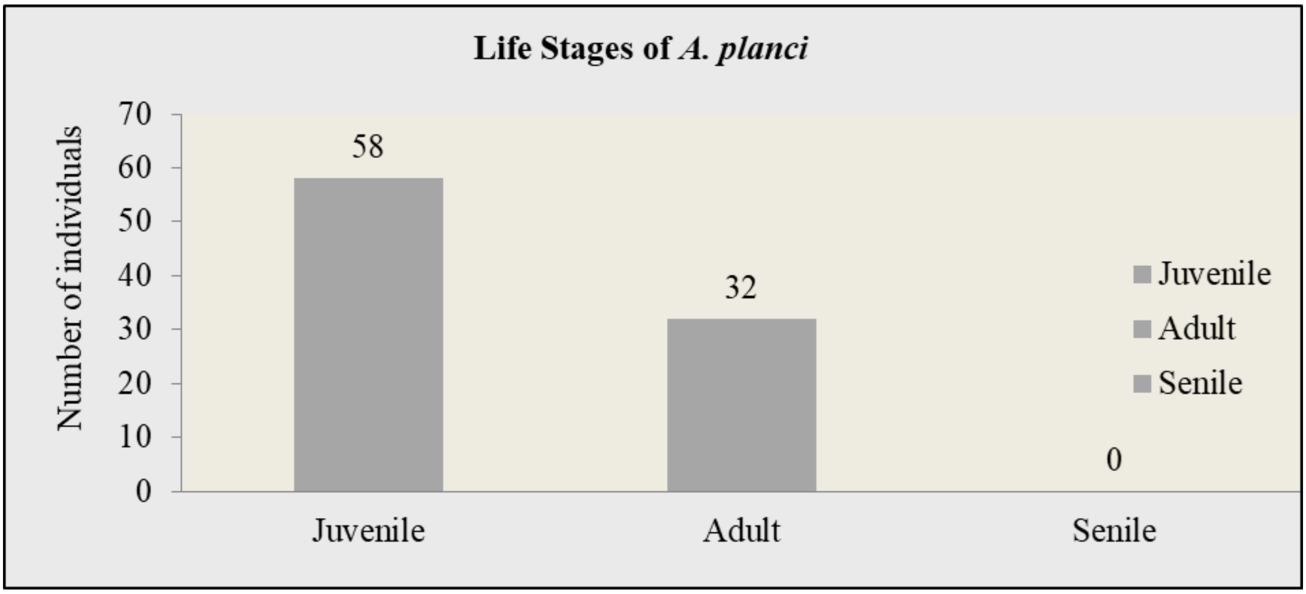

Figure 6. Column graph showing the categorization of the life stages of *A. planci* (n=90) found in Saloagan, Dimataling based on the obtained morphometrics.

Table 1. Number of occurrence and percent frequency of occurrence of the stomach contents of *A. planci* (n=30) collected in Saloagan, Dimataling,

Preyed Item	Number of occurrence (N)	Percent Frequency of occurrence (%)	Rank
Coral species			
Acropora spp. Fragments	18	60	2
Pocillopora spp. Fragments	23	76.67	1
Algae species			
Cryptonemia crenulata	5	16.67	5
Gracilaria spp.	10	33.33	3
Halimeda macroloba	2	6.67	7
Padina gymnospora	3	10	6
Sargassum polycystum	6	20	4
Seagrass species			
Cymodocea serrulata	5	16.67	5
Unidentified species			
Unidentified crab species	1	3.33	8
Unidentified bivalve species	1	3.33	8
Unidentified gastropod species	3	10	6
Total preyed item	**77**	**100%**	

For the results of the gut analysis, Table 1 shows the number of occurrence and percent frequency of the stomach contents of *A. planci* (n=30) found in the three stations in Saloagan, Dimataling. Representative examples of the preyed item found in the gut of *A. planci* that were seen under stereomicroscope are shown in Figures 7– 10.

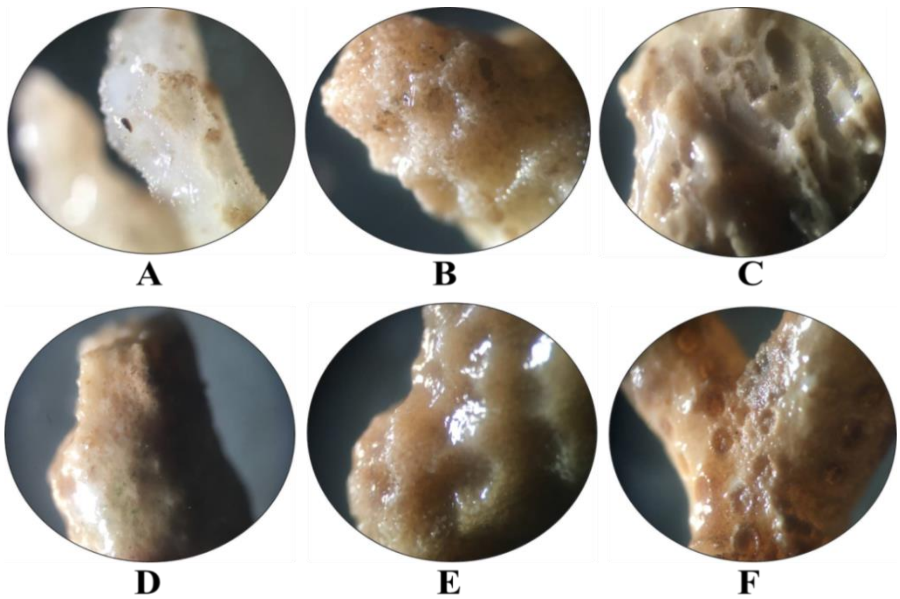

Figure 7. Coral fragments. A, B & C- Apical branch fragments of *Pocillopora* spp. D, E & F- Apical branch fragments of *Acropora* spp.

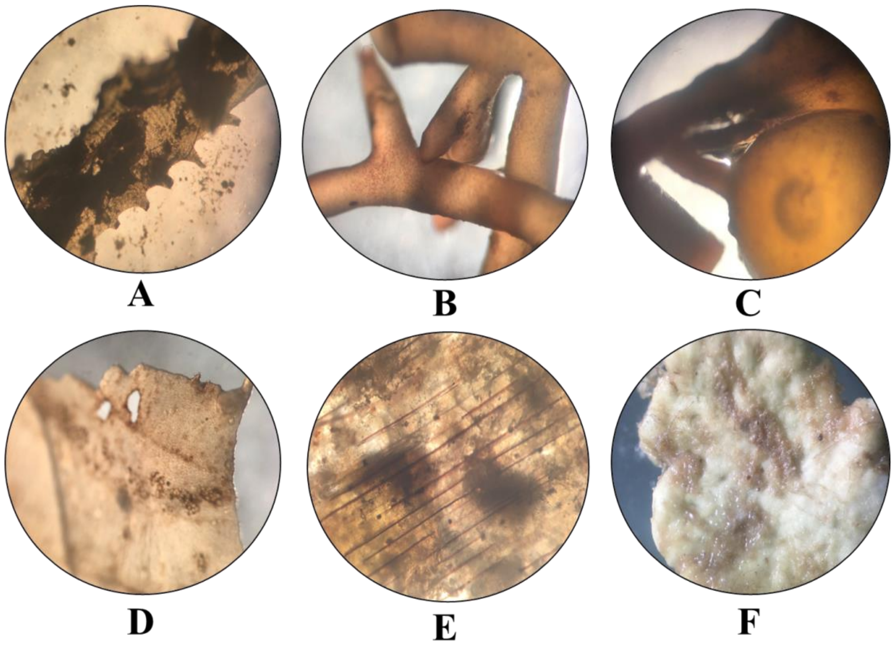

Figure 8. Algae species. A- *Cryptonemia crenulata*; B- *Gracilaria* spp.; C- *Sargassum polycystum*; D-*Padina gymnospora*; E- *Halimeda macroloba*. Sea grass species. F- *Cymodocea serrulata*.

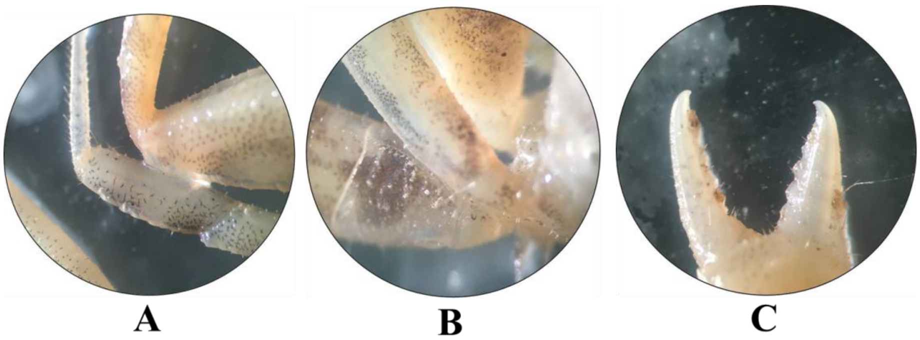

Figure 9. Unidentified species of crab. A- carpus part; B- merus part and C- dactylus part.

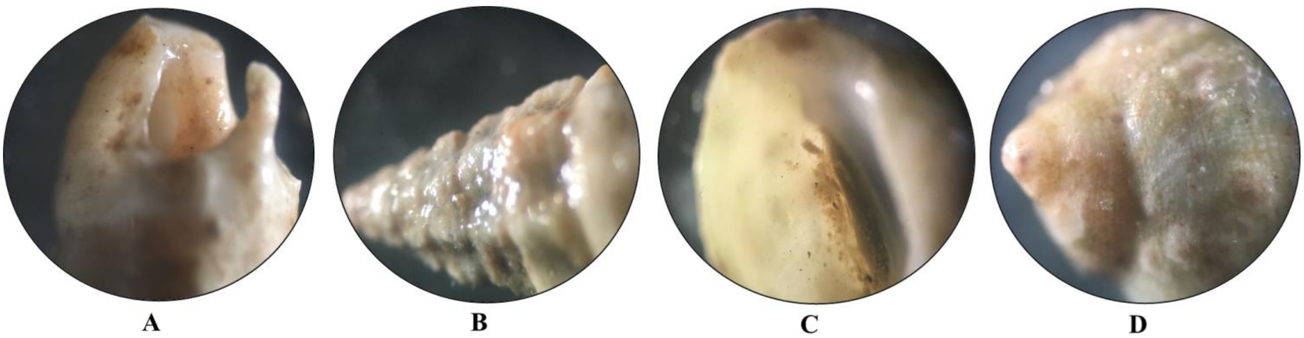

Figure 10. Unidentified species of gastropods. A & C- posterior end showing the columella, operculum and aperture; B & D- anterior end showing the apex and spiral whorls.

Availability of food is one of the main factors in determining the behavior, distribution and abundance of the species (Gaymer *et al.,* 2001; Loh & Todd, 2011). With this, the food preferences of *A. planci* were examined in the 30 *A. planci* individuals through gut analysis. In terms of the percentage of occurrence of the stomach contents of *A. planci, Pocillopora* spp. fragments were found to be the highest (76.67%) followed by *Acropora* spp. fragments which constitutes about 60%. According to the optimal diet theory, high calorific values are usually chosen as they can yield more energy per unit time (Sih & Christensen, 2001). In the study of Keesing (1990), it has been found out that species of *Acropora* had the highest energy content of 19.3-23.7 $kJ.g^{-1}$ ash-free dry weight (AFDW) while *Pocillopora* ranging between 21.6-22.7 $kJ.g^{-1}$AFDW. This could be the reason why *Pocillopora* and *Acropora* fragments were found in stomach contents of *A. planci*. This finding is in accordance with Bos *et al*. (2013) who stated that *Acropora* and *Pocillopora* genera are the most common preferred coral prey of *A. planci.*

Quantity and quality of ingested foods are the main factors responsible for sea star growth. In this study, five seaweed species; *Cyptonemia crenulata, Gracilaria* spp., *Halimeda macroloba, Padina gymnospora, Sargassum polycystum* and one sea grass species; *Cymodocea serrulata* were also found in the gut of *A. planci.* These seaweed and sea grass species are characterized by having soft tissues which suggests that it can be easily digest since the flexibility of a sea star's stomach is important in determining the number of prey it can digest (Loh & Todd, 2011). The selectivity of prey is influenced by several factors such as the prey size which depends on its body size and constraints imposed by the mechanism of intraoral digestion (Ventura *et al.,* 2001).

On the other hand, detailed examination on the gut contents of *A. planci* that are related to molluscs revealed that unidentified species of gastropod had frequency occurrence of 10%, while unidentified species of bivalve and crab had the same frequency of occurrence of 3.33%. Similarly, Hassan *et al*. (2017) had recorded some fragments of flora and fauna found in the gut of the sea star *Stellar childreni* including Mollusca such as gastropod, bivalves, seagrass, and seaweeds.

There have been several reports regarding with the feeding preferences of *A. planci* but these studies provided lack of information in relation to its stomach contents (Pratchett, 2001). Thus, this study provides insights about the feeding biology of *A.planci* in relation to the foraging behavior of *A. planci*, especially with its stomach contents.

Physico-chemical parameters known to affect the bioecological aspect of *A. planci* were measured and mean readings were recorded in Table 2.

Table 2. Mean value on physico-chemical parameters of the three sampling stations of Barangay Saloagan, Dimataling, Zamboanga del Sur.

Physico-chemical Parameters	Sampling Stations			Mean
	First	Second	Third	
Water conditions				
Temperature (°C)	31.3	33.33	35	33.21
pH	7.5	7.5	8.3	7.77
Salinity (ppt)	30	29	32	30.33
Tidal cover (m)	3.9	6.4	4.5	4.93
Phosphate content (mg/L)	3.84	4.12	3.95	3.97
Potassium content (mg/L)	331	347.67	329.3	335.99
Total Suspended Solids (mg/L)	4,765.30	4,714.30	4,275.30	4,584.97
Dissolved Oxygen (mg/L)	6.47	7.73	7.16	7.12
Edaphic Factor				
Soil texture				
Sand (%)	97	95	95	95.67
Silt (%)	0.40	2.40	2.40	1.73
Clay (%)	2.60	2.60	2.60	2.60
Substrate class	Sandy	Sandy	Sandy	Sandy

Mean physico-chemical parameters of the three sampling stations in Saloagan, Dimataling vary in terms of water conditions. Physico-chemical parameters such as the water conditions are considered to be one of the factors known to affect the growth and development of *A. planci* (Pratchett, 2001). Temperature is a key environmental factor in controlling the distribution and diversity of marine life (Grossman, 2014). Herein, water temperature ranged from 31.3-35°C which is within the preferred temperature range of *A. planci* according to Lamare *et al.* (2014). Accordingly, as the water approaches to this value, it is known that *A. planci* spawned with increased success and the populations are able to function more efficiently and reproduce more effectively (Grossman, 2014). Within this temperature range, it affects the pace of embryonic and larval development in *A. planci* and could possibly contribute to increase in larval survival (Lamare *et al.,* 2014) due to the stimulating effects on its physiological rates (Allen *et al.,* 2017).

The pH level of the water is also an important factor to be considered in studying *A. planci* because it is used to measure the acid-base balance of the sea water. The pH value ranged from pH 7.5-8.3 in all stations of the study site which falls within the typical range of the pH value in seawater of 7.5-8.4 (Chester & Jickells, 2012), The result indicates that the water body is in basic conditions meaning the concentrations of H^+ ions are low and it is not acidic. In an experiment conducted by Kamya *et al.* (2017) *A. planci* were grown in three different pH levels (pH 7.6, 7.8 and 7.9), feeding rates of *A. planci* increased at pH 7.6 condition, this may be due to the direct effect of pH levels on its physiological processes. However, the larval development of *A. planci* was suppressed in pH 7.8 that might due to the lower H^+ ions concentrations.

Salinity is another important factor to include in models of the proliferation success of *A. planci* that has a strong effect on its development (Allen, 2017). In Saloagan, Dimataling, salinity ranged from 29-32ppt which falls within the optimal value of salinity where larval survival is at 30ppt (Brodie *et al*., 2005), this finding is supported in an experiments conducted by Lucas (1973) as cited by Allen (2017) where larvae of *A. planci* were transferred to a different salinity treatments, salinity of 30ppt enhanced the survival rate of *A.planci* relative to 32 ppt. However, salinity value lower than 29ppt was found out that this level of reduced salinity may be a tipping point for deleterious effect on fertilization, early development and hatching of *A. planci* (Allen, 2017).

Haines (2015) stated that water depth is found as an important factor in predicting outbreaks of *A. planci* and used as a method in population control efforts. The water depth where *A. planci* found on the corals of Saloagan, Dimataling is between 3.9-6.4 meters which is comparable with the findings of Bos *et al.,* (2013) where the majority of *A. planci* were found at the reef crest at a depth of 3-4m and few specimens were found at a depth of 1-2m depth in Davao Gulf, Philippines. Compared to the research conducted on Koh Tao, Thailand where *A. planci* was at depths between 9.8 m deep, while the majority of *A. planci* was found at 6-9 m and 9-12 m deep which is considerably deeper than what was obtained in this study (Haines, 2015).

Another proposed hypothesis that explains the direct cause of outbreaks of *A. planci* is the 'terrestrial runoff hypothesis' by Birkeland (1982) which suggests that increased nutrient supply from terrestrial runoff leading to nutrient load increase is critical for enhanced *A. planci* larval survival (CCC, 2013). Increased nutrients such as from fertilizers and sewage discharge combined with increased soil erosion and river sediment load from agricultural usage (Brodie *et al.,* 2005).

Most fertilizers that are commonly used in agriculture contain the basic nutrients that include phosphorus and potassium. Phosphorus is found in the form of inorganic and organic phosphates (PO_4) in natural seawaters. Phosphates and potassium are the most important nutrients responsible for eutrophication of marine ecosystems which increases algae growth and affect the oxygen levels in the water (Kremser & Schnug, 2002). The natural level of phosphate content in seawater has been reported as 0.002-0.13mg/L, however, results of the study revealed that the phosphate content ranged from 3.84-4.12mg/L which is an indicative of eutrophic condition that can accelerate eutrophication process in marine ecosystem (Pawlowsky, 2008).

On the other hand, potassium contents in Saloagan, Dimataling ranged from 329.3-347.67mg/L which is lower in concentrations compared to the normal ranged of potassium contents in seawater which is approximately 380mg/L (Pawlowsky, 2008). Phosphate and potassium enter the marine ecosystem through rainwater, plant residue, fertilizer additions, and animal wastes (Hart *et al.,* 2004). The relatively high levels of phosphate and low levels of potassium observed in Saloagan, Dimataling could be due to discharges and farming activities, high rate of decomposition of organic matter from runoff, and low water circulation (Kremser & Schnug, 2002).

TSS can also contribute to the eutrophication level in marine ecosystems. It refers to the concentration of inorganic and organic matter, which is held in the water column of a stream, river, lake or reservoir by turbulence. Suspended Solids primarily affect the marine organisms through the amount of light penetrating through the water column (Bilotta & Braizer, 2008). The mean value of TSS in Saloagan, Dimataling ranged from 4,275.30 - 4,765.30mg/L. These values are lower than the normal value of TSS in seawater which is 25,000mg/L (Bilotta & Braizer, 2008). This indicates that although discharge of effluents from Saloagan, Dimataling is continuous which carries many materials from the upper land into the seawater, the rate of circulation of the water is still high (Anhwange *et al.,* 2012). Suspended solids concentrations more than 25, 000mg/L, physical alterations such as reduction in light penetration, temperature changes through the water column can be expected (Bilotta & Braizer, 2008).

Oxygen is essential for the respiration of all life including most marine and estuarine organisms. The amount of oxygen dissolved in water can be measured in concentration (mg/L) (Jack *et al.,* 2009). In Saloagan, Dimataling, dissolved oxygen concentration ranged from 6.47-7.73 mg/L which falls within the normal dissolved oxygen concentration of greater than (>) 5.0 mg/L. Dissolved oxygen (DO) concentrations lower than 4.0 mg/L is an indicative of a hypoxia condition, the state where oxygen supply to organisms is deficient. Insufficient DO can cause mortality of marine organisms and sub-lethal effects such as reduced growth and reproduction, and changes in behavior, all of these can lead to an overall decrease in ecosystem productivity. The amount of oxygen available for marine life depends on various factors that affect the solubility of oxygen in marine water. The factor includes salinity, temperature, conductivity, atmospheric exchange, barometric pressure, currents, upwelling tides (Jack *et al.,* 2009).

The movement capacity of *A. planci* is a determinant of both their distribution and impact on coral assemblages, thus substrate type affects the locomotion of *A. planci* (Pratchett *et al*., 2017). Substrate type found along the coastal areas of Saloagan, Dimataling is characterized by a sandy textural class which is composed of 95.67% sand, 1.73% silt and 2.60% clay. Sandy substrate is the preferred substrate type of *A. planci* because in areas of strong wave action, this substrate can provide a barrier to the movement of the starfish between reef patches and it allows to easily cross sand patches and may feed in (Chesher, 2012). The locomotor capacity of *A. planci* to move within and among coral communities can help in addressing long standing issues about the population outbreaks of *A. planci* (Pratchett *et al*., 2017).

Overall, findings of this study can help towards the development of a better management for the coral reef ecosystem conservation and establish population control techniques for *A. planci* that can help in better understanding when outbreaks of *A. planci* may take place in Saloagan, Dimataling. Physico-chemical parameters obtained show clear insights that the presence of *A. planci* in Saloagan, Dimataling indicates that conditions in their local habitat favours their growth and development. Therefore, further monitoring of *A. planci* populations in Saloagan, Dimataling is strongly advised to give enough information in predicting or possibly even preventing an outbreak of *A. planci* in this local area.

CONCLUSION

This study was able to describe two different color morphs of *A. planci* found in some coral communities on the coastal of Saloagan, Dimataling, Zamboanga del Sur: the purple with orange spines and the purple with red spines. There were ninety (90) *A. planci* studied, sixty-three (63) of individuals or 70% of *A. planci* were observed to be feeding while twenty seven (27) individuals or 30% of *A. planci* were observed to be non-feeding. In terms of the corals species foraged by the *A. planci*, there were fourteen (14) identified coral species where *Porites* is the most preferred coral genus which was found to be the prey of 23.33% of *A. planci*. The largest body size in diameter of *A. planci* was 270 mm weighing 365 g and the number of arms varies from 7 to 16 arms. Of the ninety (90) *A. planci* individuals, 58 *A. planci* individuals were categorized as juveniles while 32 *A. planci* individuals were categorized as adult. Feeding preference of *A. planci* in terms of its gut content was examined in (30) *A. planci* individuals where fragments of corals species such as *Pocillopora* spp. and *Acropora* spp., five seaweed species, one sea grass species and unidentified species of crab, gastropod and bivalve were present in the stomach of *A. planci*. Physico-chemical parameters known to affect the bioecological aspects of *A. planci* of the three sampling stations in Saloagan, Dimataling, vary in terms of the water conditions. All the sampling stations were characterized by sandy textural class. All of the physico-chemical parameters obtained in Saloagan, Dimataling are within the range where outbreaks of *A. planci* have been reported based from the studies. Thus, the presence of *A. planci* on the corals of Saloagan indicates that the conditions in this local habitat are suitable for their growth. Therefore, continual monitoring is strongly advised and an effective coral monitoring program should be done to prevent the outbreak of the *A. planci* in the future.

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