Coral Recruitment Spatial Distribution in its Relation With Coral Cover and Herbivorous Fish Abundance Within Conservation Area

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Abstract

The continuity of coral reef ecosystem highly depends on the new coral larvae recruitment process. Hence, the information regarding distribution, the abundance of corals, and its relation to other variables are highly important in that ecosystem management. Research was conducted at nine stations represented each zone at the conservation area of Kapoposang Marine Tourism Park (TWP Kapoposang). This research aims at seeking for spatial variations of the abundance of coral recruitment at three primary zones monitored (core zone, sustainable fishing zone and utilization zone) and we further identified its relations with spatial variation of herbivorous fishes abundance and coral cover's condition at those zones. The coral recruitment observation employed transect quadrat sampling method with size of 1x1 meter and 10 times repetition at a similar depth, and the coral recruitment abundance measurement in natural habitat based on the amounts of juvenile corals has been defined as coral colony with size of ≤10 cm. Overall, this research has found 534 coral juveniles consisted of 19 genera and 7 families, and the average of juvenile coral density stood at 5.34 ± 4.45 SE.m^{-2}. The coral reef recruitment category at TWP Kapoposang could be classified as high and its abundance spatial distribution showed no significant differences between each zone, as well as not influenced by either herbivorous fish abundance variable or the percentage of live coral cover.

Introduction

The establishment of the Marine Protected Area (KKP) is one of the important tools that has been widely used in natural resources and ecosystem management. The coral reef as one of the vital objects within the KKP is very prone towards the increasing of anthropogenic pressures as well as the impact of climate change such as the increase of sea levels, sea warmth, and acidity.

Coral larvae recruitment process is one of the vital issues in the management and coral reef conservation. Besides being the most important feature of the population dynamic that ensures the continuity and the restoration of coral reef (Abelson *et al.,* 2005; Bachtiar, *et al.,* 2012; Hughes and Tanner, 2000; Moulding, 2005), the recruitment process also proves that there is a connectivity between coral reef (Bellwood *et al.,* 2004; Cowen, 2006)as well as reflecting the occurance of coral resiliency process in recovering (Hughes *et al.,* 2007; McClanahan *et al.,* 2012).

Previously, there were several coral recruitment research carried out in Indonesia, among others are Fox (2004) who conducted his research in the Komodo National Park. He compared the coral recruitment in an area that previously blasted by fish bomb and in an area that free from fish bombing or other destructive fishing activities. Singkoh (2010) had conducted an interaction analysis of coral recruitment based on the quantity, depth, and sites in Bunaken Islands. Abrar *et al.,* (2011) conducted a research on the survival rate and the growth rate of coral recruitment in Pari Islands, Kepulauan Seribu, Jakarta. On the other, research about coral recruitment diversity and coral recruitment abundance had also been held in Kendari (Palupi *et al.,* 2012), Lembata (Bachtiar *et al.,* 2012) and in Lovina Tourism Beach, Bali (Dodik, 2012). De Leon *et al.* (2013) also saw a temporary variation and spatial recruitment in Hoga reef and in Sampela, Wakatobi. Meanwhile Abrar (2015), while researching about the abundance and the density of coral recruits, He also analyzed the relations between adult coral and algae cover.

Aside from examining the diversity and the abundance of coral recruitment in each site, the research we conducted also seek to measure the relations between coral recruitment abundance with live coral cover as well as the herbivorous fish abundance. Not only carrying important roles in managing the structure of the coral reef community, (Husain and Gardiner, 2014), the herbivorous fishes also function in limiting the growth of algae communities which will further ensure the coral reef resiliency (Green and Bellwood, 2009). In addition, the abundance of herbivorous fishes also highly corresponds with the coral recruitment abundance (Khalil, 2011) that clearing the substrate and provide places for corals' planula to stick and to develop (Bellwood *et al.*, 2004).

This research aimed at analyzing the spatial variations of coral reef recruitment abundance at three sites covered at TWP Kapoposang (core zone, sustainable fishery zone and utilization zone). We conducted this research by linking the observation with the spatial variation of the herbivorous fish abundance and the coral cover condition at those zones.

Materials and Methods

The Kapoposang Marine Tourism Park (TWP Kapoposang) is located in the Spermonde Islands and is administratively within the Pangkep District, South Sulawesi Province, Indonesia (Figure 1.). The area of TWP Kapoposang Islands spans over 50,000 ha, covering six islands including Kapoposang Makassar Strait, and its location is highly influenced Islands, Papandangan Islands, Pamanggangan Islands, Tambakulu Islands, Gondongbali Islands, and Suranti Islands. TWP Kapoposang geographically sits out in the outer ring of Spermonde archipelago, which sprawls off the by the climate and the ocean current patterns of the Makassar Strait

This research was conducted in September 2016 at nine stations represented each zone of TWP Kapoposang. Those zones are Core Zone (ZI) consisted of three stations: Suranti 1 (SR1), Suranti 2 (SR2) and Pattalibboang (PTB). The Sustainability Fishing Zone (PB) represented by Gondongbali station (GDB), Pattilingan (PTL) station and Tanjung (TJG) station. And the Utilization Zone (ZP) which comprised of Taka Palekko1 station (TP1), Taka Palekko2 (TP2) and Taka Pallawangang (TPG) station.

Coral recruitment

The coral recruitment observation had used transect quadrat sampling method with size of 1x1 meter for as much as ten repetitions and within an interval range of 5 meter at similar depth. The measurement of coral recruitment abundance was based on the amount of coral larvae or juvenile defined as coral colony sized ≤10 cm (Obura and Grimsditch, 2009). The identification included the
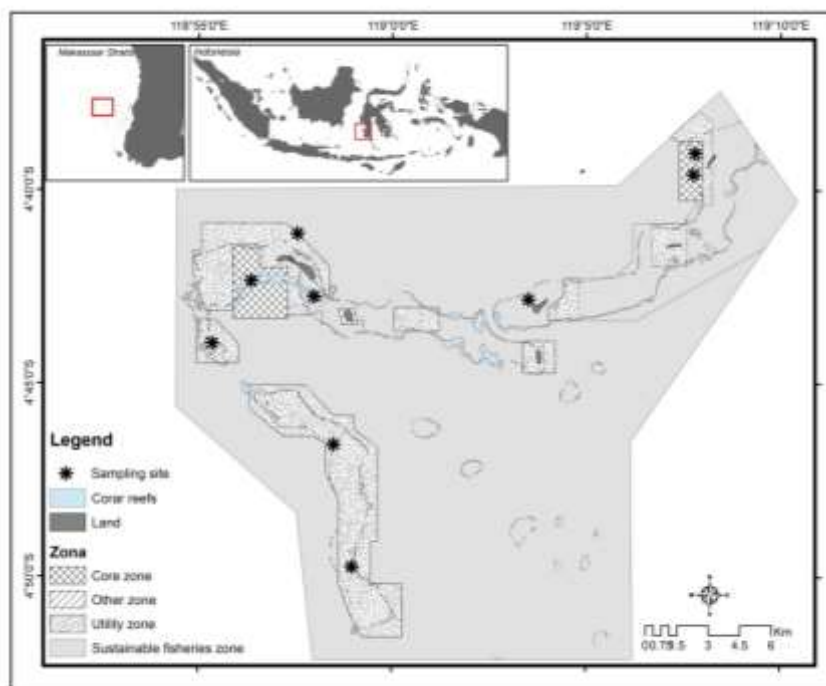

Figure 1. Research Location at Kapoposang Marine Tourism Park, South Sulawesi Province

colony number and the type of substrate found at the bottom of the water. The identification was conducted on-site supported by underwater pictures that to be further identified. The identification itself was conducted until the genus stage by referring to Kelley (2011) and Suharsono (2008). The status of coral recruitment based on Obura and Grimsditch, (2009) categories.

The coral reef condition

The observation of coral reef condition was conducted by utilizing the Underwater Photo Transect (UPT) method. The image was captured at an interval range of 1 meter along of the transect lines located at the station points within the depth between 5-7 m. The result of the transect pictures were further analyzed by using the CPCe version 4.1 software (Kohler and Gill, 2006). The analysis technique chose sampling points at 20 random areas. The coral reef condition category was determined based on the number of live coral covers percentage as stipulated in the Ministerial Regulation No. 04 Year 2001 on the Guideline Criteria of the damages to coral reef ecosystem issued by the Ministry of Environment and Forestry (MENLH, 2001).

Herbivorous fish

The classification of the herbivorous fishes was based on the ecological function of each of the species. The fish communities included in the herbivorous group were family of *Scaridae, Achanthuridae* and *Siganidae* (Giyanto *et al*., 2014). The fish observation was conducted by utilizing the *Underwater Visual Census* (English *et al*., 1997). The UVC method employed transect lines as long as 50 meters. The identification of all of the herbivorous fish species also included those fishes found as far as 2.5 meters to the left and 2.5 meters to the right of the transect lines. The fish species identification itself was based on Allen *et al* (2003). The benchmarks of the coral fish community are those commonly used community benchmarks, including the number of species (taxa), the abundance of individuals and the species diversity.

Statistical analysis

To examine the average differences of the coral recruitment, coral condition and the herbivorous fish abundance on each of the observed sites, we employed the ANOVA test. Meanwhile, to analyze the relation between the abundance of coral recruitment and the percentage of coral cover as well as the abundance of herbivorous fishes, we used the Pearson Correlation Test.

Results and Discussion

Coral juvenile

This research has found that there were 534 coral juveniles that consisted of 19 genera and 7 families. Among all of the stations observed, the average density of coral juvenile was 5.34±4.45 SE.m^{-2}, based on the category Obura and Grimsditch (2009). Hence, the coral recruitment rate at TWP Kapoposang could be classified as high. Meanwhile, a research conducted by Sawall *et al.* (2013) in several islands in the Spermonde islands found that the recruitment rate was medium. The differences in the result of these two research were might be due to the different methods employed.

The coral juvenile density was highly varied between zones. Meanwhile, the core zone's coral recruitment abundance rate recorded at 6.03±1.30 colony.m^{-2}, the rate at the sustainable fishing zone stood at 6.73±4.83 colony.m^{-2} and the rate at the utilization zone was recorded at 4.47±0.91 colony.m^{-2} (Figure 2A.). The coral juvenile abundance was dominated by four genera (*Acropora, Fungia, Porites* and *Seriatopora*) covered 76.8% of the total of coral juveniles identified. Genus *Fungia* dominated the abundance at the core zone (accounted for 47.7%) and at the sustainable fishing zone for 43.6%, meanwhile genus *Porites* dominated the utilization zone and accounted for 50% of the total genus existed (Figure 3A.). The coral recruitment rate at each zone looked vary, but based on the ANOVA test (*P*= 0.85), the number of coral recruitment genus at those three zones of TWP Kapoposang did not particularly show significant differences. We argue that this might be due to the similarity of the factors that influence the coral recruitment, including the availability of parents as larvae sources, substrates in a form of habitat variations, as well as the water dynamics such us current, temperature, and light (Abrar, 2015). At the local factor scales influencing it also tend to be similar, hence the coral recruitment patterns that took place were also relatively similar and consistent (De Leon *et al.*, 2013).

Live coral covers

The coral condition classification at TWP Kapoposang were damaged to very good condition based on the station observation findings (2.40% - 90.48%), the average of live coral cover was recorded at 41.19±11.45%. This condition was similar with the result found by Papu (2011) which his survey obtained an average value of live coral cover amounted for 48.53%. Meanwhile, the coral cover condition was varied on each zone, they were

recorded at 6.32±2.60 % at the utilization zone, 46.78±16.50 % at the sustainable fishing zone and 70.47±15.35 % at the core zone (Figure 4.). The coral abundance was dominated by four growth model types (*Acropora branching, Coral branching, Coral foliose and Coral massive*), which consisted of 83.17% of the total corals identified (Figure 2B.). *Acropora branching* consisted of Genus *Acropora* was identified dominating the abundance at the core zone (accounted for 36.55%), meanwhile at the two remaining zones, the sustainable fishing zone and the utilization zone, the Coral massive accounted for 26.75 % and 52.76 %, consisted of Genus *Porites, Goniastrea* and *Pavona* all dominated the growth model at those zones.

Based on the ANOVA result, it indeed recorded significant differences on the coral condition between zones (*P*=0.05). The high percentage of the live coral cover at this core zone has also supported the *spillover* function to the other zones. This condition further supports the role of the core zone as a larvae source as it allows connectivity to occur, considering that the ability to repair (*resilience*) from coral reef within a region depends on the connectivity efficiency between coral reef in that conservation area (Underwood *et al.*, 2013). The low percentage level of coral cover at the utilization zone (Figure 4.) is expected to recover in the years to come, and new coral recruitment could be derived from the other zones that have good level of coral cover percentage. Asides from that, the herbivorous fish abundance rate recorded at this zone was also considerably high. The recovery process of the conditions of the coral highly depends on the connectivity rate between corals which also will positively impact the coral recruitment rate (Hogan *et al.*, 2012) as well as the abundance of herbivorous fishes community (Bellwood *et al.*, 2004; Hughes *et al.*, 2007).
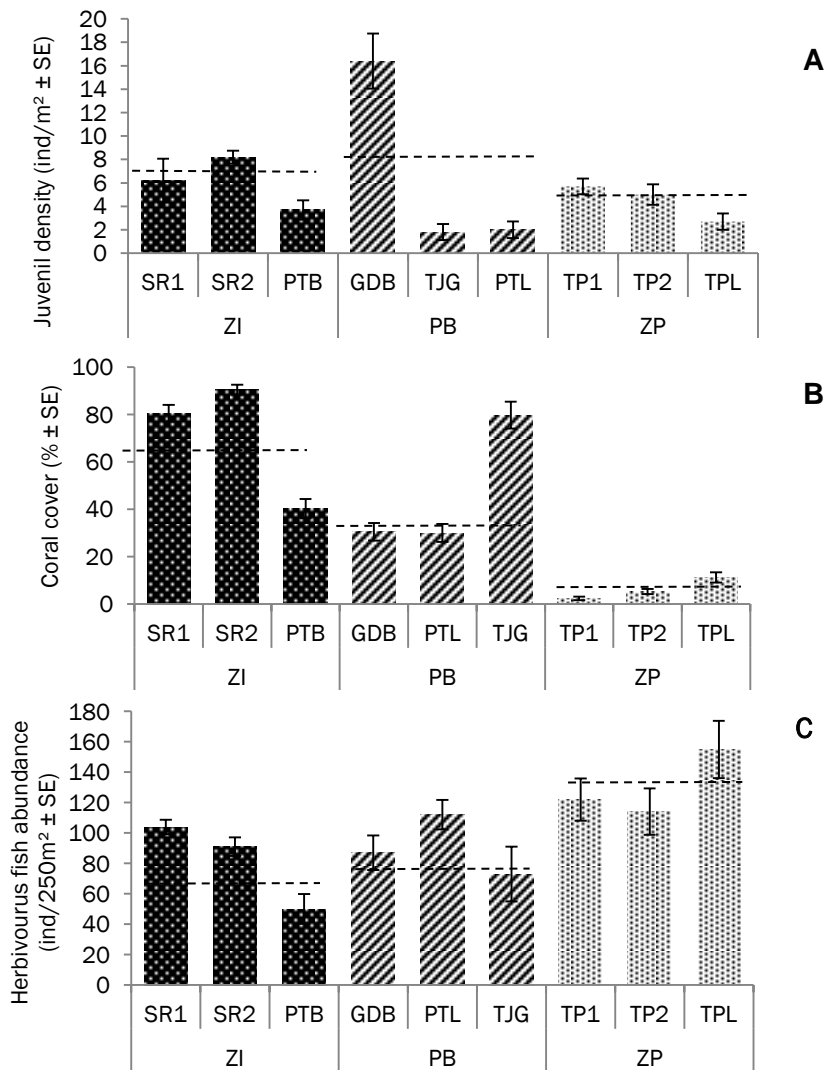

Figure 2. The average of (A) coral juvenile abundance; (B) Coral cover; and (C) Herbivorous Fishes abundance at three zones studied at TWP Kapoposang
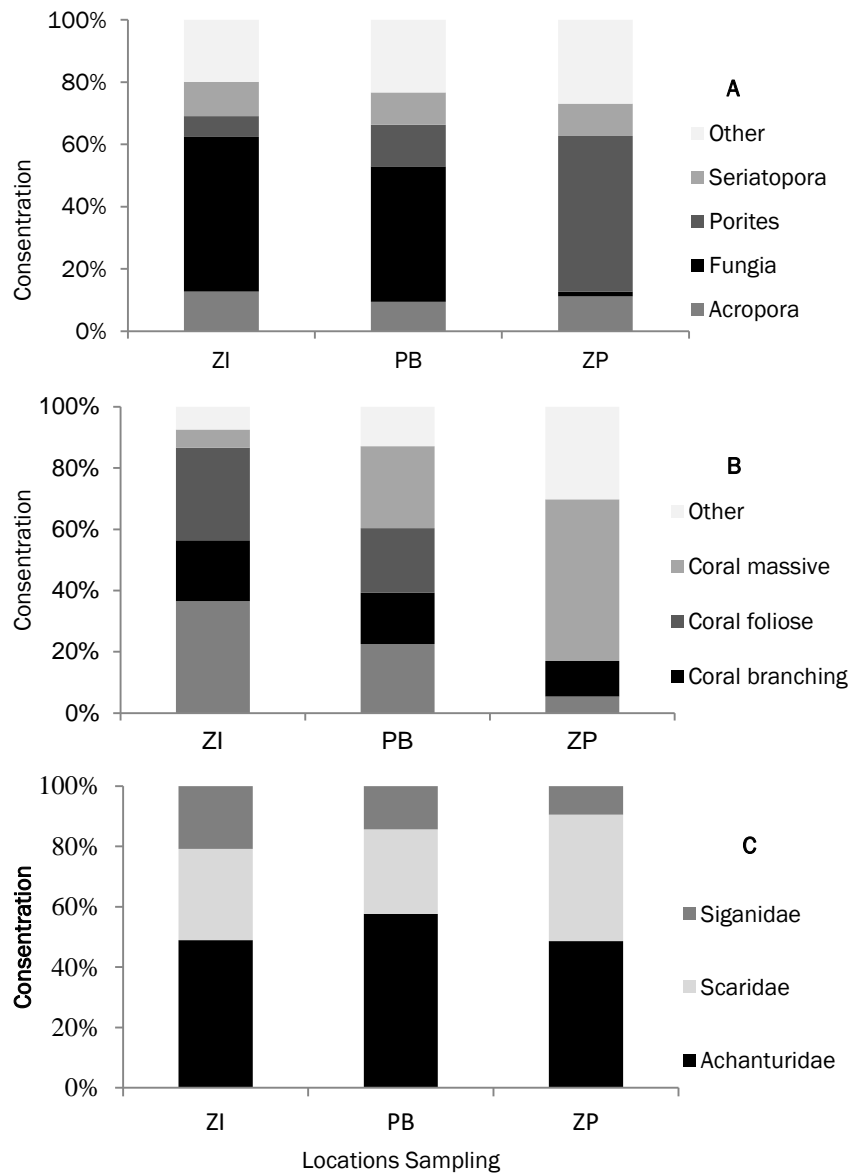
Figure 3. The proportion of (A) Coral juvenile genus; (B) Growth Type; (C) Herbivorous fish genus at three zones studied at TWP Kapoposang.

Herbivorous fish abundance

The total of herbivorous fish abundance found amounted for 1,038 individuals, 34 species and 8 genera. The family of *Achanturidae* has dominated the herbivorous fish abundance at each zone, where the abundance proportion rate at the core zone, the sustainable fishing zone, and the utilization zone was recorded at 48.98%, 57.67%, and 48.62%, respectively (Figure 2C.).

The highest number of total abundance recorded at the utilization zone was 391 individuals, this was caused by the abundance of algae that significantly high at the zone, as also shown by the

high Death Coral Alga (DCA) value compared to the other zone (*unpublished*). This as well in line with the data found by Russ (2003) on his research at the Great Barrier Reef.Russ (2003) argued that no significant relations between the algae abundance and the herbivorous fishes. However, according to Husain and Gardiner (2014), the abundance distribution and the herbivorous fish biomass at the Spermonde Islands did not solely depend on the algae's condition but also was largely influenced by the fishing activities at the area.

There were no significant differences on the coral fish abundance between zones (*P*= 0.05), and the highest abundance rate found at the utilization

zone was accounted for the average total of 130.33±12.55. Meanwhile, the core zone recorded the abundance rate of 81.67±16.27 and at the sustainable fishing zone at 90.67±11.41 (Figure 2C.). Although there were no significant differences, the abundance of herbivorous fishes looked vary along the zones, this in line with the previous findings byNemeth and Appeldoorn (2009) who argued that the herbivorous fishes could disperse along the coast or highly depend on the water depth as well as the different circumstances surrounding the coral habitats.

The relations between variables

Although that the live coral cover is one of the factors affecting the coral recruitment (Hughes *et al.*, 2000), but referring to the Pearson correlation test conducted at this research, the relation between juvenile coral variables and the live coral cover was particularly low (*P*= 0.03), the high influence of live coral cover towards coral juvenile abundance rate amounted for only 0.1 % (R²= 0.001). A research

carried out by Abrar (2015) also found a slightly low influence between coral juvenile and live coral cover (R²= 0.077). The Figure 5 shows the differences between coral cover percentage and coral recruitment abundance found at the utilization zone, the data recorded low percentage of coral cover but the coral recruitment abundance was not significantly differed from the other zones. Hence, this shows us that the locations with low percentage of coral cover are not always followed by low rate of coral recruitment abundance, De Leon *et al.* (2013) also suggested that the locations with low percentage of coral cover are not always run out of larvae supply. Those zones might likely obtain their larvae supplies from the other zones, considering that the transport of larvae could occur from one location to the other through ocean currents (Underwood *et al.*, 2013).

Coral Recruitment is strongly influenced by the herbivorous fish community, where healthy herbivorous fish communities are essential in the process of reef restoration. Based on Pearson
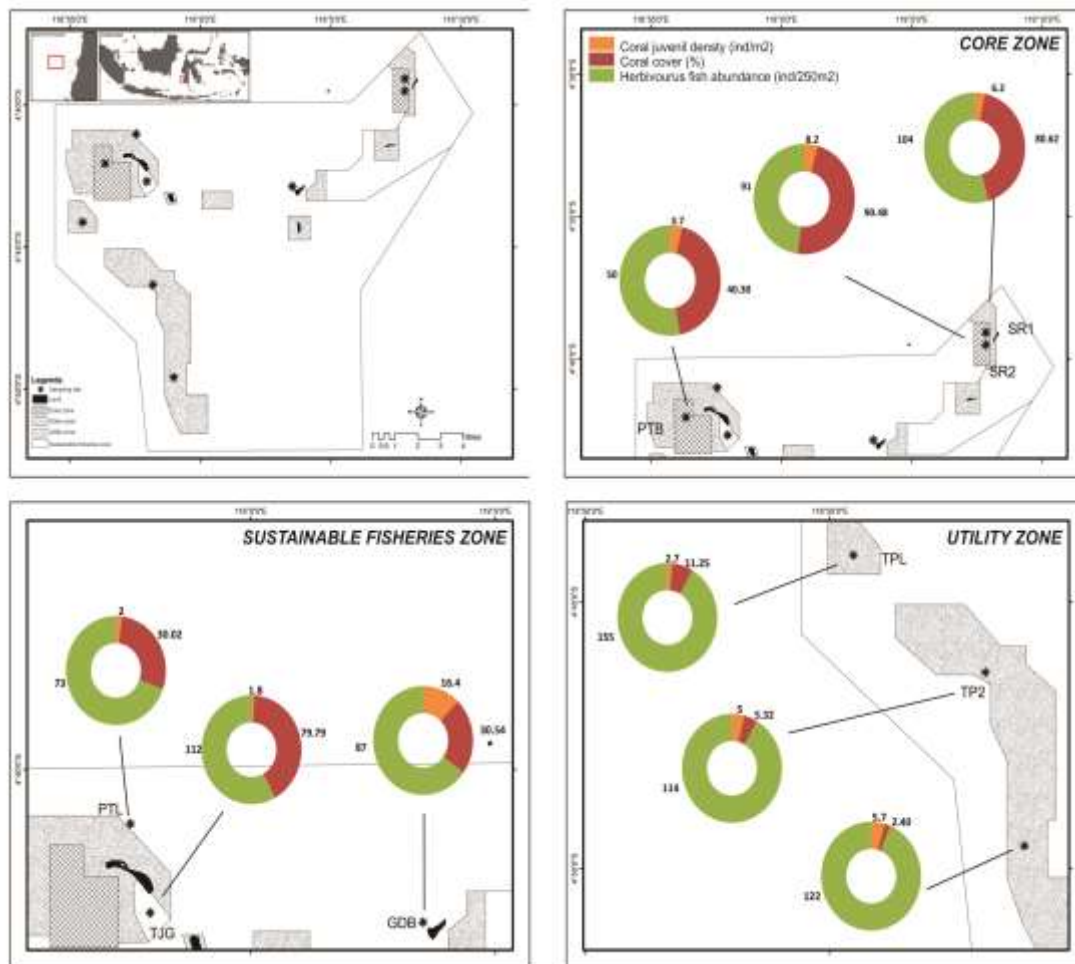

Figure 4. The spatial dispersion of coral recruitment abundance variable, coral cover and the herbivorous fish abundance at each zone of TWP Kapoposang

correlation test results obtained the relationship between juvenile coral and herbivorous fish abundance negatively correlated (-0.17), and the magnitude of the effect of herbivorous fish abundance on juvenile corals by 2.8% ($R^2 = 0.028$), this shown the effect of fish abundance variables Herbivores were not significant to the abundance of juvenile corals. The same statement by Trapon *et al*. (2013) in his study found no significant relationship between Scaridae fish with abundance of juvenile corals in the Great Barrier Reef. However, the opposite statement by Hughes *et al*. (2007) that decreased algae cover and increased coral cover were more rapid with the presence of herbivorous fish. This occurs when herbivorous fish eat algae on the surface of the reef, indirectly providing new space for juvenile corals to stick and grow into new individuals.

Conclusions

There was no differences on the spatial distribution of coral recruitment between zones at TWP Kapoposang. There was no effect of herbivorous fish and the percentage of live coral cover to the coral juvenile abundance rate. In addition, coral recruitment process also plays an important role in preserving the sustainability of coral reef ecosystem. Understanding the recruitment patterns and factors that affect them becomes highly critical especially in constructing the management plan of TWP Kapoposang in the future.

Acknowledgements

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