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TEMPORAL DYNAMICS OF EUTROPHICATION LEVEL AND SEDIMENTATION RATE IN CORAL REEF AREA OF SPERMONDE AND SEMBILAN ISLANDS, SOUTH SULAWESI

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ABSTRACT

Spermonde and Sembilan Islands (Bone Bay) are the central distribution of coral reefs in South Sulawesi. These archipelagos are likely to be at risk from eutrophication and sedimentation from intensive agriculture and aquaculture activities, in particular through transport of nutrients and materials discharged to the river systems on the Sulawesi mainland. The aim of this study was to analyse the temporal dynamics of eutrophication levels and sedimentation rates on coral reefs area of Spermonde and Sembilan Islands. Nutrient concentration and sedimentation rate were collected at monthly intervals over 4 months, at six stations: three in the Spermonde Islands (Laiya, Kodingareng, and Samalona Islands), and three in the Sembilan Islands, Sinjai District (Batanglampe, Kambuno, and Burungloe Islands), with two data collection points/replicates at each station/island. The results showed that phosphate concentration and sedimentation rates were higher in the Sembilan Islands, whereas nitrate concentrations were similar in both island groups. Nitrate concentration data indicated that eutrophication levels was varied, ranging from oligotrophic to eutrophic conditions, depends on months. In July and September, eutrophication was observed at all stations in both locations. Sedimentation rates were higher in the Sembilan Islands, but declined gradually until the end of the study time. Conversely, at stations in the Spermonde Islands, especially Samalona and Kodingarengkeke Islands, sedimentation level was increased significantly until the end of the study.

Keywords: eutrophication dynamic, sedimentation, coral reefs, Spermonde and Sembilan Islands

INTRODUCTION

Coral reef ecosystems in coastal areas and around small islands tend to be vulnerable to degradation due to the effects of pollution from the mainland (Chazottes *et al*., 2008). Costa *et al*. (2008) found that the mortality of corals in the Gulf of Bahia, Brazil, can be attributed to human activities on land; in particular, the influence of eutrophication which on trigger changes from coral communities to benthic algae, accompanied by an increase in chlorophyll concentrations and the abundance of filter-feeding animals. Increased nutrient concentrations at sites close to settlements and agricultural land can trigger the growth of macro-algae, accompanied by a decrease in the abundance of some coral species (Chazottes *et al*., 2002). Nutrient enrichment in coastal areas can cause a "phase-shift", a change from a reef that was originally dominated by live hard coral to an algal-dominated reef, in a relatively long period of time (McCook *et al*., 2000; Edinger *et al*., 1998; Costa *et al*., 2008; Renken and Mumby, 2009; Lapointe *et al*., 2005). Some cases of phase-shift phenomena showed a very strong correlation between the increase in the amount of nutrients entering the water body and increased primary productivity that ultimately lead to the growth of macroalgae, and therefore contributed indirectly to decreasing of the coral reefs condition by space competition. (Mc Cook *et al*., 2001).

The Spermonde Islands, located to the west of South Sulawesi, in the Makassar Straits, comprise 98 islands with an approximate total coral reef area of 60,000 Ha (PPTK, 2002; Faizal and Jompa 2010). Damage to these coral reefs has been caused by human activities, such as the use of bombs and cyanide to catch fish (Pet-Soede *et al.*, 2000; Nurliah, 2002) as well as by the increasing volume of domestic and industrial waste (Jompa, 1996; Edinger *et al*., 2000), including organic matter and sedimentation.

Symptoms of eutrophication have been identified as one of the causes of coral reef degradation in Spermonde Islands in recent years, characterized by high levels of correlation between macroalgae coverage, coral damage, and high nutrient concentration (Edinger *et al*., 2000; Nurliah, 2002). In the long term, increases in the supply of nutrients and sedimentation rate are likely to become major causes of coral reef degradation and act as limiting factors in the process of natural recovery from damage caused by other stressors such as destructive fishing activities. Therefore, the study of the dynamics of eutrophication and sedimentation levels in coral reefs is important, to provide information as a basis for decision making on coral reef management now and in the future, as well as in the context of controlling development activities in coastal areas.

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MATERIALS AND METHODS

The location of the study sites was determined based on the level of coral reef vulnerability to the effects of eutrophication and sedimentation. Spermonde Archipelago area can be considered highly vulnerable to the effects of eutrophication and sedimentation, taking into account the many rivers with agriculture and aquaculture activities around their watersheds and estuaries along the Makassar Straits in Makassar City, Maros and Pangkep Districts. .

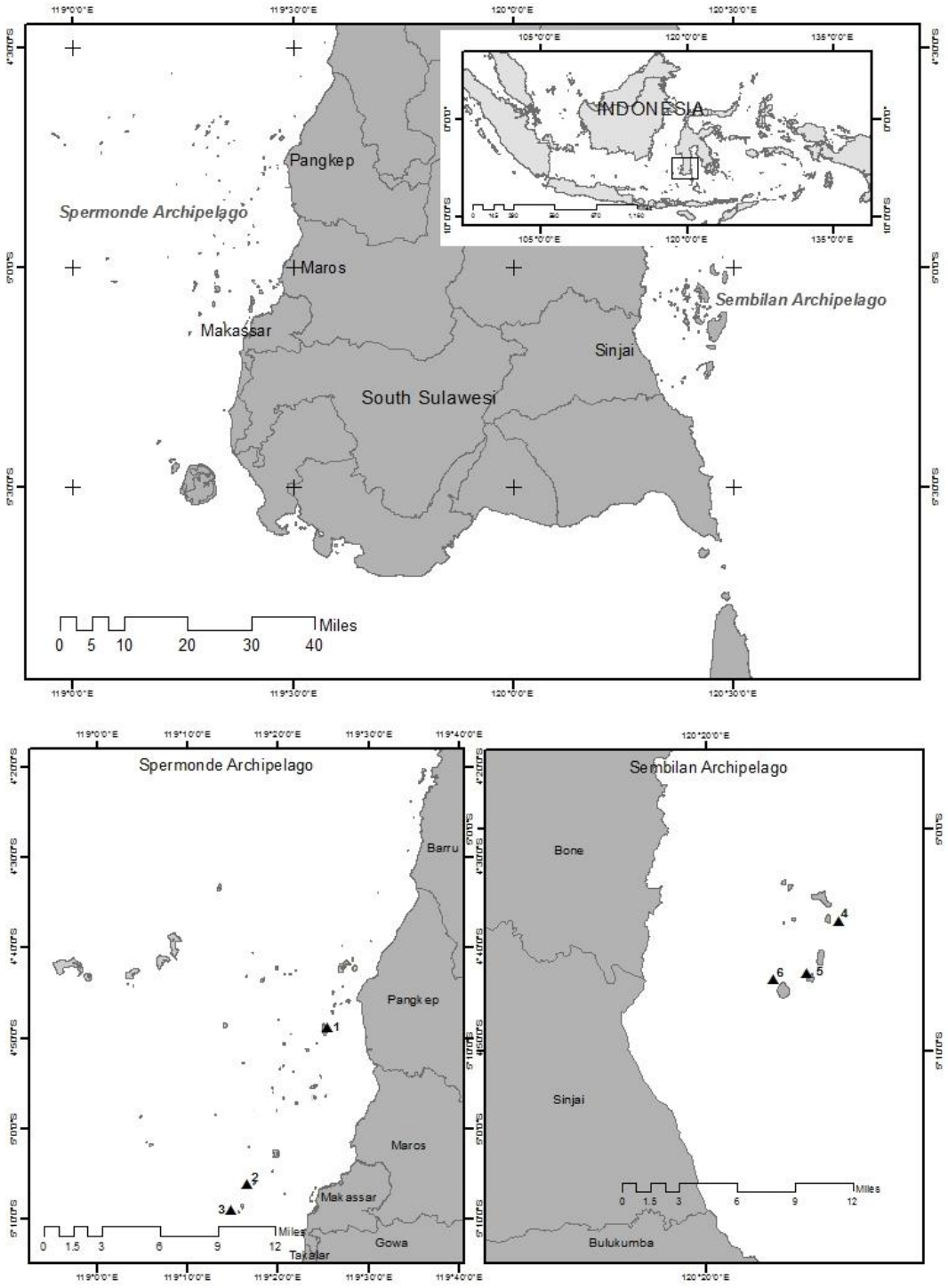

Figure 1. Sampling locations in the Spermonde and Sembilan Archipelagos.

Agriculture and aquaculture activities in the watershed of the Tangka River, in East Sinjai District, Gulf of Bone, could be a source of organic inputs to the waters around the Sembilan Islands, in the Gulf of Bone. However, these are lower in intensity compared to those likely to affect the islands of Spermonde. Thus the Sembilan Islands

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were selected to represent locations with moderate eutrophication and sedimentation impacts

Water sampling and analysis of sedimentation rate was conducted over for four months (July to October 2013). Sampling sites (Figure 1) comprised three islands in Spermonde Archipelago (Laiya, Samalona, Kodingarengkeke) and three others are in Sembilan Islands (Burungloe, Kambuno, Batanglampe). Processing and analysis of water and sediment samples was conducted in the Marine Ecology and Chemical Oceanography Laboratories, Marine Science Department, Hasanuddin University.

Research Procedures

Water samples were collected from two stations on each island at depth of 1 m using Niskin bottles for nitrate and phosphate concentrations. Each sample was stored in a 1 L bottle with 40 mg/l $HgCl_2$ as preservative. Samples then stored in a coolbox until the laboratory analyses were conducted. Nitrate concentrations were measured using Brucine method, while Stonous Cloride method was used for phosphate concentrations. Samples were analysed using spectrophotometer (HAC brand–USA; Type LPG 422.99.000012, Serial No. 1,289,304).

Sedimentation rates were measured using sediment traps (English *et al*., 1997), a tube with 15 cm length and 4 inches in diameter. Three sediment traps were installed at each station and observed every month during the study. The deposit sediment from each trap was placed in a bottle and measured in the laboratory using gravimetric method, and then calculated using equation (English *et al.*, 1997).

$$SR = \frac{W/A}{t}$$

Where:

SR = sedimentation rate ($g/m^2/day$)
W = weight of sediment (g)
A = cross-sectional area of the sediment trap (πr^2 in m^2).
t = time since the installation of the sediment trap (days)

Data Analysis

The temporal dynamics of nutrient concentrations and sedimentation rate for each island station were analysed using a line graph. Average values of these parameters were grouped by site, and the degree of difference between island stations was evaluated using the analysis of variance (ANOVA), and the results presented in graphical form.

Eutrophication levels were determined based on the nitrate and phosphate concentrations (Table 1), as proposed by Hakanson and Brhyn (2008).

Table 1.Eutrophication Level Criteria for waters above 25ppt salinity (Hakanson and Brhyn, 2008)

Eutrophication Level	Chl-a (µg/l)	Nitrate (µg/l)	Phosphate (µg/l)
Oligotrophic	<2	<110	<15
Mesotrophic	2 – 60	110 - 290	15 - 40
Eutrophic	6 – 20	290 – 940	40 - 130
Hypertrophic	>20	>940	>130

Substrate composition data were analysed graphically and coral condition determined based on percentage cover of live hard (hermatypic) corals.

RESULTS AND DISCUSSION

Nitrate Concentration

Nitrate concentrations at each station over four month period were fluctuated on a monthly basis.

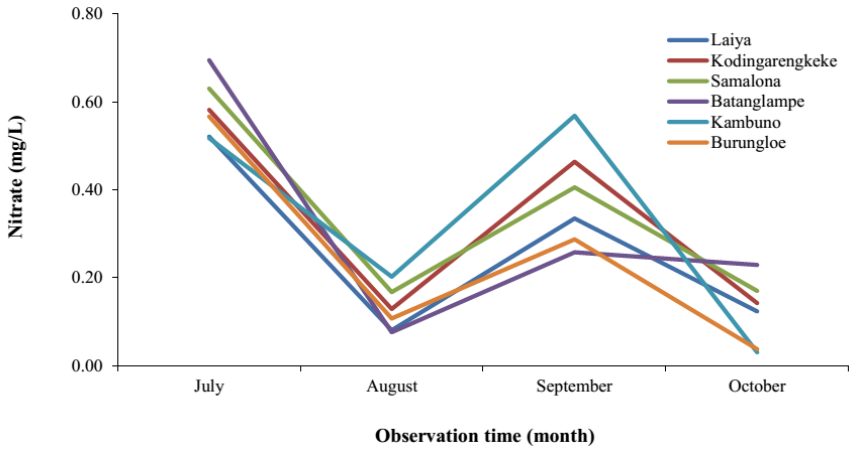

Figure 2. Temporal fluctuation in Nitrate (NO3) concentration at 6 sites in the 2 study areas

In both locations, nitrate content was measured at the beginning of the study, decreased in the following month, increased again in the 3rd month, and decreased again at the end of the study (Figure 2).

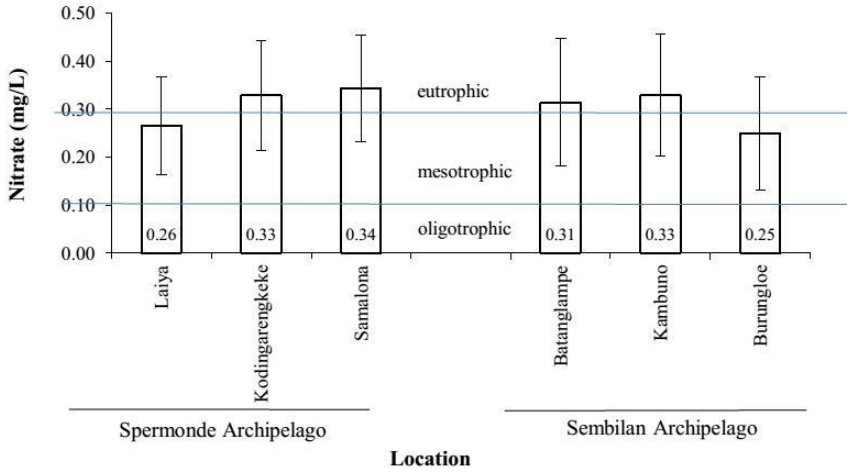

Figure 3. Average values of nitrate concentration around 6 islands in two study areas (analysis of variance showed no significant difference between stations in each study area or between study areas at α = 5%).

The average values of nitrate concentration ranged from 0.26 to 0.34mg/L in the Spermonde Islands, and 0.25 to 0.33 mg/L in the Sembilan Islands (Figure. 3). Although nitrate concentrations were slightly higher in the Spermonde Islands than the Sembilan Islands, differences between stations were not significant ($p < 0.05$).

Based on average nitrate concentration at each station, all stations experienced nutrient enrichment with eutrophication levels in the mesotrophic to eutrophic categories. Eutrophic conditions occurrred at the Samalona Island and Kodingarengkeke Island sites in the Spermonde Islands, and at the Batanglampe Island and Kambuno Island in the Sembilan Islands. Laiya Island (Spermonde Islands) and Burungloe Island (Sembilan Islands) were still within the mesotrophic category.

Phosphate concentration

Phosphate is an inorganic material that, when released into the ocean, can become a source of fertility determinants. Results from both study areas showed a declining pattern on phosphate concentration during four month sampling period (Figure. 4).

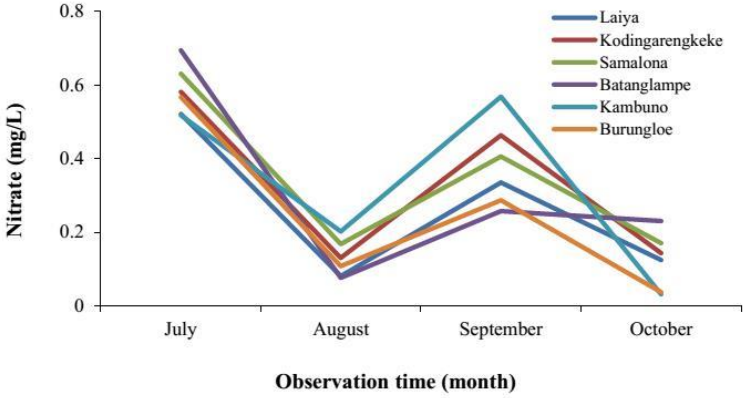

Figure 4. Temporal variation in Phosphate (PO4) concentration at six sites in two study areas

Average phosphate concentrations ranged from 0.51 to 0.54mg/L at sites in the Spermonde Islands, and 063 to 0.67mg/L at sites in the Sembilan Islands (Figure 5). Concentrations were higher in Sembilan Islands than in Spermonde Islands, however, there was no significant difference between stations in each region ($p < 0.05$).

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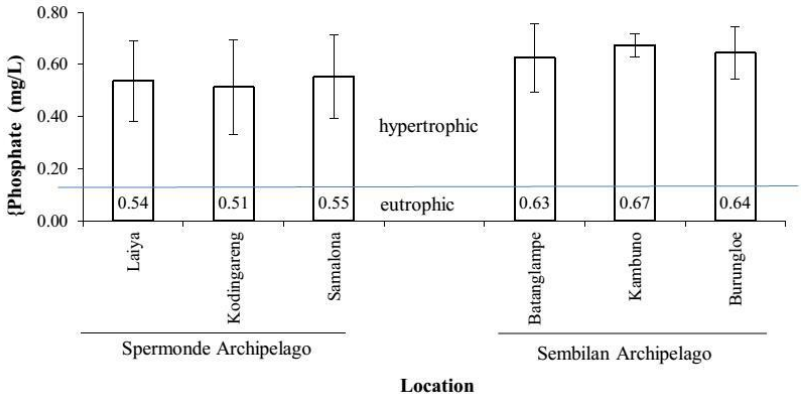

Figure 5. Average phosphate concentration at each station in both study areas (analysis of variance showed no significant difference between locations in each study area at α = 5%).

Sedimentation Rate

Sedimentation rates were recorded higher at the Sembilan islands on July when the study was started. The rates then gradually declined until the end of the study (Figure 6). This decrease was in line with the decreasing intensity of precipitation towards the end of the rainy season. On the other hand, sedimentation rate in the Spermonde Islands increased significantly, particularly at the stations around Samalona and Kodingarengkeke Islands (Figure 6). Although the average value of sedimentation on the Islands of Sembilan and Spermonde fluctuated with time, but the average value for both location were ranges from 0.0025-0.0038g/cm2/day (Figure 7).

The rise and fall of nitrate concentration observed during this research may indicate the use of this element in biological processes (photosynthesis) as well as the presence of a continuous input. These fluctuations indicate that nitrate concentration is very dynamic and that, in the process of photosynthesis, there is a greater requirement for this element compared to phosphate.

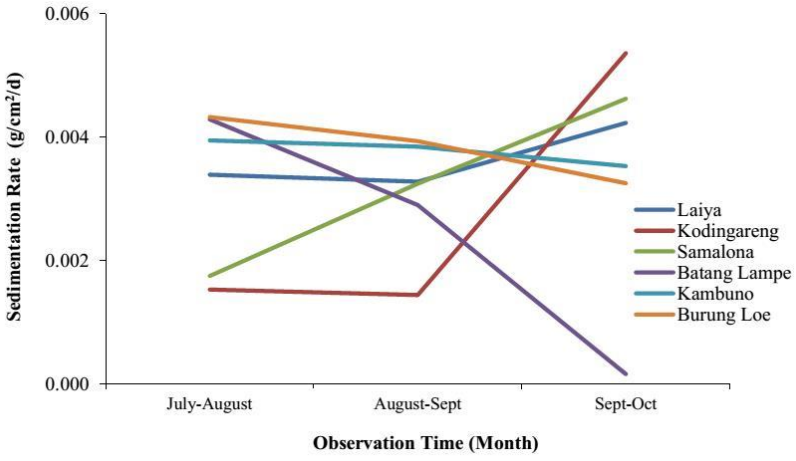

Figure 6. Temporal variation in sedimentation rates at each island in the two study areas

The level of eutrophication varied greatly at all stations in both sites, ranging from oligotrophic to eutrophic during the study period. Oligotrophic to mesotrophic levels occurred in August and October, with eutrophic levels in July and September

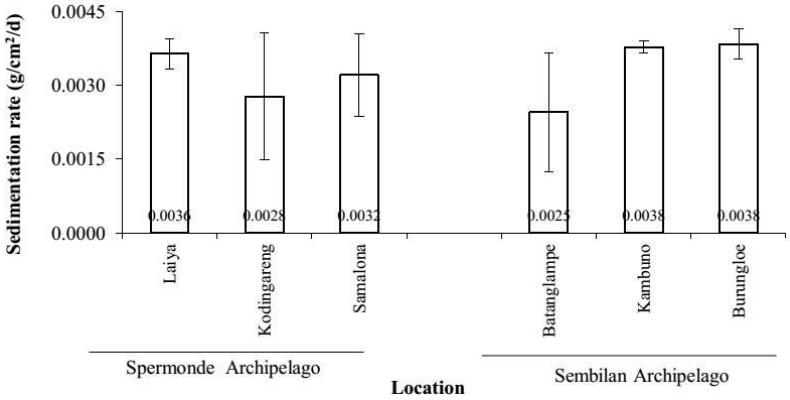

Figure 7. Average sedimentation rates for each island in the two study areas (analysis of variance showed no significant difference between stations in each study area, at α = 5%)

Nitrate concentrations at the end of the study show relatively high nitrate contents at stations in the Spermonde Island compared to those in the Sembilan Islands. This phenomenon indicates that the Sulawesi mainland influences nitrate inputs to the Sembilan Islands, especially for the islands closer to the mainland such as Kambuno Island. Similarly, in the Spermonde Islands, high nitrate concentrations were relatively high around Samalona, the island closest to the Sulawesi mainland.

The results indicate there are two factors driving higher concentrations of nitrate in both areas. Firstly, location: nitrate concentrations were found to be higher in locations close to the Sulawesi mainland and/or densely populated areas. This phenomenon is likely to occur because of the presence of major sources of nitrates derived from land-based activities such as agriculture, aquaculture, industrial and household wastes

(Lapointe, 1987; Hakanson and Brhyn, 2008) which can enter the coastal waters through rivers flowing into the sea close to the observation stations. Secondly, seasonal factors would seem to greatly affect nitrate concentrations, with much higher average levels observed during the rainy season.

The high water flow of the river led to higher supply of organic matter into the sea. Several studies have shown that the concentration of nitrate in waters greater in the wet season compared to the dry season (Stapel *et al*., 2001; Edinger *et al*., 1998; Nurliah, 2002; Costa *et al*., 2008 and Hakanson and Brhyn, 2008). The high nitrate supply of organic material, especially in the rainy season is not only depend on the amount of water flow of the river, but is also strongly influenced by rain water catchment conditions (Lihan *et al*., 2008). The same thing was found by Erftemeijer (1994) that the concentration of nitrate in the lower Barranglompo Island during the dry season (July to September) when compared with the concentration in the rainy season (November to January).

The average value of the high phosphate concentrations measured in the early months of research on all stations decreased over the study period. Steep decreasing of phosphate concentrations in Spermonde Island was higher than those in Sembilan Islands.The decreasing value was a result of their use in biological photosynthesis by primary producers, along with an increase in light intensity (dry season), especially in Spermonde Islands.

Some studies showed that a location close to coastal areas has a high concentration of phosphate (Erftemeijer, 1994; Edinger *et al*., 1998; Stapel *et al*., 2001; Nurliah, 2002). In addition, other sources of phosphate were rock weathering processes, and agricultural activity on the land in the upstream. Another source comes from the use of house hold detergents. Based on the value of phosphate concentration, it showed that at all stations in both areas of the islands has been classified as hypertrophic with value s>130 mg/L (>0.0013mg/L).

Sedimentation in Kodingarengkeke Island and Samalona Island was associated with the transition season which has higher waves during the time of study and it is suspected to be internally occurrend because of sediment re-suspension by wave motion. While on the Laiya Island, other than by stirring it also receives material supply from rivers that empty into Pangkep District. The same is also observed in Kodingarengkeke Island, Barranglompo Island and Lae-lae Island with highest concentration in July and August (Rani *et al*., 2012).

The high sedimentation rates are found on the islands close to the main land, such as on the island of Laiya and Samalona Island in Spermonde Islands; and Kambuno Island and Burungloe Island in Sembilan Island. It can be concluded sedimentation occurrend in the study areas largely due to the material from the mainland. However, no significant differences detected between islands in each study area.

CONCLUSIONS

Stations closer to the mainland in both the Spermonde and Sembilan Islands had higher nutrient concentrations and sedimentation rates. Nitrate concentration was similar between the two study areas; however phosphate concentration and sedimentation rate were higher in the Sembilan Islands. Most stations in both areas were already experiencing eutrophication based on nitrate concentrations, and were classified as hypertrophic based on phosphate concentration. The main driver of eutrophication and sedimentation at the study sites was transport of materials from the Sulawesi mainland.

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