P-ISSN: 2355-729X
Jurnal IPTEKS PSP. Vol. 9 (1) April 2022: 1 – 11 E-ISSN: 2614-5014

DECADAL REMOTE-SENSING ANALYSIS OF EUTROPHIC INDICATION IN THE SPERMONDE ISLANDS, INDONESIA

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Manuscript Recived: 7 February 2022
Revision Accapted: 29 April 2022
DOI: 10.20956/jipsp.v9i1.20061

ABSTRACT

The trophic level of marine waters is closely related to the high concentration of nutrients in the water column. One of nutrient indicators is the concentration of chlorophyll-a. The research aims to map the decade of change in Spermonde waters' status with the indicator of chlorophyll-a by utilizing remote sensing technology. The research method used the digital image processing for the analysis of chlorophyll-a concentrations. Data distribution were plotted with kriging techniques and the trophic level was classified based on the Hakanson method. The results showed that there was a change in the trophic level of the Spermonde Islands in 1996-2020. Mesotrophic conditions changed by 166 m and eutrophic conditions by 134 m every year.

Keywords: Trophic level, Chlorophyll-a, Remote Sensing, Eutrophic indication, Spermonde

INTRODUCTION

The 2030 Agenda for Sustainable Development Goals (SDGs) is a road map with the world's countries in the framework of peace and prosperity for humans on this planet. One of the SDGs goals is to conserve and sustainably use the oceans, seas, and marine resources for sustainable development, with one of the targets to reduce nutrient pollution (UNDP, 2015). Nutrient pollution causes eutrophication in waters (Nixon, 1995; Nixon, 2009; UNDP, 2015). Eutrophication is an increase in the supply of organic material to aquatic ecosystems, increasing primary productivity (Nixon, 1995; Jorgensen, 1996). Eutrophication is a significant problem affecting the integrity and health status of coastal marine ecosystems, the process of which is caused by nutrients or an increase in the supply of organic material, which increases the primary productivity of ecosystems (EEA, 2001).

Eutrophication at peak conditions will cause significant changes in the structure and dynamics of ecosystems [Nixon 1995; Ferreira et al., 2011; Nixon, 2009; Desmit et a.,l 2018). There are differences in eutrophication between freshwater and seawater ecosystems. In freshwater is strongly influenced by the decline in Biological Oxygen Demand (BOD) (Kinsey 1991; Hallock et al 1993; Szmant & Forrester

P-ISSN: 2355-729X
E-ISSN: 2614-5014

1996), whereas in marine ecosystems occurs when nutrient conditions are extreme (Bell 1992; Lapointe 1992; Lapointe 1997). The essential difference between eutrophication on freshwater and seawater is the content of phosphorus and nitrate. Phosphorus is the only limiting factor in some freshwater and estuary waters (Jickels et al 1989; Sharpley et al 1999), whereas nitrogen is a limiting factor for the growth of elements in seawater (D'Elia & Wiebe 1990; Nixon et al 1996). Several indicators are currently used to assess eutrophication conditions in the water system; phosphate, ammonia, and nitrate, which are the primary nutrients that cause eutrophication (Duarte, 2009); chlorophyll-a as an indicator of phytoplankton biomass as an effect of eutrophication (D'Elia et al 1981); Chemical Oxygen Demand (COD); and Biochemical Oxygen Demand (BOD) as an indicator of organic matter contamination (Kinsey 1991; Hallock et al 1993; Szmant & Forrester 1996). Hakanson & Bryhn (2008) divides four levels of the tropical status of marine waters with a salinity criterion >25 ppt; oligotrophic, mesotrophic, eutrophic, and hypertrophic. Criteria for the distribution of water conditions are based on nutrient content and chlorophyll-a as in (Table 1). All of the indicators can be measured directly through water sampling using the field survey method. The survey method using ships is expensive and takes a long time.

Table 1. Trophic level criteria for salinity above 25 ppt

Tropical Level	Concentration			
	Chl-a (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	Cyanobacteria (mg/l)
Oligotrophic	<2	<110	<15	<55
Mesotrophic	2 - 6	110 - 290	15 - 40	55 -680
Eutrophic	6 – 20	290 – 940	40 - 130	680 - 4040
Hypertrophic	>20	>940	>130	>4040

Satellite remote sensing technology can be implemented with low cost, fast time with comprehensive area coverage. Besides remote sensing, data can provide time in several decades. One thing that can be done is collecting Chlorophyll-a concentration data as an indicator of eutrophication assessment (Cloern; 2001). The remote sensing method can visualize changes in the distribution of tropical status in waters. It can even be used as a raw prediction model for the trophic status of waters.

Spermonde Islands locate in the Makassar Strait precisely in the West of South Sulawesi, which includes Makassar City, Maros Regency, and Pangkep Regency. There has been various damage to aquatic ecosystems in this region due to anthropogenic activities such as destructive fishing (Pet-Soede et al 2000) and an increase in the amount of domestic waste (Jompa 1996; Edinger et al 2000; Faizal 2012) which can lead to eutrophication. The symptoms of eutrophication in the Spermonde Islands have been noted in several studies, (Edinger et al 2000) suggested that there is a correlation between the level of coral damage and macroalgae cover in some island's high nutrient concentrations at a depth of 3 m. Furthermore, (Nurliah 2002) suggested a eutrophication indication on Kayangan Island, which caused damage to coral reefs and Faizal (2012) the occurrence of macroalgae invasion on islands close to the mainland to a high concentration of nutrients. Based on various phenomena of eutrophication symptoms and as part of the SDGs program, periodic monitoring of the distribution of eutrophication in Spermonde waters is conducted. The purpose of this research is to map decades of changes in the status of Spermonde waters with the indicator Chlorophyll-a utilizing remote sensing technology.

MATERIAL AND METHOD

Research site

This research is a laboratory-scale study, in the form of processing Ocean-Color satellite imagery from 1996-2020. The location of the study was the waters of the Spermonde Islands, South Sulawesi Province, Indonesia (118°49'45"E 4°34'54"S and 119°30'04"E 5°18'01"S (Figure 1).

Material Data

The material used in this research is data Ocean color satellite imagery for 1996-2020. The data were obtained from SeaWiFS at the link: http: //oceancolor.g sfc.nasa.gov/cgi/level3.pl/. Data resolution, 9 km /monthly

Method

Image analysis. Chlorophyll-a concentration data extraction using Morel Algorithm 4 (Morel & Maritorena 2001). Morel 4 algorithm equation:

$$Chl - a = 10\ (a0 + a1 \times R^2 + a3 \times R^3)$$
$$R = Log(B2/B3)$$

Where:

a0 = 1.03117
a1 = -2.40134
a2 = 0.3219897
a3 = -0.291066
B2 = blue band
B3 = red band.

The resulting ASCII data were interpolated using the kriging method (Olea & Ricardo 1999; Bayraktar et al 2005). The results of data interpolation are presented in the form of distribution contour maps and graphs. Changes in the trophic level distribution every five years are carried out using a linear regression test.

P-ISSN: 2355-729X
E-ISSN: 2614-5014

Figure 1. The study location in Spermonde Waterways. Indonesia.

RESULTS AND DISCUSSION

Results

Spatial trends as identification of spatial models were developed from analysis of Ocean Color NOAA AVHR imagery (Resolution 9 km), and MODIS Imagery (Resolution 4 km) in 1996, 2000, 2005, and 2010, 2015, 2020. The results of satellite image analysis using the Morel algorithm and classification based on the trophic level criteria from (Hakanson & Bryhn 2008) as shown in (Figure 2).

P-ISSN: 2355-729X
E-ISSN: 2614-5014

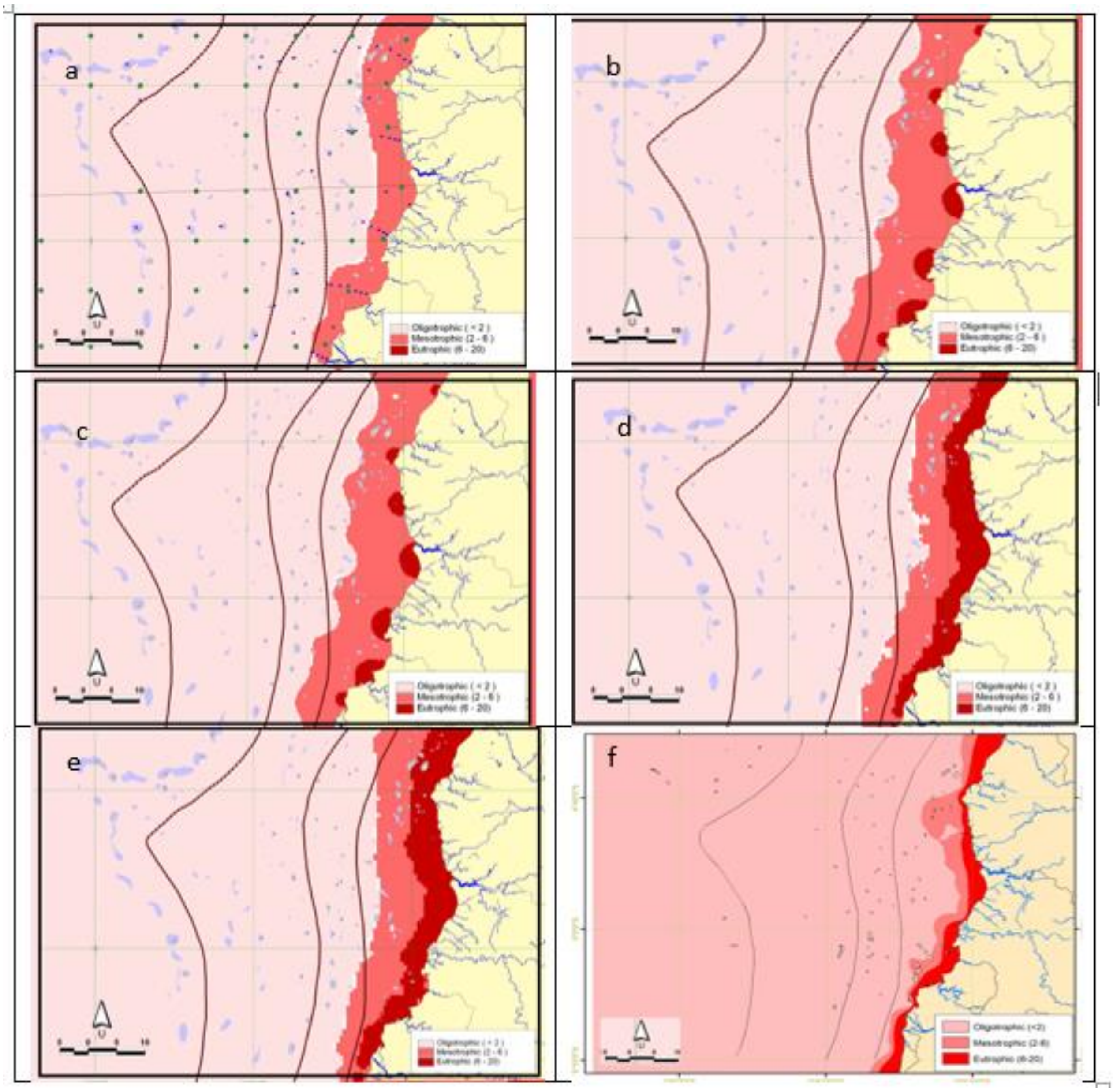

Figure 2. Map of trophic level of Spermonde Islands waters based on chlorophyll-a concentration in (a) 1996, (b) 2000 (c) 2005, (d) 2010, (e) 2015, and (f) 2020. Need to make clear all legends

The results of chlorophyll-a image analysis based on the tropics level criteria at a crossing of >25 ppt showed a trophic level change between 1996-2020. Image analysis in 1996 showed that the mesotrophic conditions of Spermonde Islands waters were in the range of 1.6 - 10.5 km from the coastline and eutrophic conditions in the range 0.08 - 0.78 km from the shoreline. Whereas in 2020, there was a very high increase, where the range of mesotrophic conditions was 8.3-11.57 km from the coastline, and eutrophic conditions were in the range of 1.45 - 9.4 km. Mesotrophic conditions tend to shift from the coast to the high seas, but the shift is not constant. They were changing tropic level waters, as in (Figure 3).

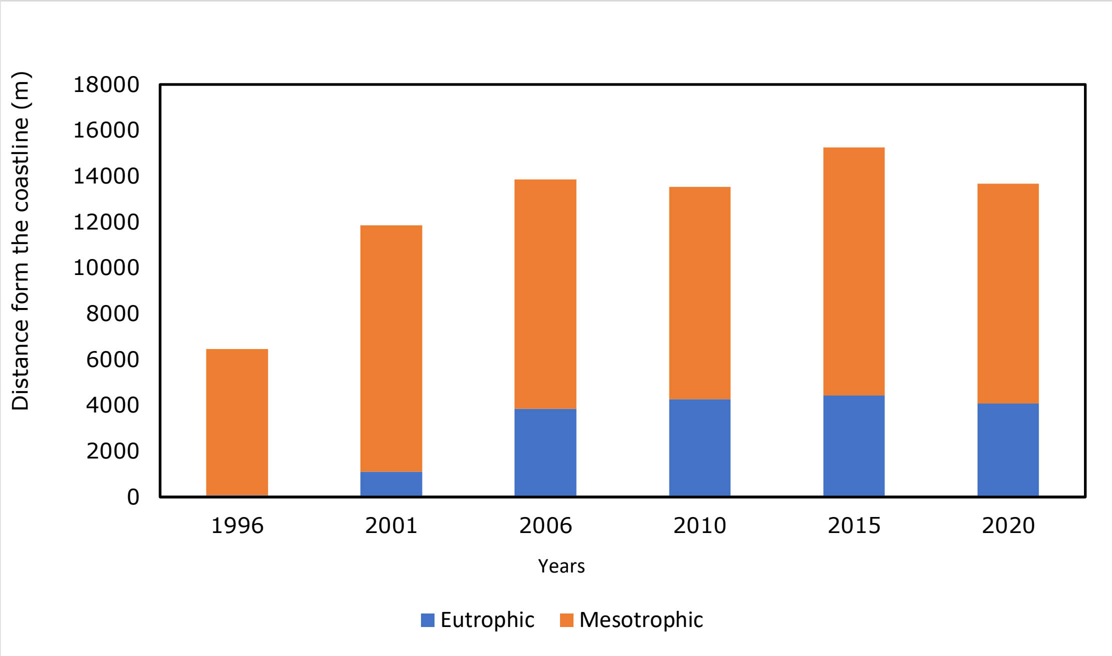

Figure 3. Changes in the trophic level of Spermonde Islands waters based on the distance from the coastline.

In Figure 3, a mesotrophic level shift occurred quite quickly between 1996-2015, then it experienced a decline in 2015-2020. For the condition of eutrophic levels in 1996-2000, almost not found in the waters of the Spermonde Islands, in 2000, eutrophic symptoms began to appear in river mouths and experienced an increase in 2005-2015. Eutrophic conditions spread almost in all coastal waters to a distance of 6.1 km, these symptoms indicate a considerable increase in nutrients in the last 20 years and cause an increase in trophic water level in the Spermonde Islands.

Increasing trophic level urges oligotrophic conditions to be further from the coastline. Optimal water conditions for the growth of coral reefs and other ecosystems are oligotrophic conditions, which will cause ecosystem degradation. Statistically, the extent of shifting the trophic level distribution in the Spermonde Islands is analyzed by linear regression, as in (Figure 4).

Figure 4. shows that the shift in mesotrophic level corresponds to the equation y = 95.567x - 182431 (R = 0.55), which causes an increase in the average distance from the coastline each year by 166 m, with a coefficient of determination of 0.26 whereas the eutrophic conditions undergo a shift from the coast each year by the regression equation y = 183.35x - 365189 (R = 0.75), with an average of 134 m addition to the high seas.

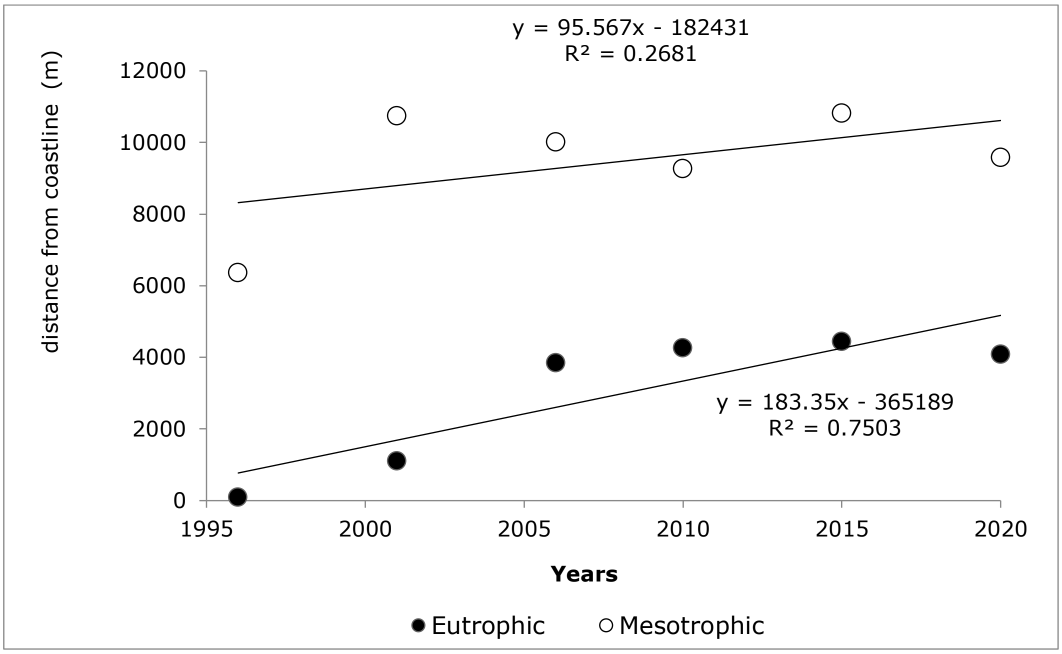

Figure 4. Relationship between distance from coastline (m) and year by trophic level distribution

Discussion

In several studies of eutrophication, chlorophyll-a is an indicator of water fertility. Increased nutrient concentrations in the waters cause an increase in chlorophyll-a consisting of plankton and several other green plants (D'Elia et al 1981; Charpy et al 1998). Chlorophyll is the pigments involved in light absorption and photochemistry in lower plants such as algae, higher plants, and bacteria (Tambaru et al 2008). Chlorophyll consists of several elements chlorophyll-a-b-c and d. Chlorophyll-a is used in field parameters because it is a significant component in photosynthesis.

Figure 2. shows the spatial and temporal distribution of trophic water levels based on chlorophyll-a concentrations. In 1996 most were still in oligotrophic and mesotrophic conditions in parts close to the mainland, whereas eutrophic conditions were only found in small spots in river mouths. Mesotrophic or eutrophic level conditions only occur at the coast and river mouths. This is in line with the statement of (Rast & Thornton 1996). that the occurrence of eutrophication is caused by the use of watersheds or water bodies for commercial purposes and basic needs. The tremendous growth of algae marks the initial symptoms, and water quality becomes damaged and deoxygenation of the bottom water layer. In 2020, trophic water levels will change, especially those close to the mainland, from oligotrophic to eutrophic. This is in line with what was stated by Faizal et al (2012;2020) that during the rainy season, most areas close to the mainland in the Spermonde Islands are in eutrophic conditions.

P-ISSN: 2355-729X
E-ISSN: 2614-5014

Figures 3 and 4 show an increase in the Spermonde Islands trophic level in the 1996-2020 period. This is by the findings of (Edinger et al 2000); that trophic water levels vary significantly in the Spermonde Islands, the closer the mainland, the higher trophic levels. The same thing has been found by (Stapel et al 2001) in seagrass ecosystems in Makassar City islands, the trophic level around Lae-lae and Gusung Tallang are much higher than the trophic level on Barranglompo Island. The same condition is also found on the coast of Maros Regency, where the chlorophyll-a content is higher in the inner waters compared to the outside (Tambaru 2008; Nasir et al 2015).

The linear regression equation in Figure 4 shows the low coefficient of mesotrophic determination R = 26%, and eutrophic condition R = 75%. This is caused by the fact that there are still many other factors that influence the trophic water level. (Hakanson & Bryhn 2008) further explained that in addition to the parameters of chlorophyll-a concentration, the concentration of nitrate and phosphate in the waters was crucial to the eutrophication. The regression equation also shows that there is an increase in the trophic level distribution of waters from year to year.

CONCLUSIONS

Chlorophyll-a concentrations in the Spermonde Islands in the 1996-2020 period increased, thereby changing the trophic level from oligotrophic to eutrophic conditions, especially in waters near the central plain. Oligotrophic conditions increasingly away from the mainland and shifting mesotrophic conditions by 166 m each year and eutrophic conditions by 134 m per year.

ACKNOWLEDGEMENT

We thanks to Fahril Muhajir and Andi Arham Atjo for their assistance during field study in this research

REFERENCES

Bayraktar, Hanefi, Sezer, Turalioglu 2005 A Kriging-based approach for locating a sampling site—in the assessment of air quality. Stochastic Enviromental Research and Riskand Assessment. 19(4);301–305.

Bell P. R. F., 1992 Eutrophication and coral reefs: some examples in the Great Barrier Reef lagoon. Water Research, 26(5);553-568

Charpy L., Charpy-Roubaud C., Buat P., 1998 Excess primary production, calcification, and nutrient fluxes of patch reef (Tikehau atoll French Polynesia). Marine Ecology Progress Series. 173;139-147

Cloern J. E., 2001 Our evolving conceptual model of the coastal eutrophication problem. Marine Ecology Progress Series. 210;223–253.

D'Elia C. F., Webb K. L., Porter J. W., 1981 Nitrate-rich groundwater inputs to Discovery Bay,

P-ISSN: 2355-729X
E-ISSN: 2614-5014

Jamaica - A significant source of N to local coral reefs. Bulletin of Marine Science. 31(4);903-910.

D'Elia C. F., Wiebe W. J., 1990 Biogeochemical nutrient cycles in coral reef ecosystems. In: Z. Dubinsky (ed) Coral reefs. Ecosystems of the world 25. Elsevier, New York, pp. 49-74.

Desmit X., Thieu V., Billen G., Campuzano F., Dulière V., Garnier J., Lassaletta L., Ménesguen A., Neves R., Pinto L., Silvestre M., Sobrinho J. L., Lacroix G., 2018 Reducing marine eutrophication may require a paradigmatic change. Science of the Total Environment. 635(1);1444–1466.

Duarte C. M., 2009 Coastal eutrophication research: a new awareness. Hydrobiologia. 629;263–269

EEA (European Environment Agency), 2001 Eutrophication in Europe’s Coastal Waters, Topic Report 7, Copenhagen, 86 pp.

Edinger E. N., Limmon G. V., Jompa J., Widjatmoko, Wisnu, Heikoop, Jeffrey M., Risk Michael J., 2000 Normal Coral Growth Rates on Dying Reefs: Are Coral Growth Rates Good Indicators of Reef Health?. Marine Pollution Bulletin. 40(5);404-425.

Faizal A., 2012 Dinamika Spasio-Temporal Pengaruh Eutrofikasi Dan Sedimentasi Terhadap Degradasi Terumbu Karang. Disertasi. Program Pasca Sarjana Universitas Hasanuddin. Makassar. 270 pp.

Faizal A., Jompa J., Nessa M. N., Rani C., 2012 Dinamika spasio-temporal tingkat kesuburan perairan di Kepulauan Spermonde, Sulawesi Selatan. Prosiding Seminar Nasional Tahunan IX Penelitian Perikanan dan Kelautan, Universitas Gadjah Mada. MB09;1-18

Faizal A., Amri K., Rani C., Nessa M. N., Jompa J., 2020 Dynamic model; the effects of eturophication and sedimentation on the degradation of coral reefs in Spermonde Archipelago, Indonesia. IOP Conference Series: Earth and Enviromental Science. 564(2020);012084

Ferreira J. G., Andersen J. H., Borja A., Bricker S. B., Camp J., Cardoso da Silva M., Garcés E., Heiskanen A. S., Humborg C., Ignatiades L., Lancelot C., Menesguen A., Tett P., Hoepffner N., Claussen U., 2011 Overview of eutrophication indicators to assess environmental status within the European Marine Strategy Framework Directive. Estuarine Coastal and Shelf Science. 93;117-131

Hakanson L., Bryhn A. C., 2008 Eutrophication in the Baltic Sea Present Situation, Nutrien Transport Processes, Remedial Strategies. Springer-Verlag Berlin Heidelberg, 263 pp.

Hallock P., Muller-Karger F., Halas J. C., 1993 Coral reef decline - anthropogenic nutrients and the degradation of Western Atlantic and Caribbean coral reefs. Research and Exploration. 9(3);358-378.

Jickels T. D., Smith S. R., Boyd S., Knap A. H., 1989 Phosphorus limitation in the Bermuda inshore waters. Estuarine Coastal and Shelf Science. 28;121-132.

Jompa J., 1996 Monitoring and Assessment of Coral Reefs in Spermonde Archipelago, South Sulawesi, Indonesia. Thesis. McMaster University. Canada 81 pp.

Jorgensen B. B., 1996 Material flux in the sediment. In: Jorgensen, B.B. and Richardson, K. Eds., Eutrophication in Coastal Marine Ecosystems, American Geophysical Union, Washington, pp.115-135.

Kinsey D. W., 1991 Systems-level management, monitoring, and research: The Australian perspective on environmental change. In:

C.F. D'Elia, R.W. Buddemeier & S.V. Smith (eds) Workshop on Coral Bleaching, Coral Reef Ecosystems, and Global Change: Report of Proceedings, Mariland Sea Grant College, publication UM-SG-TS-. 91(3); 47-49.

Nasir A., Lukman M., Tuwo A., Fadilah N., 2015 Rasio Nutrien terhadap Kumunitas Diatom-Dinoflagellata di Perairan Spermonde, Sulawesi Selatan. Jurnal Ilmu dan Teknologi Kelautan Tropis. 7(2);587-601.

Nixon S. W., 1995 Coastal marine eutrophication: a definition, social causes, and future concerns. Ophelia. 41;199–219.

Nixon, S.W. Ammerman J. W., Atkinson L. P., Berounsky V. M., Billen G., Boicourt W. C., Boynton W. R., Church T. M., Ditoro D. M., Elmgren R., Garber J. H., Giblin A. E., Jahnke R. A., Owens N. J. P., Pilson M. E. Q., and Seitzinger S. P., 1996 The fate of nitrogen and phosphorus at the land-sea margin of the North Atlantic Ocean. Biogeochemistry. 35;141- 180.

Nixon, S.W. 2009 Eutrophication and the macroscope. Hydrobiologia. 629;5-19.

Nurliah, 2002 Kajian mengenai dampak eutrofikasi dan sedimentasi pada ekosistem terumbu karang di beberapa pulau Perairan Spermonde, Sulawesi selatan. Tesis Program Pasca Sarjana Universitas Hasanuddin. Makassar. 128 pp.

Morel A., Maritorena S., 2001 Bio-optical properties of oceanic waters: A reappraisal. Journal of Geophysical Research. 106(C4);7163-7180.

Lapointe B. E., 1992 Eutrophication thresholds for macroalgal overgrowth of coral reefs. In: K. Thacker (ed) Protecting Jamaica's coral reefs: water quality issues. Negril Coral Reef Preservation Society, Negril, Jamaica, pp.105-112.

*** 1997 Nutrient thresholds for bottom-up control of macroalgal blooms on coral reefs in Jamaica and southeast Florida. Limnology and Oceanography. 42(5);1119-1131.

Olea Ricardo A., 1999 Geostatistics for Engineers and Earth Scientists, Kluwer Academic, 303 pp.

Pet-Soede C. H., Caesar S. J., Pet S. J., 2000 Economic Issues Related to Blast Fishing on Indonesian Coral reefs. Pesisir dan Lautan. 3(2);33-40.

Rast W., Thornton J. A., 1996 Trends in eutrophication research and control. Hydrological Process. 10(2);295-313.

Sharpley A. N,., Daniel T., Sims T., Lemunyon J., Stevens R., and Parry S., 1999 Agricultural phosphorus and eutrophication, U.S. Department of Agriculture, Agricultural Research Service, ARS, 149 pp.

Stapel J., Marten A., Hemminga, Cornelis, Bogert B., Yvonne E. M., 2001 Nitrogen (15N) retention in small Thalassia hemprichii seagrass plots in an offshore meadow in South Sulawesi, Indonesia. Limnology and Oceanography. 46(1);24-37

Szmant A. M., Forrester A., 1996 Water column and sediment nitrogen and phosphorus distribution patterns in the Florida Keys, USA. Coral Reefs. 15;21-41.

Tambaru R., Adiwilaga E. M.,Muchsin I., Damar A., 2008. Dinamika Kelimpahan Komunitas Fitoplankton dalam Hubungannya dengan Variabilitas Intensitas Cahaya dan Nutrien di Perairan Pesisir Maros. Torani Journal Ilmu Kelautan. 13(1);98-106

UNDP (United Nation Development Program), 2015 Sustainable development goasl; gol 14 live below water. Accessed on May 21, 2020. From https://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-14-life-below-water.html.