

Primary productivity of coastal ecosystems in the Seribu Islands (case study on Kelapa Dua Island, Pramuka Island and Pari Island)

Nurrahman Y A¹ and Nurdjaman S²

¹ Department of Marine Science, Faculty of Mathematics and Natural Sciences, Universitas Tanjungpura, Indonesia

² Department of Oceanography, Faculty of Earth Sciences and Technology, Institut Teknologi Bandung, Indonesia

E-mail: yusuf.budhysatrya@gmail.com

Abstract. A determination of the primary productivity in coastal ecosystems, namely mangrove, seagrass and coral reef was done in the Seribu Islands (Kelapa Dua Island, Pramuka Island and Pari Island). Data collection was performed by oxygen methods with a light-dark bottle. Data were collected on 11 - 16 February 2016. The data were Mangrove density, seagrass density, seagrass cover, and, coral reefs cover. Physical-chemical parameters of the water were water temperature, salinity, dissolved oxygen, and nutrient content. Mangrove density in Pramuka Island is the highest among the others with density 19,500 trees/ha. The highest seagrass density is found in Kelapa Dua Island of 1,099 stand/m². Life corals in Kelapa Dua Island has the highest coverage by percentage of 53.2 %. The calculation results of primary productivity values show the highest value in Pulau Kelapa Dua up to 3.0062 gC / m² / day. The lowest value obtained in Pari Island that was equal to 0.6 gC / m² / day. Based on research, mangrove density, seagrass density and life corals coverage have a positive correlation to primary productivity.

1. Introduction

Indonesian waters cover 17% of the world's marine areas with high primary productivity. This is because Indonesia has a high level of biodiversity, especially in their coastal ecosystems. Coastal areas and oceans, in terms of various kinds of designation, is a very productive area. Primary productivity in coastal areas such as estuary, mangrove, seagrass, and coral reef ecosystems can reach more than 10,000 gC / m² / yr, which is about 100-200 times greater than the primary productivity in the open ocean. The high primary productivity of coastal ecosystems enables high levels of secondary productivity (fish and other marine animals). The Seribu Islands consists of 110 islands, and 11 of them are populated. The other islands are used for recreation, nature reserves, cultural heritage and other designations. The Seribu Islands area is approximately 108,000 ha, located off the north coast of Jakarta with an elongated position from north to south marked by small white sandy islands and coral reefs. Seribu Islands have a high marine biodiversity including a variety of coastal ecosystems such as mangroves, seagrass and coral reefs. This has led to high primary productivity in the Seribu Islands. Measurement of primary productivity of phytoplankton is a basic requirement to study the structure and function of aquatic ecosystems ^[1]. This study aims to determine primary productivity in some



coastal ecosystems and the relationship between primary productivity with coastal ecosystem conditions such as mangrove, sea grass and coral reefs in Seribu Islands.

In the sea, especially open water, phytoplankton is the main autotrophic organism that determines the primary productivity of waters. The primary productivity of waters is the amount of organic matter produced by autotrophic organisms, i.e. organisms capable of producing organic materials from inorganic materials with the help of solar energy. Primary productivity is often estimated as the amount of carbon present in living material and is generally expressed as the number of grams of carbon produced in one square meter of water per day ($\text{g C} / \text{m}^3 / \text{day}$)^[1].

In a humid tropical climate, high primary productivity due to the high intensity of sunlight and evenly throughout the year^[1]. The high intensity of light causes the increase in the speed of photosynthesis. The existence of the effect of light intensity on the speed of photosynthesis causes primary producers in the deepwater environment is getting lower.

2. Research location

The research location is located in the waters of Pari Island, Pramuka Island and Kelapa Dua Island, which is administratively located in the Seribu Islands Administrative District, DKI Jakarta Province (Fig 2.1). On each island are placed 3 research stations for each ecosystem located on site.

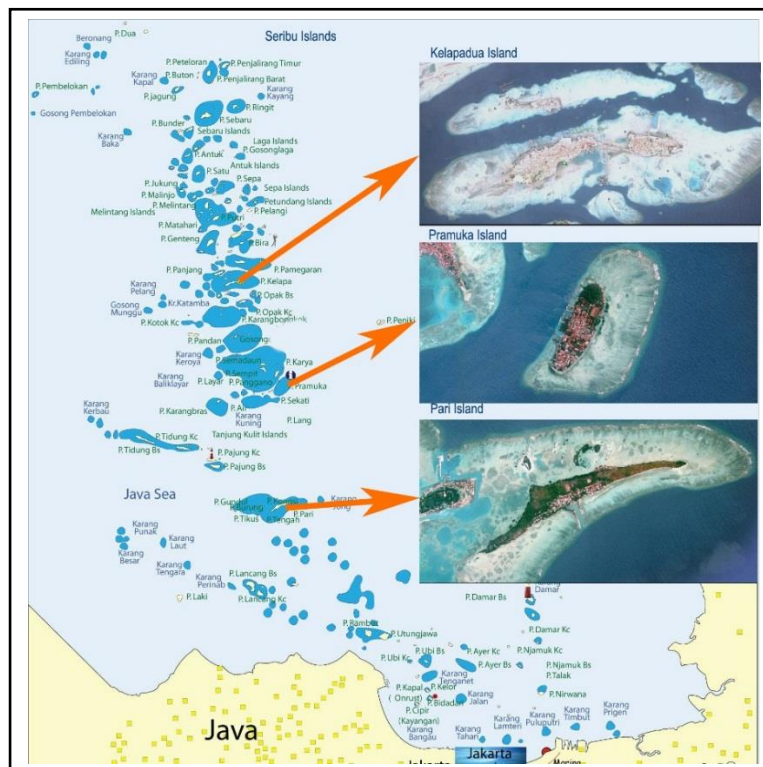


Figure 1. Seribu Islands map

Kelapa Dua Island is a fairly small island and nearby are Kelapa Island and Harapan Island: There are offices and mess of Kepulauan Seribu National Park, Hawksbill turtles captive breeding (*Eretmochelys imbricata*), and mangrove arboretum. The mangrove ecosystem is found in the east of the island along with the seagrass ecosystem. Meanwhile, coral reef ecosystems is found in the west, south, and the east of the islands.

Pramuka Island is the capital of Kepulauan Seribu Administrative District and is also known as a tourist island. Mangroves and seagrasses are found to the east of the Island, adjacent to the offices of the Kepulauan Seribu National Park Authority. Mangrove contained in Pramuka Island is the result of

planting. Coral reefs are found around the island and 3 locations in the south, east and north are taken as observation stations.

Pari Island is the most crowded tourist island visited by tourists every weekend with the existence of marine tourism object and Pasir Perawan Beach. The seagrass observation station 1 is located in the south of the island, with a relatively small growth area, seagrass 2 and 3 observation stations are located around the Pasir Perawan Beach. Mangroves are found in the north of the island, starting from Pasir Perawan Beach to the west. Mangrove that was found in Pari Island is a natural mangrove. Meanwhile, coral reef data are taken in the north, east, and south of the islands.

3. Research methods

Research stations are determined based on satellite imagery observations. After obtaining the image data, the location of the station will be determined based on the type of ecosystem and its conditions in the field.

3.1 Primary productivity measurement

Primary productivity measurements was conducted using oxygen, water sampling in each ecosystem contained in the research area. Equipment needed is water sampler, light and dark bottles size 300 ml and Oxygen meter. Incubation was carried out at the best time interval from 9.00 to 14.00^[12].

3.2 Coral reefs measurement

The method used to describe the condition of coral reefs is by Line Intercept Transect (LIT) method^[9]. The clustering of coral community structures was carried out using lifeform categories by looking at the morphology of live coral cover, dead coral, substrate form (sand, mud), algae and other biota existence. Coral specs are expected to be recorded as a form of coral growth (lifeform).

3.3 Seagrass measurement

Data collection was conducted to determine the condition of seagrass (type, density and percentage of seagrass cover). Observations of seagrass beds will be conducted at low tide, with a depth of less than 1 meter. Method for observation of seagrass ecosystem used quadratic transect method. The squares to be used are 1 x 1 m and the transects will be horizontally aligned with the coastline starting from the first region of Seagrass up to the closest to the reef^[12].

3.4 Mangroves measurement

Mangrove vegetation data was collected using survey technique and mangrove vegetation analysis. Analysis of mangrove forest vegetation in this research activity is done by a combination method of transect method (transect method) and quadrat method (quadrat method)^{[3][8]}.

Water quality data were taken in each ecosystem at each station using refractometer to measure aquatic salinity, luxmeter to measure light intensity, and thermometer to measure water temperature and DO meter to measure dissolved oxygen.

4. Data Processing

4.1 Primary productivity data processing

The primary productivity value of the waters was measured using the following formula^[1]:

$$\frac{(O_2BT - O_2BA) \times 1000 \times 0,375}{PQ(t)} \quad (1)$$

Where NPP is the net primary productivity (mg C / m³ / hr), O₂BT is oxygen in the bright bottle (BT) after incubation (mg / l), O₂BA is oxygen at the initial bottle (BA) (mg / l), PQ is the coefficient Photosynthesis, t is the incubation time (hr), 1000 is the conversion of liter to m³, and 0.375 is the oxygen conversion coefficient to carbon.

4.2 Mangrove data processing

The calculation of the quantitative value of the mangrove vegetation parameters, especially in the determination of the density is done by using the following formula: ^[3]

$$cr = \frac{ci}{c} \times 100\% \quad (2)$$

Where:

cr : Relative density

ci : Species density

c : All species density

4.3 Seagrass data processing

To determine the extent of certain seagrass cover areas compared to the total area of cover for all seagrass species, a method was adapted from the Saito and Atope Methods ^[2].

$$c = \frac{\sum seagrass}{\sum A} \quad (3)$$

Where:

c = Seagrass density

A : Total area

4.4 Coral reefs data processing

Coral reef condition is obtained from direct measurement result in field by Line Intercept Transect method. Furthermore, data processing is done by calculating Percentage of Coverage ^[9], i.e. :

$$n_i = \frac{l_i}{L} \times 100\% \quad (4)$$

Where:

n_i = life hard corals coverage percentage

l_i = life form transect length

L = total transect length

5. Results and discussion

5.1 Mangrove ecosystem condition

Mangrove ecosystems in the Seribu Islands particularly among the sites are generally a result of mangrove planting in the region of Kepulauan Seribu National Park on the island of Kelapa Dua and Pramuka. The species found was *Rhizophora Stylosssa*. While for the natural Mangrove found in Pulau Pari. The highest mangrove density was found in Pramuka Island precisely at Station 1 with the value of density reach 19,500 stands / hectares and the lowest is in the island of Pari precisely at Station 1 with a value of 1267 stands / hectare. This significant difference is caused by differences in Mangrove condition in Kelapa Dua island and Pramuka island where the a mangrove planting is very dense in distance, unlike the mangrove in Pari island that grows naturally with it condition which has big stem diameter.

Table 1. Mangrove density

Station	Density (stands/ha)	Category ^[7]
Kelapa 2-1	8,600	Good
Kelapa 2-2	12,060	Good

Kelapa 2-3	10,220	Good
Pramuka-1	19,500	Good
Pramuka-2	15,500	Good
Pramuka-3	14,233	Good
Pari-1	1,267	Good
Pari-2	1,567	Good
Pari-3	3,133	Good

5.2 Seagrass ecosystem condition

Seagrass species found in the study sites are *Enhalus acoroides*, *Thalassia hemprici*, *Halophila spinulosa*, and *Halodule uninervis*. The condition of Seagrass ecosystem at the highest research location is found in Kelapa Island precisely at Station 3 which is 1,099 stands / m². Meanwhile, for the lowest density is found in Pari Island precisely at station 2, however, the Seagrass plants in Pari Island have larger leaves than those found on other islands.

Table 2. Seagrass density and coverage

Station	Density (stands/m ²)	cover (%)	Category/status ^[6]
Kelapa 2-2	469	34	Damaged/less
Kelapa 2-3	1099.33	34	Damaged/less
Pramuka-1	690.33	40	Damaged/less
Pramuka-2	671	33,33	Damaged/less
Pramuka-3	502.67	24	Damaged/poor
Pari-1	413.33	15	Damaged/poor
Pari-2	30	4	Damaged/poor
Pari-3	71	5	Damaged/poor

5.3 Coral reefs ecosystem condition

The condition of coral reef ecosystem at the best research sites is found in Harapan Island with live coral cover reach up to 52.3% and the lowest is in Pramuka Island station 2.

Table 3. Coral reefs coverage

Station	Coverage (%)	Category ^[4]
Kelapa	26.76	Average damaged
Kelapa Dua	36.78	Average damaged
Harapan	53.20	Good
Pramuka-1	42.40	Average damaged
Pramuka-2	21.70	Heavily damaged
Pramuka-3	50.90	Good
Pari-1	45.46	Average damaged
Pari-2	29.32	Average damaged
Pari-3	41.3	Average damaged

5.4 Primary productivity

Data retrieval of primary productivity in the waters of the Seribu Islands carried out at each coastal ecosystems in each island. In general, the largest primary productivity found in mangrove ecosystem in Kelapa Dua Island, with an average of 3.0062 gC / m³ / day or 1097.3 gC / m³ / year. Meanwhile, the lowest primary productivity value was found on the seagrass ecosystem in Pari Island with an average primary productivity of 0.6 gC / m³ / day or 225.26 gC / m³ / year.

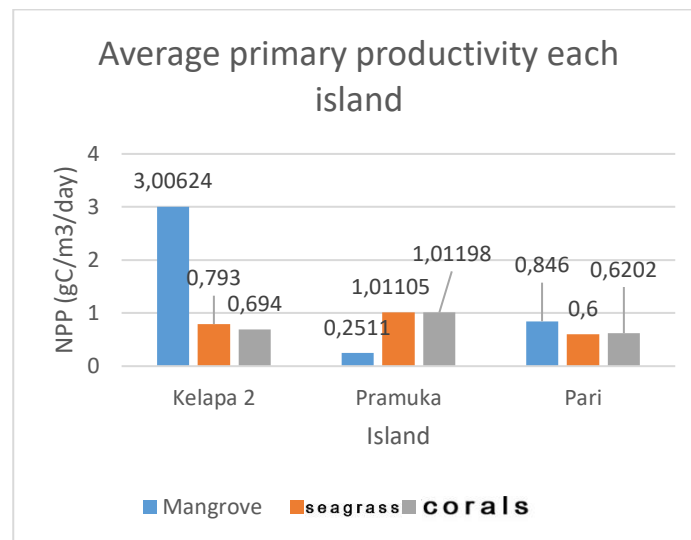


Figure 2. Primary productivity in Seribu Islands

5.5 Relationship of Primary Productivity with Aquatic Chemical-Physical Parameters

The intensity of light greatly affects the productivity of the slicker primer. At the maximum light intensity of 77,000 lux, the primary productivity also reached the highest value of 3.354 gC / m³ / day. Salinity in the study sites ranged from 28.5 to 33 psu, where the highest salinity was found in the waters of Kelapa island and surrounding areas precisely in the mangrove community. And the lowest is in the waters of the Pramuka island, precisely in the community of mangrove and seagrass. In the process of data collection it is clear that at the time of data collection in the Pramuka island, the weather conditions were rainy while at the time of measurement in the Kelapa island , the weather conditions were bright.

Water temperatures in the study sites ranged from 28.65 - 33.3 °C. This surface temperature is strongly influenced by the high solar irradiance. This water temperatures are closely related to the primary productivity of waters.

Nitrate concentration in the three islands is very high, exceeds the quality standard that is 0.008 mg / l and exceeds the tolerance limit of 0.2 mg / l except in Kelapa Dua Island. This excess of nitrate triggers the growth of algae in large quantities. With the growth of these algae, there can be a shortage of oxygen in the water. In the field observations there are many seagrass covered by algae and it is found DCA (Dead Coral Algae) or dead corals that have been overgrown with algae on the coral reef ecosystem. Phosphate content in the waters of the three islands exceeds the standard of quality and the tolerance limit except in some stations that exhibit very small phosphate levels of less than 0.01 mg / l. Phosphate concentrations below 0.03 mg / l can stimulate the growth of phytoplankton, but in larger concentrations can cause algae growth that interfere with the life of phytoplankton in the sea. The content of nitrate and phosphate is opposed to its primary productivity value, but in fact nutrients are one of the main factors affecting the primary productivity of waters. Nitrate and phosphate is a nutrients and used by phytoplankton for its growth process, so with little nutrient content, it can be said that the optimum growth of phytoplankton in the area, so the value of primary productivity is high and vice versa if excess nutrients can trigger the growth of algae interfere with the growth of phytoplankton.

5.6 Relationship between Primary Productivity and Mangrove

Mangrove density is related to primary productivity, as shown in Figure 5.2. It exhibits that the mangrove ecosystem in Kelapa Dua Island and Pari Island in line with its primary productivity value. However, there is a difference on Pramuka Island compared to the other islands, it because primary productivity is closely related to sunlight intensity and at the time of data collection in Pramuka Island, the weather conditions were cloudy and rain, it causing primary productivity decrease due to reduced light intensity and mangrove tree canopy meeting is blocking the light.

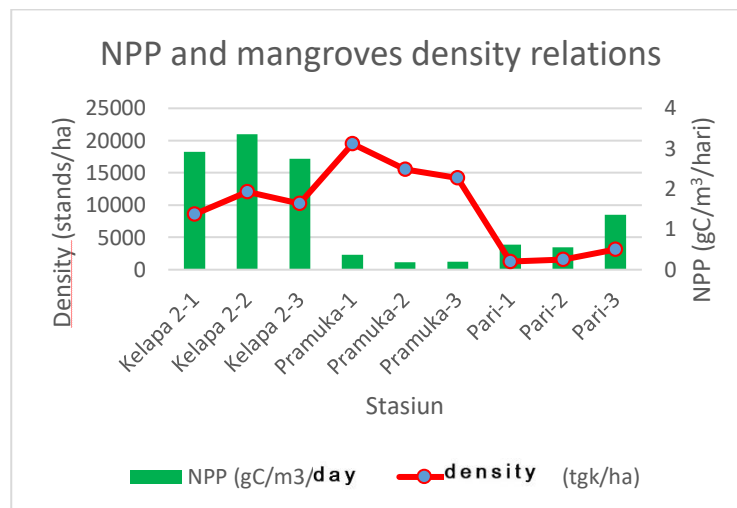


Figure 3. NPP and mangroves density relations

5.7 Relationship between Primary Productivity and Seagrass

According to the obtained data, the higher seagrass density, the higher primary productivity value of the waters. The relationship between primary productivity value and seagrass density is presented in Figure 5.3. Seagrass is a plant that can perform photosynthesis so that the productivity of waters is produced by phytoplankton and is also produced by seagrass. However, the primary productivity value obtained only came from photosynthesis of phytoplankton because the water that incubated in bright and dark bottles did not including seagrasses.

Based on the obtained data, the density of seagrass in Kelapa Dua Island is higher than that of seagrass in Pramuka Island, but its primary productivity is higher in Pramuka Island, this is because the type of seagrass found in Pramuka Island is only one type of *Enhalus acoroides* while in Kelapa Dua Island found more than one type. *Enhalus acoroides* is known to have the highest primary productivity among other seagrass species ^[12]. This causes the primary productivity of seagrass in Pramuka Island is higher than the productivity of seagrass in Kelapa Dua Island.

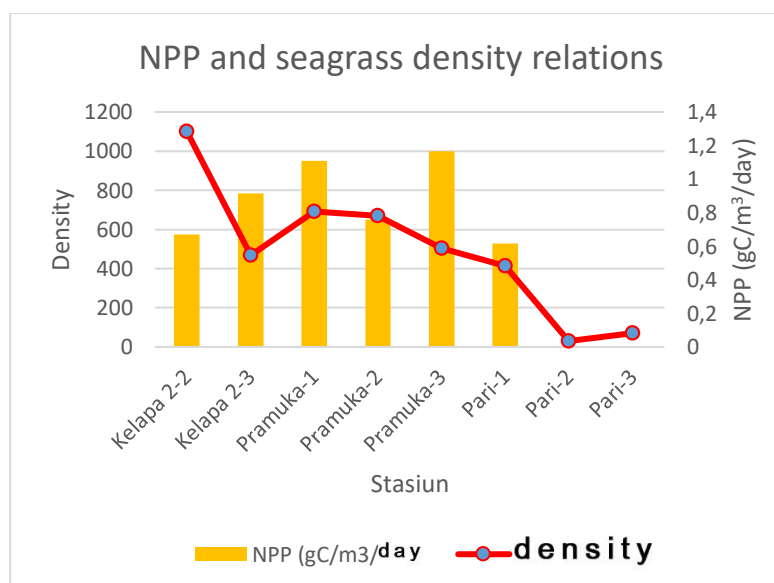


Figure 4. NPP and seagrass density relations

5.8 Relationship between Primary Productivity and coral reefs

According to the obtained data, primary productivity value is closely related to the value of live coral cover in the study sites, as shown in the figure, increase in primary productivity value followed by increase in live coral cover value and also decrease in primary productivity value followed by decrease in live coral cover value. This proves that the high value of primary productivity is influenced by the height of life coral cover and its species diversity ^[10].

The highest primary productivity value of the coral reef ecosystems is found in Pramuka island at station 3, but the highest coral cover is found in Kelapa Dua island at station 3. This is due to the diversity of species diversity, based on visual observation in the field, the diversity of coral lifeform in Pramuka island at station 3 is larger than Kelapa Dua island at station 3.

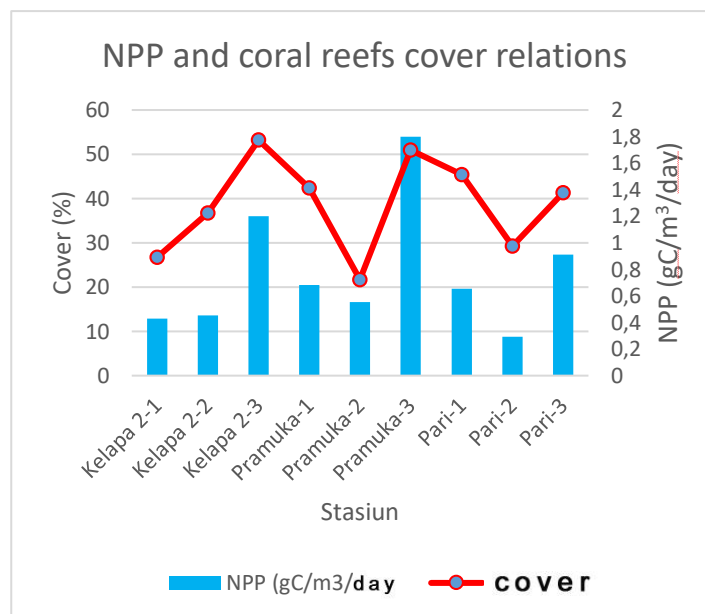


Figure 5. NPP and coral reefs cover relations

6. Conclusion

Based on the results, the research can be concluded as follows: (1) Generally, the condition of coastal ecosystems in Seribu Islands have various conditions, from severely damaged to still in good category. The position of the island from the mainland (Java) is getting much higher primary productivity with the highest in Kelapa Dua island in the range of 3.0062 gC / m³ / day, followed Pramuka Island with a range of 1.01 gC / m³ / day, while The lowest was found on Pari Island with primary productivity values in the range of 0.6 gC / m³ / day. (2) Mangroves at the research sites (Pulau Kelapa Dua, Pulau Pramuka and Pulau Pari) are categorized as good. The best mangrove condition is found in Pramuka Island with the density of 19,500 stands / hectare and the worst condition is found in Pari Island with 1,267 stands / hectare. (3) Seagrass at the research site is categorized as damaged. The best seagrass condition is found in Kelapa Dua Island with a density of 1,099 stands / m², whereas the worst condition is found in Pari Island with a density of 30 stands / m². (4) The best coral reefs found in Kelapa Dua Island with live coral cover reach 53.2% and the heavily damaged category is found in Pramuka Island with live coral cover only 21.7%. (5) Primary productivity in the highest mangrove ecosystem is found in Kelapa Dua Island 2.74 - 3.35 gC / m³ / day and the lowest is in Pramuka Island with primary productivity 0.18 - 0.37 gC / m³ / day. (6) The primary productivity of the highest seagrass ecosystems was found in Pramuka Island with a value of 0.7-1.11 gC / m³ / day and the lowest was in Pari Island with a primary productivity of 0.6 gC / m³ / day. (7) The primary productivity of the highest coral reef ecosystems was found on Pramuka Island in the range of 0.55 - 1.8 gC / m³ / day and the lowest was found on Pari Island with primary productivity of 0.29 to 0.91 gC / m³ / day.

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