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Research Article

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The Prediction of Plankton Diversity and Abundance in Mangrove Ecosystem

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ABSTRACT

The abundance of phytoplankton and zooplankton have correlation with mangrove conditions in coastal area. The mangrove degradation give negative impact for abundance and diversity phytoplankton and zooplankton. The research aimed to analysis and construct prediction model of abundance and biodiversity of phytoplankton and zooplankton in mangrove ecosystem. The research used the transect method (to determine mangrove density), filtering method (to analyze abundance of phytoplankton and zoopankton) and statistical method (to develop estimation modeling of plankton abundance). The results showed that (1) the mangrove density between 250 trees/Ha - 1.250 trees/Ha (2) the phytoplankton abundance were 10.675 ind/L (in mangrove rarely) - 24.290 ind/L (in mangrove high density), (3) the zooplankton abundance were 261 ind/L (in mangrove rarely) - 2.204 ind/L (in mangrove high density) (4) The modelling analysis showed that (1) the phytoplankton abundance (y) = $0.0303x^2 - 22.0590x + 13004$ and (2) the zooplankton abundance (y) = $0.0057x^2 - 5.39x + 1458.2$, with x = mangrove density.

Keywords: phytoplankton and zooplankton, mangrove density, abundance, estuary and lagoon

ABSTRAK

Kelimpahan fitoplankton dan zooplankton diduga memiliki korelasi dengan kondisi mangrove di wilayah pesisir. Sedangkan kerusakan mangrove memiliki dampak negatif bagi kelimpahan dan keanekaragaman hayati dari fitoplankton dan zooplankton. Penelitian ini bertujuan untuk menganalisis dan membangun model prediksi kelimpahan dan keanekragaman hayati dari fitoplankton dan zooplankton. Penelitian ini menggunakan metode transek (untuk menduga kerapatan mangrove), metode penyaringan air (untuk menganalisis kelimpahan fitoplankton dan zooplankton). Hasil penelitian menunjukan bahwa (1) kerapatan mangrove antara 250 pohon/Ha - 1250 pohon/Ha (2) kelimpahan fitoplankton adalah 10.675 ind/L (di mangrove jarang), 24.290 ind/L (di mangrove padat), (3) kelimpahan zooplankton adalah 261 ind/L (di mangrove jarang) - 2.204 ind/L (di mangrove padat) (4) untuk model pendugaan adalah (1) Kelimpahan fitoplankton (y) = $0.0303x^2 - 22.059x + 13004$ dan (2) kelimpahan zooplankton (y) = $0.0057x^2 - 5.39x + 1458.2$, dengan x = kerapatan mangrove.

Kata kunci: fitoplankton dan zooplankton, kepadatan mangrove, kelimpahan, estuari dan laguna

1. Introduction

Mangrove ecosystem is a specific community structure consists species composition, growth structure and productivity (Giesen et al. 2006; Hilmi et al., 2015) and has important function as habitat of plankton and other organisms. The density and abundance of organisms can be used to analysis mangrove sustainability indicator (Ardli & Wolff, 2008; Badola & Hussain, 2005; Hilmi et al., 2017). The basic indicators to show mangrove sustainability are mangrove diversity (Dangan-Galon et al., 2016), vegetation structure (Ardli & Wolff, 2008), ecological stability (Moya et al.,

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2011), mangrove litterfall (Kusmana et al., 2000; Mukherjee & Ray, 2012b), water quality assessment (Bargos et al., 1990) (Bargos et al., 1990; Menteri Negara Lingkungan Hidup, 2004), and mangrove function (Alvarez and Garcia 2003; Ardli et al., 2011; Masagca 2008). Related with phytoplankton and zooplankton, mangrove has specific function as feeding, spawning and nursery ground.

Planktons are aquatic organism with microscopic size and move actively against the sea current (Effendi et al., 2016; Su et al., 2015; Yan et al., 2012). Plankton consists of zooplankton and phytoplankton (Abdulwahab and Rabee 2015; Cairns and Pratt 1993; Effendi et al. 2016; Honggang et al., 2012; Khalifa et al. 2015; Li et al. 2012; Mckinstry and Campbell 2017; Ormanczyk et al., 2017; Pratiwi et al. 2016; Simanjuntak 2009). Phytoplankton is microscopic aquatic plant, while zooplankton is animal (Gharib et al., 2011; Honggang et al., 2012; Khalifa et al., 2015; Pratiwi et al., 2016; Simanjuntak, 2009). The phytoplankton in aquatic ecosystem is the main producer, able to conduct photosynthetic process, producing organic material by converting inorganic nutrient into carbohydrate (Berthold et al. 2018; Roy et al., 2012). Planktonic food web constitutes the base of life in ocean (Yilmaz et al., 2018). The phytoplankton forms as first level in food chain and zooplankton is the second level as primary consumer. As consumer, zooplankton is unable to conduct photosynthesis due to lack of chlorophyll (Li et al., 2012; Masuda et al., 2017).

The phytoplankton and zooplankton need the suitable environment and habitat to support their life. The factors influenced the life of phytoplankton and zooplankton are water quality (TSS, water turbidity, pH, salinity, alkali, ammonia, nitrate, phosphate), and soil properties (Berthold et al., 2018; Menteri Negara Lingkungan Hidup, 2004; Mukherjee & Ray, 2012a; Simanjuntak, 2009). The habitats to support phytoplankton and zooplanktons to life are mangrove ecosystem and lagoon ecosystem.

The mangrove and lagoon ecosystem in Meranti Island have been characterized to support plankton to life and grow including soil and water quality (Alvarez & Garcia, 2003; George et al., 2013; Kusmana et al., 2000). But, the degradation of mangrove and lagoon ecosystem (Ardli et al., 2011) caused loss of abundance and increasing mortality of phytoplankton and zooplankton (Abdulwahab & Rabee, 2015; Khalifa et al., 2015; Pratiwi et al., 2016). The degradation of mangrove ecosystem can be seen from the density and biodiversity of mangrove ecosystem. The degradation of mangrove ecosystem can be assumed give impact for the abundance and biodiversity of plankton. This research aimed to analysis and construct prediction model of abundance and biodiversity of phytoplankton and zooplankton in mangrove ecosystem. This analysis using mangrove density as main factot to analysis abundance and biodiversity of phyto and zooplanktoon.

2. Material and Methods

2.1. Research Site

This research conducted on mangrove and lagoon ecosystem in Meranti Regency with geographical coordínate between 100º 52'- 102º 10' E and 2º 3' - 0º 17' N (Figure 1). The site research divides three stations (islands) were Merbau Island (Station 1), Rangsang Island (station 2), and Tebing Tinggi Island (Station 3).

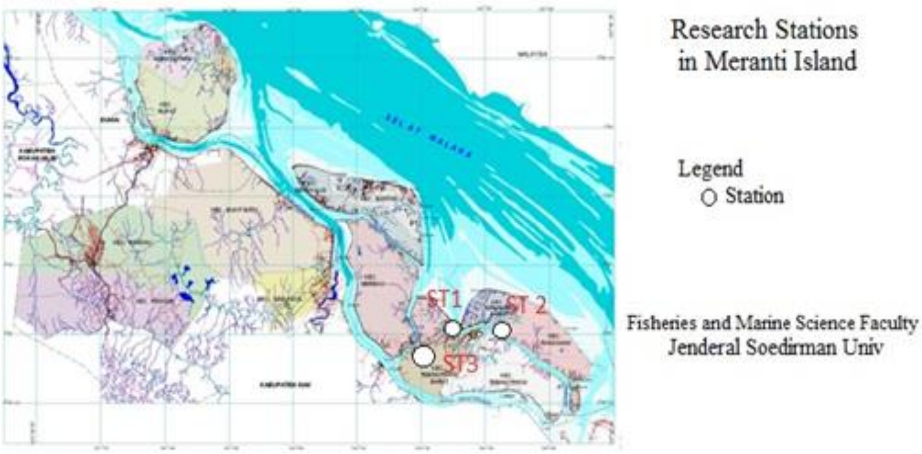

Figure 1. The Site Research

2.2. Research Method

Research Variable

The research variables were mangrove density, the abundance of phytoplankton and zooplankton, the soil properties and the water quality.

The mangrove density

The method of mangrove density used transects method (Hilmi et al. 2017; Kusmana 1997). The mangrove density used equation was Di = $\frac{\sum xij}{ni}$ (mangrove ha^{-1}), note = Di is density of mangrove in station -i, xij is density of mangrove species -j, station i, and ni is station -i.

The soil properties

The soil properties method used Bored method and the laboratory analysis (Table 1). The variables of soil properties were pH, C organic, total N, Na, P, K, Ca, Mg, texture and salinity.

The water quality

The method of water quality used laboratory analysis. The variables of water quality were Total suspended solid, water turbidity, pH, salinity, alkali, ammonia, nitrate, and phosphate (Table 2).

The abundance of plankton

To measure plankton abundance used filtering sample method followed density equation (Honggang et al., 2012; Khalifa et al., 2015; Mckinstry & Campbell, 2017; Ormanczyk et al., 2017; Pratiwi et al., 2016)

$$N = \frac{(ax20)x\ c}{L}$$

Notes that are N: plankton dense, a: average of plankton in 1 ml of water (equal 20 water pipe), c: volume of water (ml), and L: volume of water were filtered (lt)

The biodiversity of plankton

The biodiversity index to analyze plankton are heterogeneity and evenness. The heterogeneity used Shannon Wiener with equation $(H') = \sum_{i=1}^{s}(pi)Ln\,(pi)$, where s = number of species, pi = proportion of species density. The evenness used equation = (exp (H'))/s. (Magurran, 1996)

2.3. Data Analysis

The data analysis used descriptive comparative (graph's and tables) with the reference from (Abdulwahab & Rabee, 2015; Honggang et al., 2012; Khalifa et al., 2015; Menteri Negara Lingkungan Hidup, 2004; Pratiwi et al., 2016) and develop the relation model between abundance of phytoplankton and zooplankton with mangrove density.

3. Results and Discussion

3.1. The mangrove density

The mangrove density in Meranti Island was dominated by *Avicennia* spp, *Rhizophora* spp, and *Sonneratia* spp (Table 3). The data showed the influencing of mangrove distribution to support plankton life and grow. The presence of phytoplankton and suspended microphytobenthos in lagoon are influenced by the water column (Tsuji & Montani, 2017) the existence of mangrove ecosystem, and presence of the major species and dominant species (Hilmi, 2018; Hilmi et al., 2017; Kusmana et al., 2000, 2005; Mukherjee & Ray,

Table 1. The Soil Properties Method

Variables	Unit	Method	Reference
Soil pH	-	Potensiometric/pH meter	APHA, 2005 and 2012
Soil texture	%	*Gravimetric*	APHA, 2005 and 2012
Nitrate (NO_3)	%	*Brucine*	Soil research dept, 2005
Phosphate (PO_4)	%	ascorbic acid	APHA, 2005 and 2012
C organic	%	Walkey and Black	Soil research dept, 2005

Table 2. The Water Quality Method

No	Variables	Unit	Method
Physic			
1.	TSS	mg/l	APHA,20th.1998 2542-D /Gravimetri
2.	Water Turbidity	NTU	APHA,20th.1998 2130-B /Turbidimeter
Chemical			
1.	pH	-	APHA,20th.1998 450-H^+/pH meter
2.	Salinity	$^0/_{00}$	APHA,20th.1998 2520-B /handrefractometer
3.	Alkalinity	mg$CaCO_3$/l	APHA,20th.1998 2320-B / Titrimetrik
4.	Ammonia (NH3+NH4)	mg/l	APHA,20th.1998 4500-F /Phenate/ Spectrophotometer
5.	Nitrite (NO_2-N)	mg/l	APHA ed,20th.1998 4500-B /sulfinik/ Spectrophotometer
6.	Nitrate (NO_3-N)	mg/l	APHA ed,14th.1998 4500-B /BrusinSulfat/ Spectrophotometer
7.	Phospate	mg/l	APHA,20th.1998 4500-P-E /Ascorbi acid/ Spectrophotometer

2012a). The landscaping and domination species (Hilmi, 2018) of mangrove ecosystem is influenced by soil properties and water quality. The mangrove density in Meranti Island had three grade that were mangrove rare (25 - 50 trees ha^{-1}) (Station 2), moderate (525-650 tress ha^{-1}) (station 1) and dense (900 - 1300 trees ha^{-1}) (station 3). But, based on Kusmana et al. (2005), Menteri Negara Lingkungan Hidup, (2004) and Ardli and Wolff (2008) note that the mangrove in Meranti Island can be categorized as mangrove rare - moderate.

Based on land cover, density of trees, abrasion, sedimentation (Sari et al., 2016; Syakti et al., 2013), abrasion and intrusion (Hilmi, 2018; Hilmi et al., 2017), the mangrove density in Meranti Island had category as the mangrove degradationn, especially station 2 (rare and high degradation). The mangrove degradation in Meranti Island could be caused by (1) the exploitation of commercial mangrove like as *Rhizophora* spp and *Bruguiera* spp. (2) illegal logging of mangrove to support the house building. (3) Over exploitation to support activity of charcoal, pulp and paper. (4) The social opinion of low value of mangrove ecosystem can accelerate degradation of mangrove ecosystem and conversion of mangrove in Meranti Island (Hilmi et al., 2017). Hilmi et al. (2019) and Sari et al. (2016) emphasis that the degradation of mangrove ecosystem also was caused by the decreasing of total economic value from mangrove ecosystem. The degradation of mangrove ecosystem decrease supporting of spawning, feeding and nursery ground for phytoplankton and zooplankton (Cadier et al., 2016; Kruk et al., 2016; Masuda et al., 2017), loosing of the phytoplankton and zooplankton habitat's.

3.2. Soil properties

The soil texture, pH, C- organic, N-Organic, P, Ca, Mg, K, Na, and soil salinity (Ashton & Macintosh, 2002; J. G. Kairo et al., 2001; James G. Kairo et al., 2008; Macintosh et al., 2002) have function to support mangrove grow. The soil properties of mangrove ecosystem in Meranti Island were showed by Table 4. The soil properties also were used to find level of fertilize of mangrove ecosystem and classification of soil properties to support mangrove life, phytoplankton and zooplankton growth.

The soil properties in mangrove ecosystem both of (a) chemical properties were pH, C organic N total, capacity of soil cation exchange (CEC), soil fertility matter (P, Ca, Mg, K, Na), soil salinity and (b) physical properties was soil texture can be shown on Table 4. The data of soil properties showed that mangrove ecosystem in Meranti Island had soil properties that were acid - very acid, highest of C organic, N matter moderate, the soil fertility matter like as phosphate and calcium were low, magnesium, potassium, and sodium were highest. The other soil properties were capacity of soil cation exchange was moderate, and salinity was moderate. Based on data suggested that the soil properties in Meranti Island can be categorized good suitable to support mangrove grow (Ashton & Macintosh, 2002; James G. Kairo et al., 2008; Ragavan et al., 2014). Kusmana et al. (2005), Ragavan et al. (2014), Kairo et al. (2001) write that the environment suitability to support mangrove grow are salinity < 30 ppt, pH acid - neutral, soil texture between clay - sandy clay - loam.

Kantharajan et al. (2018), Kusmana et al. (2005) and Truong, Ye, and Stive (2017) write mangrove need supporting of soil fertilizer like as C- organic, N- Organic, P, Ca, Mg, K and Na to grow. But mangrove ecosystem also could support to increase soil fertilizer by leaves, fruit, flower and stem decomposition. The supporting of mangrove ecosystem with decomposition gives positive impact for soil

Table 3. The mangrove density in Meranti Island Regency

Sample Plot	Location	Species	Growth stage: Trees (ind/Ha)	Sapling (ind/Ha)	Seedling (ind/Ha)	Categorized
Station 1	Merbau Island	*Avicennia alba*	500 - 625	4,000	25,000	Rare- Moderate (moderate degradation)
		Sonneratia alba	25 - 50			
Station 2	Rangsang Island	*Avicennia alba*	25			rare (High degradation)
		Sonneratia alba	25			
Station 3	Tebing Tinggi Island	*Avicennia alba*	750 - 1,125	8,000	25,000	Moderate-dense (low degradation)
		Sonneratia alba	25 - 50			
		Xylocarpusgranatum	25			
		Rhizophoramucronata	25 - 50			
		Rhizophoraapiculata	25 - 50			

Table 4. Soil properties of Mangrove Ecosystem in Meranti Island

Station	pH (H_2O)	C org (%)	N total (%)	P	Ca	Mg	K	Na	CEC	texture			Salinty µs/cm
				Me 100 gr						sand	dust	clay	
Station 1 (merbau)	5.0	6.00	0.26	6.1	4.01	10.21	1.02	6.01	27.40	5.72	26.57	67.71	8.93
Station 2 (rangsang)	5.4	5.5	0.24	7.2	3.9	8.18	0.75	5.64	26.58	3.44	44.22	52.34	9.23
Station 3 (Tebing Tinggi)	4.5	6.13	0.28	5.8	4.11	11.62	1.15	6.60	29.26	6.78	25.51	67.71	8.71

Soil Standard

Soil properties	Unit	Lowest	Low	Moderate	High	Highest
C	%	<1.00	1 - 2	2.01- 3.00	3.01 - 5.00	> 5.00
N	%	<0.1	0.1	0.2 - 0.5	0.51 - 0.75	>0.75
P_2O_5HCl	mg/100 gr	<10	10 - 20	21 - 40	41 - 60	>60
CEC	me/100 gr	<5	5 - 16	17 - 24	25 - 40	>40
K	me/100 gr	<0.1	0.1 - 0.2	0.3 - 0.5	0.6 - 1.0	>1.0
Na	me/100 gr	<0.1	0.1 - 0.3	0.4 - 0.7	0.8 - 1.0	>1.0
Mg	me/100 gr	<0.4	0.4 - 1.0	1.1 - 2.0	2.1 - 8.0	>8.0
Ca	me/100 gr	<2	2 - 5	6 - 10	11 - 20	>20
pH	-	<4.5 (very acid)	4.5 - 5.5 (acid)	5.6 - 6.5 (moderate acid)	6.6 - 7.5 (netral)	7.6 - 8.5 (Alkali)

fertilizer. The potential of soil fertilizer in Meranti Island Regency (like as Mg, K, Na, CEC, C organic) showed moderate - high potential. The potential of soil fertilizer will influence to increase mangrove growth including for seedling, sapling and mangrove trees. The soil properties in Meranti Island Regency give the important role for nutrient cycle process in a lagoon and estuary ecosystem to support existence of plankton, zooplankton and benthos as key players of organic nutrient cycling in coastal regions. For example is *Arcuatula senhousia* (Takenaka et al., 2018) need supporting of C- organic, N-Organic, P, Ca, from decomposition of mangrove leaves, stem and others.

3.3. Water quality

The data of water quality in Meranti Island Regency (Table 5) showed the performs of lagoon ecosystem to support phytoplankton and zooplankton life. Abdulwahab and Rabee (2015) and Hilmi, Sari, and Setijanto (2019) write that the main variables of water quality have high correlation with plankton are water temperature, pH, EC, turbidity, TDS, DO, BOD$_5$, total hardness, Ca^{+2}, Mg^{+2}, chloride, nitrate and reactive phosphate. Bagheri, Turkoglu, and Abedini (2014) writes that the potential of water quality in Ye-ihrmak Rivers to support phytoplankton are temporal surface temperature had variation between 8.80 and 28.6°C with the annual average temperature was 18.1±7.07 °C. Salinity variations, varied between 7.33 and 12.7 psu, the annual average surface salinity in 2003 was 11.3±0.63 psu.

The data on Table 5 also showed that the water qualities of estuary and lagoon ecosystems in Meranti Island Regency were influenced by mangrove density. The mangrove ecosystem decreasing of water turbidity (from 140 NTU to 25 NTU) and total solid suspended (from 512 mg/l to 244 mg/lt), increasing of pH for aquatic ecosystem (from pH 5,73 (acid) to 7,25 (alkaline). The potential of water salinity in Meranti Island Regency had good suitability to support life of zooplankton and phytoplankton. The other properties of water quality were the decreasing of alkalinities (the mangrove rare to mangrove dense), but mangrove didn't give impact for the potential of nitrate and phosphate.

The Phosphate and nitrogen are essential of an organic matter to support growth and life stage of phytoplankton. The high potential of nutrient matter in aquatic ecosystem will increase the plankton density. MENLH (2004) write the standard value of phosphate is 0.015 mg/l or 0.465 µg A/l, nitrate is 0.008 mg/l or 0.112 µg A/l (0.49-1.07 µg A/l or 0.007-0.015) and the standard of Ammonia is not more than 0.42 ppm - 0.3 mg/l or 4.20 µg A/l.

Table 5. The water quality of estuary ecosystem in Meranti Island.

Variables	Unit	Study area I (Merbau)	II (Rangsang)	III (Tebing Tinggi)	Method
Physic					
TSS	mg/l	284	512	244	APHA,20th.1998 2542-D /Gravimetri
Water turbidity	NTU	58	140	25	APHA,20th.1998 2130-B /Turbidimeter
Chemical					
pH	-	7.28	7.25	5.73	APHA,20th.1998 450-H^+/pH meter
Saliniy	$^0/_{00}$	29	26	20	APHA,20th.1998 2520-B /handrefractometer
Alkalinity	$mgCaCO_3/l$	100.00	90.00	24.00	APHA,20th.1998 2320-B / Titrimetrik
Ammonia ($NH_3{}^+NH_4$)	mg/l	0.498	0.514	0.577	APHA,20th.1998 4500-F /Phenate/ Spectrofotometer
Nitrite ($NO_2{}^-N$)	mg/l	0.003	0.052	0.043	APHA,20th.1998 4500-B /sulfinik/ Spectrofotometer
Nitrate ($NO_3{}^-N$)	mg/l	0.038	0.179	0.181	APHA,14th.1998 4500-B /Brusin Sulfat/ Spectrofotometer
Phosphate	mg/l	0.100	0.074	0.061	APHA,20th.1998 4500-P-E /Ascorbi acid/ Spectrofotometer

The other properties of water quality are pH and dissolve oxygen. The potential pH to support plankton, fish and aquatic organism in brackish water is 5 - 9 (Menteri Negara Lingkungan Hidup, 2004). The potential of dissolve oxygen is 2 - 10 ppm or less than 2 ppm (Simanjuntak, 2009). Basicaly the nutrient matter in aquatic ecosystem to support plankton growth correlated with water drainage and the potential of water pollution (Simanjuntak, 2009).

George et al., (2013) also writes that the mangrove ecosystem as mixing of fresh water with marine water has temperature variation between 22-33.2 ^oC, pH between 7.8 to 8.3, dissolved oxygen has the range of 0.1 mg L^{-1} - 12.3 mg L^{-1}, salinity between 1.2-31.5 ppt, and ammoniacal nitrogen between 0.001 - 0.744 mg L^{-1}. According Yan et al., (2012) write that salinity (S), pH, chemical oxygen demand (COD), and nitrite (NO_2 -N) were importantly environmental factors influencing the distribution of phytoplankton community. Li et al. (2012) also emphasize that excess nitrogen (N) and phosphorus (P) being primarily responsible for fueling primary production and excessive organic matter accumulation.

The decomposition and remineralization of mangrove detritus is important in nutrient dynamics (Roy et al., 2012) which will increase the water fertilization in mangrove ecosystem. Decomposition and remineralization supply detritus and nutrient through leaching and break down of leaf litter into the adjacent estuary and thus regulates the productivity (Roy et al., 2012). Mukherjee & Ray, (2012b) write that cycling of carbon and nutrients in forest ecosystems shows the forward litter decomposition process. Highly productive mangrove ecosystems (approx. productivity 2500 mg C m^{-2} day^{-1}) shows mangrove ecosystem as source of nutrients. Litter fall is one of the driving forces and the main energy source in this system. Mangrove litter undergoes first degradation and then decomposition into dissolved inorganic nutrients, which are important for growth of phytoplankton. Berthold et al., (2018) also write that pphosphorus supports primary production in the water column and can elevate phytoplankton and macrophyte growth.

3.4. The abundance and diversity of phytoplankton

The abundance and diversity of phytoplankton in Meranti Island Regency were shown on Table 6. A lagoon and Estuary in Meranti Island Regency are the important ecosystem to support ecological processes and has functionally linked terrestrial, freshwater, and marine ecosystems (Yamamoto et al., 2018), including as aquatic organism habitat. The phytoplankton is an aquatic organism which has ability to do photosintetic activity as the plant organism with size between 2 - 200 µm (Effendi et al., 2016; Su et al., 2015). Phytoplankton has the main contributor to spatial increases in total cell abundance in mesohaline water as a result of the lake's hydrographic characteristics and water quality (Tsuji & Montani, 2017). Phytoplankton as great importance role to

Table 6. The Abundance and Diversity of Phytoplankton in Meranti Island

Organism	Station		
	I	II	III
CYANOPHYCEAE (ind/L)			
Trichodesmium	8,7	5,8	464
BACILLARIOPHYCEAE (ind/L)			
Steptotheca sp.	2552	2871	3944
Nitzschia sp.	2204	1044	2517
Chaetoceros sp.	1189	435	1148
Bachteriasum sp.	58	0	928
Bacillaria sp.	1218	551	3109
Thalassionema sp.	29	29	348
Thalassiothrix sp.	0	0	1276
Thalassiosira sp.	348	3190	0
Rhizosolenia sp.	435	87	928
Biddulphia sp.	377	29	1740
Ditylum sp.	29	0	928
Pleurosigma sp.	174	203	2436
Skeletonema sp.	1566	3161	580
Coscinodiscus sp.	87	58	0
Bellerocheaa sp.	203	232	0
Cyclotella sp.	0	29	2668
Leptocylindrus sp.	0	0	580
Asterionella sp.	0	0	116
Navicula sp	0	0	0
Amphora sp.	2900	0	580
Lauderia sp.	0	0	0
DINOPYCEAE (ind/L)			
Peridinium sp.	8,700	0	0
Number of taxa	17	14	18
Density (ind/L)	10672	11977	24290
Heterogenity index	2.14	1.75	1.91
Evennes index	0.75	0.66	0.66
Domination index	0.15	0.24	0.20

drive the transportation activity of surface organic carbon in the coastal, lagoon and mangrove ecosystem are either consumed by detrital feeders or deposited and stored in the sediment (Yilmaz et al., 2018).

The potential of phytoplankton in Meranti Island Regency (Table 6) can be shown as the abundance, number of taxa, biodiversity index, dissimilarity index and domination index. The species compositions and community structures of halophytic plants, gastropods, and brachyurans in lagoon have the important role to reach sustainability of lagoon ecosystem (Henmi et al., 2017). The data on Table 5 explained that potential of phytoplankton in mangrove ecosystem were dominated by 1) Cyanophyceae that is *Trichodesmium* spp (2) Bacillariophyceae, that are *Steptotheca* sp, *Nitzschia* sp., *Chaetoceros* sp., *Bachteriasum* sp., *Bacillaria* sp., *Thalassionema* sp., *Thalassiothrix* sp., *Thalassiosira* sp., *Rhizosolenia* sp., *Biddulphia* sp., *Ditylum* sp., *Pleurosigma* sp., *Skeletonema* sp., *Coscinodiscus* sp., *Bellerocheaa* sp., *Cyclotella* sp., *Leptocylindrus* sp., *Asterionella* sp., *Navicula* sp., *Amphora* sp., *Lauderia* sp., (3) Dinopyceae that is Peridinium sp. Yilmaz et al., (2018) writes that Western Artic Peninsula and Galindez Islan have 50 phytoplankton that are *Chaetoceros atlanticus, Corethron pennatum, Coscinodiscus radiatus, Odontella aurita, O. weissflogii, Cocconeis britannica, Entemoneis alata, Membraneis challengeri, Nitzschia bilobata, Plagiotropis gaussii* from diatoms; *Prorocentrum micans* from dinoflagellates; *Dictyocha antarctica* and *D. speculum* from silicoflagellates). Onyema (2007) find in a Polluted Estuarine Creek in Lagos, Nigeria has 48 taxa from 26 genera and 3 classes namely Bacillariophyceae (37 taxa), Cyanophyceae (10 taxa), and Shizomycetes (1 taxon). And Soylu & Gönülol, (2003) write 47 taxa was found in the plankton of the River Yeilırmak divided into Bacillariophyta (31 taxa), Euglenophyta (6 taxa), Cyanoprokaryota (6 taxa) and Chlorophyta (4 taxa).

Based on data's showed that the station 2 had lowest relatively of number of taxa, pytoplanton dense and a heteronegnity. The station 2 representative of mangrove rare showed the low of mangrove dense give negative impact for the potential of phytoplanton (Kruk et al., 2016; Su et al., 2015), because the mangrove density will support the potential of nutrient matter especially phospate and nitrate were essential nutrient matter for phytoplankton to grow up (Berthold et al., 2018; Su et al., 2015). The primary factors controlling coastal phytoplankton distribution and growth are surface temperature, turbidity, river nutrient loads, and benthic and pelagic consumers (Su et al., 2015).

The data also showed that the number taxa of phytoplankton between 14 - 18 taxa's with density between 10,672-24,290 indi/L, heterogeneity index between 1.75 - 2.14 and evenness index between 0.66 - 0.75. Gharib et al., (2011) observe 203 phytoplankton species which are influenced by marine environments, biotic and abiotic environmental factors give important effects for phytoplankton succession and abundance. Yan et al., (2012) note that in Xiaoqing River estuary has abundance of phytoplankton range from 0.6×104 to 213.30 ×104 cells.m^{-3} with species dominant are *Skeletonema costatum*, *Tribonema affine*, and *Chlorella* sp. Gharib et al., (2011) also noted that south-eastern Mediterranean Sea, Egypt is dominated by Bacillariophyta (61 genera, 120 species), Pyrrophyta (22 genera, 52 species) and in the freshwater ecosystem is dominated by Cyanophyta, Chlorophyta and Euglenophyta. In Southern Kyushu is dominated by *Batillaria multiformis* and *B. Attramentaria* (Yamamoto et al., 2018). Kruk et al., (2016) also note that the dominant taxa are Cyanoprokaryota, Bacillariophyta and Chlorophyta is lower than mangrove ecosystem in Meranti Island Regency. But, potential of phytoplankton taxa dominant in Meranti Island Regency is lower than Mahakam Delta which has 48 taxa phytoplankton belonging to Bacillariophyceae (35), Dinophyceae (6), Chlorophyceae (4), and Cyanophyceae (3). Tsuji & Montani, (2017) reported that the dominant suspended microphytobenthostaxa (*Cocconeis* spp. and *Melosira varians*) were mainly distributed in oligo- and mesohaline water, with peaks in mesohaline bottom water. In contrast, the dominant phytoplankton taxa (*Skeletonema* spp., *Heterocapsa triquetra*, and *Prorocentrum* spp.) were abundant at different salinity levels.

Basically, the abundance and diversity phytoplankton also can be used as the indicator of the density status of mangrove. The abundance and diversity of phytoplankton in station 2 (indicated as mangrove rare) lower than station 1 (moderate dense of mangrove) and station 3 (mangrove dense). This data showed that the mangrove density gave positive impact for the abundance and diversity of phytoplankton. The mangrove density will increase the abundance, the potential taxa and the density of phytoplankton.

The data also showed that the potential of phytoplankton in Meranti Island Regency had high relatively dense. The high density, abundance and number of taxa of phytoplankton in Meranti Island Regency indicated good condition of aquatic ecosystem in Meranti Island Regency. The water quality has positive correlation with potential of phytoplankton (George et al., 2013; Masuda et al., 2017; Su et al., 2015). The aquatic ecosystem in Meranti Island Regency had good water quality to aid growth of phytoplankton.

3.5. The abundance and diversity of zooplankton

Zooplankton is a type of plankton which has characteristic as animal using the coastal, lagoon and Estuary area as suitable habitat of zooplankton including copepoda as a micro crustcea dominanted in the brackish ecosystem, sea or ocean (Kitamura et al., 2017; Mckinstry & Campbell, 2017; Ormanczyk et al., 2017). Zooplankton also has the important role of aquatic ecosystems and Estuaries areas (Honggang et al., 2012). The abundance and diversity of zooplankton bot of the number, domination index, heterogeneity index and evenness index of zooplankton in Meranti Island Regency were shown on Table 7.

The data explained that potential of zooplankton in Meranti Island Regency was dominated by Protozoa (*Tintinnopsis* sp, and *Favella* sp), (2) Crustaceae (*Nauplius* (stasia), *Oithona* sp., *Euterpina* sp., *Eucalanus* sp., and *Paracalanus* sp.,) and (3) Larva of Polychaeta. The total taxa of zooplankton between 3 - 7, the density between 261 - 2204 ind/L, with heterogenity between 0.86 - 1.61, evennes between 0.79 - 0.83. Mckinstry & Campbell, (2017) collected 188 species of zooplankton in Alaska with *Oithona similis*, *Limacina helicina*, *Pseudocalanus* spp., and

Table 7. The abundance and diversity of zooplankton in Meranti Island

Organism	Station		
	I	II	III
PROTOZOA (ind/L)			
Tintinnopsis sp.	29	0	232
Favella sp.	29	261	348
CRUSTACEAE (ind/L)			
Nauplius (stasia)	29	174	870
Oithona sp.	145	29	464
Euterpina sp.	0	0	174
Eucalanus sp.	0	0	87
Paracalanus sp.	0	0	29
LARVA OF POLYCHAETA (sp.1)	29	0	0
Number of taxa	5	3	7
density (ind/L)	261	464	2204
Heterogenity index	1.30	0.86	1.61
Evennes index	0.81	0.79	0.83
Domination index	0.36	0.46	0.24

Acartia longiremis as dominant zooplankton. The dominants taxa are *Oithona similis*, *Pseudocalanus* spp., *Limacina helicina*, and *Acartia longiremis*. (Ormanczyk et al., (2017) emphasize that The zooplankton stock in atlantic has average 524,878 ind.m^{-2} (range: 428,700 - 596,600 ind.m^{-2}). Whereas, zooplankton in Lake Nasser namely Copepoda, Cladocera and Rotifera and Protozoa (Khalifa et al., 2015).

Pratiwi et al., (2016) write that zooplankton community in Tangerang coastal has 12 groups of zooplankton that are Protozoa (2 genera) Rotifera (3 genera), Crustacea (5 genera and nauplius stage), Ctenophora (1 genus), Chaetognata (1 genus), Urochordata (3 genera) with abundance is 2,894,149 ind.m^{-3}. Gülle et al., (2010) shows that the Lake Burdur has Six zooplankton taxa were determined, *Hexarthra fennica*, *Brachionus plicatilis* from Rotifera and *Arctodiaptomus burduricus* from Copepoda were the dominant species. Average zooplankton density was 399,074 ind.m^{-3} and they were 51% *H. fennica*, 9% *B. plicatilis* and 40% *A. burduricus* (Gülle et al., 2010). The potential of zooplankton was influenced by response of surrounds river mouth, organic matter and nutrient, and mangrove ecosystem. The number of zooplankton had positive correlation with mangrove density. The data on Table 7 showed that the mangrove dense had number taxa, density, heterogenity more than mangrove rare. This data show that mangrove ecosystem is a suitable habitat to support growth of zooplankton as nursery ground, feeding ground and spawning ground.

3.6. The model prediction of potential zooplankton and phytoplankton

The model prediction of potential zooplankton and phytoplankton used correlation between mangrove density as independent variable (X) with the potential of phytoplankton (Figure 2) and zooplankton (Figure 3) as dependent variable (Y). The model prediction of phytoplankton was the abundance of phytoplankton, $y = 0.0303x^2 - 22.059x + 13004$ (polynomial equation) and $y = 11.637x + 8955.1$ (linier equation). The model of zooplankton was the abundance of zooplankton, $y = 0.0057x^2 - 5.3921x + 1458.2$ (polynomial equation) and $y = 2.2235x - 450.38$ (linier equation).

4. Conclusions

Mangrove ecosystem in Meranti Island Regency has categorized rare - moderate have influence for abundance and diversity of phytoplankton and zooplankton. The number taxa of phytoplankton between 14 - 18 taxa's, density between 910,600 - 10,846,000 ind sample^{-1}, heterogenity index between 1.75 - 2.14 and evennes index between 0.66 - 0.75. The total taxa of zooplankton between 3 - 7, the density between 2610 - 22040 ind/sample, with heterogenity between 0.86 - 1.61, evennes between 0.79 - 0.83. The grade of mangrove density gives the different potential of zooplankton and phytoplankton.

The best model to estimate plankton and zooplanton are abundance with mangrove trees density are the abundance of phytoplankton, $y = 0.0303x^2 - 22.059x + 13004$ and the abundance of zooplankton, $y = 0.0057x^2 - 5.3921x + 1458.2$.

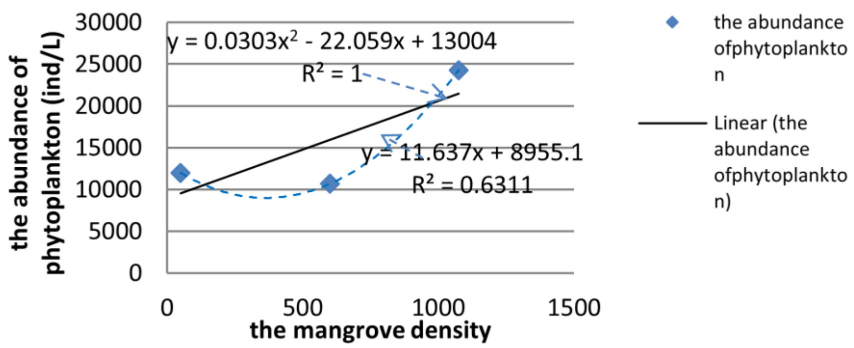

Figure 2. The Relation Between Mangrove Density and Phytoplankton Abundance

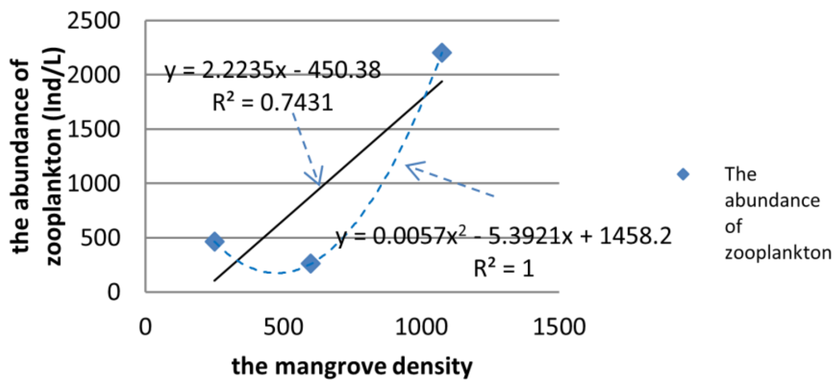

Figure 3. The Relation Between Mangrove Density and Zooplankton Abundance

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References

Abdulwahab, S., & Rabee, A. M. 2015. Ecological factors affecting the distribution of the zooplankton community in the Tigris River at Baghdad region , Iraq. The Egyptian Journal of Aquatic Research 41(2): 187-196.

Alvarez, R. ., & Garcia, I. H. 2003. Biodiversity Associated with Mangroves in Colombia Biodiversity Associated with Mangroves. ISME/Glomis Electronic Journall 3(1).

Ardli, E. ., & Wolff, M. 2008. Quantifying Habitat and Resource Use Changes in the Segara Anakan Lagoon (Cilacap, Indonesia) over the Past 25 Years (1978-2004). Asian Journal of Water, Environment and Pollution 5(4): 59-67.

Ardli, E. R., Yani, E., & Widyastuti, A. 2011. Density and spatial distribution of Derris trifoliata Lour and Acanthus ilicifolius as a biomonitoring agent of mangrove damages at the Segara Anakan lagoon (Cilacap, Indonesia). In The 2nd International Workshop for Conservation Genetics of Mangroves' on: 19-20.

Ashton, E. C., & Macintosh, D. J. 2002. Preliminary assessment of the plant diversity and community ecology of the Sematan mangrove forest, Sarawak, Malaysia. Forest Ecology and Management 166(1-3): 111-129.

Badola, R., & Hussain, S. 2005. Valuing ecosystem functions : an empirical study on the storm protection function of Bhitarkanika mangrove ecosystem , India. Environmental Conservation 32(1): 85-92.

Bagheri, S., Turkoglu, M., & Abedini, A. 2014. Phytoplankton and Nutrient Variations in the Iranian Waters of the Caspian Sea (Guilan region) during 2003-2004. Turkish Journal of Fisheries and Aquatic Sciences 14: 231-245.

Bargos, T., Mesanza, J., Basaguren, M. An., & Orive, E. 1990. Assessing River Water Quality By Means Of. Wat. Res. 24(1): 1-10.

Berthold, M., Karstens, S., Buczko, U., & Schumann, R. 2018. Science of the Total Environment Potential export of soluble reactive phosphorus from a coastal wetland in a cold-temperate lagoon system : Buffer capacities of macrophytes and impact on phytoplankton. Science of the Total Environment 616-617: 46-54.

Cadier, M., Gorgues, T., Sourisseau, M., Christopher, A., Aumont, O., Mari, L., & Memery, L. 2016. Assessing spatial and temporal variability of phytoplankton communities' composition in the Iroise Sea ecosystem (Brittany, France): A 3D modeling approach. Part 1: Biophysical control over plankton functional types succession and distribution. Journal of Marine Systems 165: 47-68.

Cairns, J., & Pratt, J. R. 1993. A history of biological monitoring using benthic macroinvertebrates. Freshwater Biomonitoring and Benthic Macroinvertebrates, 10-27.

Dangan-Galon, F., Dolorosa, R. G., Sespeñe, J. S., & Mendoza, N. I. 2016. Diversity and structural complexity of mangrove forest along Puerto Princesa Bay, Palawan Island, Philippines. Journal of Marine and Island Cultures 5(2): 118-125.

Effendi, H., Kawaroe, M., Fauzia, D., & Permadi, T. 2016. Distribution of phytoplankton diversity and abundance in Mahakam. Procedia Environmental Sciences 33: 496-504.

George, B., Kumar, J. I. N., & Kumar, R. N. 2013. Study on the influence of hydro-chemical parameters on phytoplankton distribution along Tapi estuarine area of Gulf of Khambhat , India. The Egyptian Journal of Aquatic Research 38(3): 157-170.

Gharib, S. M., El-sherif, Z. M., Abdel-halim, A. M., & Radwan, A. A. 2011. Phytoplankton and environmental variables as a water quality indicator for the beaches at Mediterranean Sea, Egypt : an assessment. Oceanologia 53(3): 819-836.

Giesen, W., Wulffraat, S., Max, Z., & Scholten, L. 2006. M Angrove Guidebook For Southeast Asia (L. Dharmasarn Co. (Ed.)). FAO and Wetlands International.

Gülle, I., Turna, I. I., Güçlü, S. S., Gülle, P., & Güçlü, Z. 2010. Zooplankton Seasonal Abundance and Vertical Distribution of Highly Alkaline Lake Burdur , Turkey. Turkish Journal of Fisheries and Aquatic Sciences 254: 245-254.

Henmi, Y., Fuchimoto, D., Kasahara, Y., & Shimanaga, M. 2017. Community structures of halophytic plants, gastropods and brachyurans in salt marshes in Ariake and Yatsushiro seas of Japan. Plankton and Benthos Research 12(4): 224-237.

Hilmi, E. 2018. Mangrove landscaping using the modulus of elasticity and rupture properties to reduce coastal disaster risk. Ocean and Coastal Management, 165: 71-79.

Hilmi, E., Kusmana, C., Suhendang, E., & Iskandar. 2017. Correlation Analysis Between Seawater Intrusion and Mangrove Greenbelt. Indonesian Journal of Forestry Research 4(2): 151-168.

Hilmi, E., Pareng, R., Vikaliana, R., Kusmana, C., Iskandar, Sari, L. K., & Setijanto. 2017. The carbon conservation of mangrove ecosystem applied REDD program. Regional Studies in Marine Science 16: 152-161.

Hilmi, E., Sari, L. K., Cahyo, T. N., Kusmana, C., & Suhendang, E. 2019. Carbon sequestration of mangrove eosystem in Segara Anakan Lagoon, Indonesia. BIOTROPIA : The Southeast Asian Journal of Tropical Biology 26(3): 181-190.

Hilmi, E., Sari, L. K., & Setijanto. 2019. The mangrove landscaping based on Water Quality: (Case Study in Segara Anakan Lagoon and Meranti Island). IOP Conference Series: Earth and Environmental Science 255(1).

Hilmi, E., Siregar, A. S., & Febryanni, L. 2015. Struktur Komunitas, Zonasi Dan Keanekaragaman Hayati Vegetasi Mangrove Di Segara Anakan Cilacap. Omni-Akuatika, 11(2), 20-32. https://doi.org/10.20884/1.oa.2015.11.2.36

Honggang, Z., Baoshan, C., & Xiaoyun, F.

2012. Species diversity and distribution for zooplankton in the inter- tidal wetlands of the Pearl River estuary , China. Procedia Environmental Sciences 13: 2383 - 2393.

Kairo, J. G., Dahdouh-Guebas, F., Bosire, J., & Koedam, N. 2001. Restoration and management of mangrove systems - A lesson for and from the East African region. South African Journal of Botany 67(3): 383-389.

Kairo, James G., Lang'at, J. K. S., Dahdouh-Guebas, F., Bosire, J., & Karachi, M. 2008. Structural development and productivity of replanted mangrove plantations in Kenya. Forest Ecology and Management 255(7): 2670-2677.

Kantharajan, G., Pandey, P. K., Krishnan, P., Ragavan, P., Jeevamani, J. J. J., Purvaja, R., & Ramesh, R. 2018). Vegetative structure and species composition of mangroves along the Mumbai coast, Maharashtra, India. Regional Studies in Marine Science 19: 1-8.

Khalifa, N., El-damhogy, K. A., Fishar, M. R., Nasef, A. M., & Hegab, M. H. 2015). Vertical distribution of zooplankton in Lake Nasser. The Egyptian Journal of Aquatic Research 41(2): 177-185.

Kitamura, M., Amakasu, K., Kikuchi, T., & Nishino, S. 2017). Seasonal dynamics of zooplankton in the southern Chukchi Sea revealed from acoustic backscattering strength. Continental Shelf Research, 133 (April 2016): 47-58.

Kruk, M., Jaworska, B., Jabłońska-Barna, I., & Rychter, A. 2016. How do differences in the nutritional and hydrological background influence phytoplankton in the Vistula Lagoon during a hot summer day? Oceanologia 58(4): 341-352.

Kusmana, C. 1997. Metode Vegetasi Survey. IPB Press. Bogor.

Kusmana, C., Puradyatmika, P., Husin, Y. ., Shea, G., & Martindale, D. 2000. Mangrove litter fall studi at the Ajkwa Estuary Irian Jaya. Indonesian Journal of Tropical Agriculture 9(3): 39-47.

Kusmana, C., Wilarso, S., Hilwan, I., Pamoengkas, P., Wibowo, C., Tiryana, T., Triswanto, A., Yunasfi, Y., & Hamzah. 2005. Teknik Rehabilitasi. Fakultas Kehutanan, Institut Pertanian Bogor, Bogor.

Li, Y., Waite, A. M., Gal, G., & Hipsey, M. R. 2012. Do phytoplankton nutrient ratios reflect patterns of water column nutrient ratios? A numerical stoichiometric analysis of Lake Kinneret. Procedia Environmental Sciences 13: 1657-1667.

Macintosh, D. J., Ashton, E. C., & Havanon, S. 2002. Mangrove rehabilitation and intertidal biodiversity: A study in the Ranong mangrove ecosystem, Thailand. Estuarine, Coastal and Shelf Science 55(3): 331-345.

Magurran, A. 1996. Ecological Diversity and Its Measurement. Springer, Dordrecht

Masagca, J. T. 2008. Occurrence and distributional range of mangrove vascular flora of catanduanes Island, Luzon, Philippines. Biotropia 15(2): 87-94.

Masuda, Y., Yamanaka, Y., Hirata, T., & Nakano, H. 2017. Competition and community assemblage dynamics within a phytoplankton functional group : Simulation using an eddy-resolving model to disentangle deterministic and random effects. Ecological Modelling 343: 1-14.

Mckinstry, C. A. E., & Campbell, R. W. 2017. Seasonal variation of zooplankton abundance and community structure in Sound, Prince William, Alaska, 2009-2016. Deep-Sea Research Part II, xxxx, 0-1.

Menteri Negara Lingkungan Hidup, M. 2004. Kriteria Baku Dan Pedoman Penentuan Kerusakan Mangrove (Vol. 201). Menteri Negara Lingkungan Hidup Indonesia.

Moya, E. C., Twilley, R. R., Rivera-monroy, V. H., Marx, B. D., Coronado-molina, C., & Ewe, S. M. L. 2011. Patterns of Root Dynamics in Mangrove Forests Along Environmental Gradients in the Florida Coastal Everglades , USA. Ecosystems 14: 1178-1195.

Mukherjee, J., & Ray, S. 2012a. Carbon cycling from mangrove litter to the adjacent Hooghly estuary, India - A modelling study. Procedia Environmental Sciences 13: 391-413.

Mukherjee, J., & Ray, S. 2012b. Procedia Environmental Sciences Carbon cycling from mangrove litter to the adjacent Hooghly estuary , India - A modelling study. Procedia Environmental Sciences 13: 391-413.

Onyema, I. C. 2007. The Phytoplankton Composition , Abundance and Temporal

Variation of a Polluted Estuarine Creek in Lagos , Nigeria. Turkish Journal of Fisheries and Aquatic Sciences 96: 89-96.

Ormanczyk, M. R., Gluchowska, M., & Olszewska, A. 2017. Zooplankton structure in high latitude fjords with contrasting oceanography (Hornsund and Kongsfjorden, Spitsbergen). Oceanologia

Pratiwi, N. T. M., Arditho, Wulandari, D. Y., & Iswantari, A. 2016. Horizontal distribution of zooplankton in Tangerang Coastal. Procedia Environmental Sciences 33: 470-477.

Ragavan, P., Ravichandran, K., Jayaraj, R. S. ., Mohan, P. M., Saxena, A., Saravanan, S., & Vijayaraghavan, A. 2014. Distribution of mangrove species reported as rare in Andaman and Nicobar islands with their taxonomical notes. Biodiversitas 15(1): 12-23.

Roy, M., Ray, S., & Bhusan, P. 2012. Procedia Environmental Sciences Modelling of Impact of Detritus on Detritivorous Food Chain of Sundarban Mangrove Ecosystem , India. Procedia Environmental Sciences 13: 377-390.

Sari, L. K., Adrianto, L., Soewardi, K., Atmadipoera, A. S., & Hilmi, E. 2016. Sedimentation in lagoon waters (Case study on Segara Anakan Lagoon). AIP Conference Proceedings, 1730.

Simanjuntak, M. 2009. Hubungan Faktor Lingkungan Kimia, Fisika Terhadap Distribusi Plankton Di Perairan Belitung Timur, Bangka Belitung. Jurnal Perikanan (Journal of Fisheries Sciences) 11(1): 31-45.

Soylu, E. N., & Gönülol, A. 2003. Phytoplankton and seasonal variations of the River Yesılırmak, Amasya, Turkey. Turkish Journal of Fisheries and Aquatic Sciences 3: 17-24.

Su, J., Tian, T., Krasemann, H., Schartau, M., & Wirtz, K. 2015. Response patterns of phytoplankton growth to variations in resuspension in the German Bight revealed by daily MERIS data in 2003 and 2004 §. Oceanologia 57(4): 328-341.

Syakti, A. D., Ahmed, M. M., Hidayati, N. V., Hilmi, E., Sulystyo, I., Piram, A., & Doumenq, P. 2013. Screening of Emerging Pollutants in the Mangrove of Segara Anakan Nature Reserve, Indonesia. IERI Procedia 5: 216-222.

Takenaka, R., Komorita, T., & Tsutsumi, H. 2018. Accumulation of organic matter within a muddy carpet created by the asian date mussel, *Arcuatula senhousia*, on the Midori River tidal flats, Japan. Plankton and Benthos Research 13(1): 1-9.

Truong, S. H., Ye, Q., & Stive, M. J. F. 2017. Estuarine Mangrove Squeeze in the Mekong Delta, Vietnam Estuarine Mangrove Squeeze in the Mekong Delta, Vietnam. Journal of Coastal Research 33(4): 747-763.

Tsuji, Y., & Montani, S. 2017. Spatial variability in an estuarine phytoplankton and suspended microphytobenthos community. Plankton and Benthos Research 12(3): 190-200.

Yamamoto, T., Kagohara, T., Yamamoto, K., Satomi, K., & Hamaguchi, M. 2018. Distribution of *Batillaria multiformis* and *B. attramentaria* (Batillariidae) in Southern Kyushu. Plankton Benthos Res 13(1): 10-16.

Yan, F., Yuhong, W., Yihao, L., Hua, X., & Zhenbo, L. 2012. Feature of phytoplankton community and canonical correlation analysis with environmental factors in Xiaoqing River estuary in autumn. Procedia Engineering 37: 19-24.

Yilmaz, I. N., Ergul, H. A., Mavruk, S., Tas, S., Vedat, H., Yıldız, M., & Ozturk, B. 2018. Coastal Plankton Assemblages in the Vicinity of Galindez Island and Neumayer Channel (Western Antarctic Peninsula) during the First Joint Turkish - Ukrainian Antarctic Research Expedition. Turkish Journal of Fisheries and Aquatic Sciences 584: 577-584.