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Plankton and benthos similarity indices as indicators of the impact of mangrove plantation on the environmental quality of silvofishery ponds

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Abstract. *Hastuti ED, Hastuti RB, Darmanti S. 2018. Plankton and benthos similarity indices as indicators of the impact of mangrove plantation on the environmental quality of silvofishery ponds. Biodiversitas 19: 1558-1567.* This research was carried out in a coastal area of Semarang City, Central Java, Indonesia. It aimed to study the composition of plankton and benthos communities in silvofishery ponds, and to analyze the similarity in plankton and benthos composition between ponds as an indicator of variation in pond environmental quality. Nine pond treatments were sampled for their plankton and benthos composition. The nine treatments consisted of a factorial combination of three mangrove species assemblages (*Avicennia marina* (M1), *Rhizophora mucronata* (M2), and a mixture of both (M3)) at three mangrove populations (5 trees (S1), 10 trees (S2), and 15 trees (S3)). Similarity index analysis was conducted to measure the impact of treatments on the plankton and benthos communities. The total number of plankton species identified in observation periods in May, July and September of 2016, were 23, 16 and 21 species repectively, while for the benthos there were eight somewhat different species identified in each of the three observation periods. Fluctuation in plankton and benthos composition tended to achieve a balance in richness by the time of the the third observation period. Diatoms, particularly *Gyrosigma* sp., were the most widely distributed plankton in the first and third observation periods, while *Pyramidella sulcata* was the only well-distributed benthos species in the three observation periods. Pairwise similarity indices between treatments ranged from 0% to 62.5% for plankton and from 16.7% to 100% for benthos. The results of the investigation suggested that mangrove species affected plankton and benthos species richness in this initial stage of a silvofishery development: plankton composition appeared to be richer in ponds with *A. marina,* while benthos was richer in ponds with *R. mucronata*.

Keywords: Composition, richness, sediment, similarity, silvofishery, water

INTRODUCTION

Excessive utilization of coastal areas in Indonesia, especially conversion of mangrove forests to ponds for aquaculture, has caused degradation of the environment in these habitats (Suwarto et al. 2015). In order to overcome the increasing impacts of unmanaged, abandoned ponds, a system of silvofishery has been proposed that integrates mangrove plantations within the ponds (Setiawan et al. 2015). The application of silvofishery is expected to lead to improved water quality. It is suggested that mangrove plantations provide environment services such as bioremediation of pollutants and of pond effluent, greater nutrient availability, and stabilization of physical parameters of water quality (Hastuti and Budihastuti 2016). Thus, aquaculture activity could be revived at the same time as enhancing conservation of the coastal habitats.

Improvement in environmental quality of silvofishery pond is an important indicator of mangrove plantation effectiveness (Sambu 2014). Physical, chemical and biological parameters together provide neasures of the suitability and carrying capacity of ponds (Sachoemar et al. 2014). In order to assess the suitability of specific coastal habitats for supporting fish culture activities, such parameters of environment quality should be known before and during the implementation of such activities. However, the conditions of silvofishery ponds change over time, and these changes can affect their suitability and carrying capacity (Suwarto et al. 2015). Thus, periodic monitoring of silvofishery pond quality is required in order to apply best management practices.

Among the various measures of aquatic environmental quality, biological parameters are considered to represent short- and long-term indicators of pond quality. Plankton species, which mostly have short lifespans, potentially provide short-term information about pond water quality (Chellappa et al. 2009). Since plankton growth requires several days, assessment of plankton species composition and abundance can be useful in understand the time-limited, cummulative impact of environmental management options on water quality (Moritsch et al. 2010); in contrast to physical and chemical water quality parameters which change every hour. On the other hand, benthos having longer lifespans, are likely to provide better information about the long-term pond quality (Li et al. 2010). Thus, the study of biological indicators of environment quality is expected to provide more appropriate information to identify current ecosystem conditions and to guide management formulation (Kenney et al. 2009).

Pond environment quality is influenced by the source of its water (Chughtai and Mahmood 2012). For silvofishery ponds, the composition of the mangrove flora is another factor that can affect environmental quality (Gatune et al. 2014). The interaction of mangrove plants with the pond habitat affects the physical, chemical and biological characteristics of silvofishery ponds (Hastuti 2017). Even though silvofishery practices have been applied in aquaculture for decades, there is still a lack of information about the impact of these practices on the biological components of the aquaculture environment.

The existence and composition of mangrove flora within silvofishery ponds has been shown to affect the environmental quality of the ponds, including the physical and chemical quality of the water and the sediment nutrient concentrations (Hastuti and Budihastuti 2016). Even though mangrove plantations may be established according to different models, their impacts on the environmnetal quality may not vary greatly. Mangrove plants produce litter that is decomposed by pond organisms to supply nutrients in the pond (Gatune et al. 2014). The nutrient supply along with associated physical and chemical conditions are major factors determining the composition of plankton and benthos that arise from the impact of mangrove composition on the silvofishery pond environment. It appears that the greater the range of species availability the better is the environment quality (Veronica et al. 2014). Unfortunately, the optimum mangrove composition is not well understood. Short-term and long-term structure of the mangrove population might be linked to biological indicators of pond environment quality.

Different silvofishery settings are likely to result in differences in the composition of plankton and benthos. Our research sought to understand how various silvofishery settings provide suitable ecosystems for plankton and benthos populations and how mangrove composition influences the development of the ecosystems. The research aimed to study the composition of plankton and benthos within silvofishery ponds in the coastal environment of Semarang City, in Central Java, Indonesia: to determine the similarity indices between ponds in their plankton and benthos composition; and to evaluate the impact of different mangrove plantation settings on pond water quality as asssessed by these biological indicators.

MATERIALS AND METHODS

Study area

The research was conducted in silvofishery ponds of Mangunharjo Village, Tugu Sub-district, Semarang City, Central Java, Indonesia from May to September 2016. The research location is shown in

Figure **1**. Field sampling of plankton and benthos was conducted in May, July and September, while laboratory identification was conducted in the Ecology and Biosystematics Laboratory, Faculty of Science and Mathematics, Diponegoro University, Semarang, Indonesia. The sampling sites were located along a transect 230m long, situated between coordinates 6°57'16.90"S, 110°18'39.07"E and 6°57'21.18"S. 110°18'45.42"E.

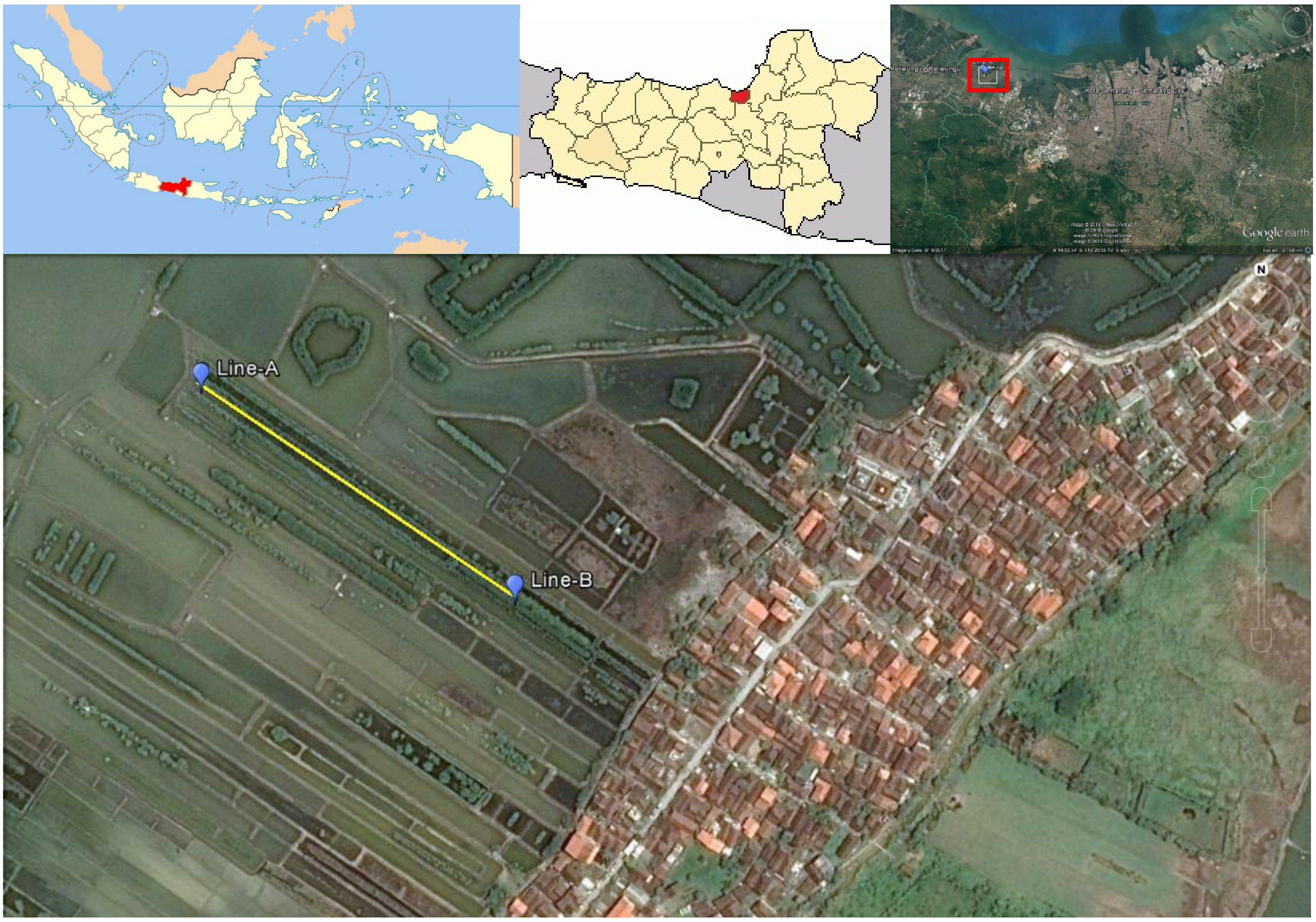

Figure 1. The research location in Mangunharjo Village, Tugu Sub-district, Semarang City, Central Java, Indonesia

Experiment design

The experimental design along the transect involved a factorial combination of different mangrove populations together with different mangrove species. The mangrove populations were: 5 trees (S1); 10 trees (S2); and 15 trees (S3). The mangrove species were *Avicennia marina* (M1); *Rhizophora mucronata* (M2); and a mixture of both (M3). Thus a total of 9 combinations comprised the research ponds sampled in the study.

Data collection focused on sampling plankton and benthos species in the nine pond environments. The nine pond environments were sampled in three periods: May (I); July (II); and September (III) to understand the composition changes between observation periods.

The collection of plankton samples was conducted by filtration of water from the ponds. A total volume of 100 litres per pond was filtered using 10 litre buckets, and the filtered sample was condensed and stored in a 100 ml bottle. A plankton net with 25µm mesh size was used as the filter. Collected samples were then fixed with 1 ml of 4% formalin solution (Black and Dodson 2003; Pollupuu 2007). Benthos was sampled with a tube sampler, 30 cm long and 10 cm diameter. Three random spots were picked as the samples within each pond.

Collected sediments from each pond were filtered with a 0.5 mm sieve mesh (Bett 2013; Marini et al. 2013). The collected macrobenthos was then stored in a 250 ml bottle and preserved with rose bengalein 5% formaldehyde solution (Chandrasekera and Hettiarachchi 2011).

Data analysis

Similarity index analysis was conducted on the composition of plankton and benthos between mangrove treatment combinations and observation periods. Similarity indices between treatments combinations were determined as indicators of the resemblance of environment conditions between treatments, while similarity indices between observation periods were detemined as indicators of the consistency in environmental condition over time. Similarity index analysis used Jackards coefficient as the following formula (Tyokumbur and Okorie 2013):

$$J = (c / (a + b + c)) \times 100\ \%$$

Where:

a: number of plankton / benthos species present only in treatment 'a'

b: number of plankton / benthos species present only in treatment 'b'

c: number of plankton / benthos species present in treatment 'a' and treatment 'b'

For example, the index of similarity for plankton species between treatment S1M1 (i.e. 'a') and SM1M2 (i.e. 'b'), in the first observation period in May would be given by dividing the number of species which were present in both treatments by the sum of the number of species that were present in both, the number of species that were present only in treatment S1M1, and the number of species that were present only in treatment S1M2, and then multiplying this fraction by 100 to give a percentage.

Similarity index values were evaluated as very high down to very low, as indicated below: (i) > 80%: very high similarity; (ii) 60-80%: high similarity; (iii) 40-60%: moderate similarity; (iv) 20-40%: low similarity: (v) < 20%: very low similarity

Further analysis was then conducted using the chi-square test to test the effect of the treatments on the structural composition of plankton and benthos communities. Chi-square can be used to analyze the likelihood of organism communities in the different environment condition (Drenner et al. 2009). The analysis tool utilized was SPSS with a confidence interval of 95% ($\alpha = 0.05$).

RESULTS AND DISCUSSION

Composition of plankton and benthos

Based on field observation and laboratory investigation, we identified 33 plankton and 13 benthos species in the silvofishery ponds of the research area.

The presence of plankton species was not constant, but changed over time; the total number of species identified was 23, 16 and 21 respectively for the first, second and third sampling occasions. On the other hand, the number of benthos species number was constant at eight species on each sampling occasion, although the benthos species composition varied across the sampling occasions. Table 1 and Table 2 respectively show the detailed composition of plankton and benthos species found on each sampling occasion (I, II, III) for each of the nine treatments (S1M1 ... S3M3) within the silvofishery ponds.

The presence of plankton as presented in Table 1 showed that at the first plankton sampling in May, *Diatoma* sp. was highly distributed in all treatments. Six identified plankton species were fairly evenly distributed in this first sampling period. In the second observation period, in July, no particular plankton species was highly distributed across treatments, but there were four plankton genera that had a moderate distribution range. In the third observation period in September, *Gyrosigma* sp. had a high distribution range and two other species had a fair distribution range. Identification of plankton across all three observation periods showed that five plankton species were highly distributed; namely *Cocconeis* sp., *Cyclotella* sp., *Diatoma* sp., *Gyrosigma* sp. and *Navicula* sp., while ten other species were found to have a moderate distribution range.

Based on the distribution of benthos species listed in Table 2, it is clear that in the first sampling period *Pyramidella sulcata* was highly distributed, being observed in all pond treatments; other species had narrow distributions. In the second observation period, *P. sulcata* was again highly distribute, while one other species was found to be moderately distributed. In the third observation period, *P. sulcata* and *P. ventricosa* was found to have a high distribution range and another two species had a moderate distribution range. Across the three observations periods, only *P. sulcata* and *P. ventricosa* were found to have a high distribution range, while four other species had a moderate distribution range.

Table 1. Plankton species composition for each of nine silvo-fishery treatments on each of three sampling occasions (May (I); July (II); and September (III)).

Plankton species	S1M1			S1M2			S1M3			S2M1			S2M2			S2M3			S3M1			S3M2			S3M3		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Chrysophyta																											
Achnanthes sp.	+	-	+	+	-	-	+	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	+
Amphora sp.	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Biddulphia sp.	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Chaetoceros sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Cocconeis sp.	-	-	-	-	-	-	-	+	-	-	+	-	+	+	-	-	+	+	-	+	+	-	+	-	+	-	-
Cyclotella sp.	+	-	+	+	+	-	+	-	-	-	+	-	+	-	-	+	+	-	+	-	-	-	+	-	-	-	-
Cymbella sp.	-	-	-	-	-	+	-	-	-	+	-	+	-	-	-	-	+	-	-	+	+	-	-	-	+	-	-
Diatoma sp.	+	+	+	+	-	-	+	-	-	+	+	-	+	-	-	+	-	-	+	-	-	+	-	-	+	-	-
Epithemia sp.	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fragilaria sp.	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	+	+	-	+	-	+
Gyrosigma sp.	-	-	+	+	-	+	-	+	+	-	-	+	-	-	+	-	+	+	-	+	+	-	-	+	-	-	+
Navicula sp.	-	-	-	+	-	-	+	-	-	-	-	+	-	-	+	+	+	+	+	-	+	+	-	-	+	+	-
Pleurosigma sp.	-	-	-	+	-	+	-	-	-	-	-	+	-	-	-	+	-	-	+	-	-	-	-	+	-	-	-
Rhizosolenia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Surirella sp.	-	-	+	-	-	-	+	+	-	+	-	-	+	-	+	-	-	-	+	-	-	+	-	-	-	-	-
Synedra sp.	-	-	-	-	-	-	-	-	+	+	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-
Amphiprora sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-
Cyanophyta																											
Anabaena sp.	+	-	-	-	-	-	+	-	-	+	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Coelosphaerium sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Oscillatoria sp.	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pyrrophyta																											
Peridinium sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Noctiluca sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euglenophyta																											
Phacus sp.	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-
Chlorophyta																											
Oocystis sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-
Chlorella sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Zooplankton																											
Brachionus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-
Nauplius	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	+	-	-	-	+	-	-	+	-	+
Tintinnopsis sp.	+	-	+	-	-	-	+	-	-	-	-	-	-	-	+	+	-	-	-	-	+	-	-	-	+	-	-
Codonella sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Difflugia sp.	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-
Frontoniella sp.	-	+	-	-	+	-	-	+	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Nematoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	+	-	-	-	-
Crustacea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+
Number of Species	**6**	**3**	**6**	**7**	**3**	**5**	**7**	**4**	**6**	**6**	**5**	**6**	**6**	**4**	**6**	**7**	**10**	**4**	**7**	**4**	**6**	**9**	**5**	**4**	**11**	**4**	**5**

Table 2. Benthos species composition for each of nine silvo-fishery treatments on each of three sampling occasions (May (I); July (II); and September (III)).

Benthos Species	S1M1			S1M2			S1M3			S2M1			S2M2			S2M3			S3M1			S3M2			S3M3		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Mollusca																											
Cerethidea cingulata	-	+	-	-	-	-	-	-	+	+	+	-	+	-	-	+	+	+	-	-	-	-	-	-	-	+	+
Cerethidea quadrata	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Gemmula monilifera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Pyramidella auriscati	-	-	+	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-
Pyramidella sulcata	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pyramidella ventricosa	-	-	+	-	-	-	-	-	+	-	-	+	-	-	+	-	-	-	-	-	+	-	-	+	-	-	+
Telescopium telescopium	-	+	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	+	-	-
Terebralia palustris	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Terebralia sulcata	-	-	-	-	+	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Cerithium pfefferi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Nassarius luridus	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	+
Bivalvia																											
Anadara granosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-
Tapes literata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Number of Species	**1**	**3**	**3**	**2**	**2**	**3**	**2**	**1**	**4**	**4**	**3**	**2**	**2**	**2**	**4**	**2**	**2**	**3**	**3**	**4**	**4**	**1**	**2**	**4**	**2**	**2**	**4**

Similarity of plankton and benthos composition

Analysis of the data in Tables 1 and 2 was conducted to determine the similarities in plankton and benthos species composition between as well as across treatments and sampling periods. Analysis was grouped into four categories: similarity between treatments a within sampling period; similarity between treatments across all periods; similarity between periods within treatments; and similarity between periods across all treatments. Statistical data analysis was conducted to understand the significance of plankton and benthos composition differences. The comparison of plankton composition by the involvement of chi-square had been conducted by Budihastuti et al. (2013), Fedorenko (1973), and Paiva-Maia (2013). The applications included for feeding habit analysis as well as the impact of environmental improvement. The detailed results of these analyses are presented in Table 3, 4 and 5. The results of statistical tests of significance are also presented in the tables.

Table 3. Similarity indices for plankton and benthos composition between treatments

Treatments		Between treatments within periods						Between treatments			
		Plankton			Benthos			Plankton		Benthos	
		I	II	III	I	II	III	Total	Pearson's Chi-Square	Total	Pearson's Chi-Square
S1M1	S1M2	30.0%	50.0%	10.0%	50.0%	25.0%	50.0%	40.0%	278.9**	42.9%	263.3**
	S1M3	62.5%	16.7%	9.1%	50.0%	33.3%	75.0%	56.3%	317.4**	66.7%	242.4**
	S2M1	20.0%	33.3%	9.1%	25.0%	50.0%	66.7%	38.9%	760.8**	37.5%	137.0**
	S2M2	33.3%	16.7%	33.3%	50.0%	66.7%	40.0%	41.2%	351.1**	57.1%	266.2**
	S2M3	30.0%	0.0%	11.1%	50.0%	66.7%	20.0%	23.8%	518.0**	33.3%	583.9**
	S3M1	18.2%	0.0%	20.0%	33.3%	40.0%	75.0%	27.8%	423.5**	44.4%	281.0**
	S3M2	15.4%	14.3%	11.1%	100.0%	25.0%	75.0%	28.6%	415.3**	42.9%	451.6**
	S3M3	21.4%	16.7%	22.2%	50.0%	66.7%	40.0%	23.8%	433.3**	66.7%	241.7**
S1M2	S1M3	40.0%	16.7%	10.0%	33.3%	50.0%	40.0%	30.0%	534.6**	42.9%	677.2**
	S2M1	8.3%	33.3%	37.5%	20.0%	25.0%	25.0%	44.4%	697.8**	22.2%	411.1**
	S2M2	18.2%	16.7%	10.0%	33.3%	33.3%	16.7%	31.6%	494.5**	37.5%	683.7**
	S2M3	40.0%	8.3%	12.5%	33.3%	33.3%	50.0%	42.1%	432.5**	33.3%	388.1**
	S3M1	40.0%	0.0%	22.2%	25.0%	20.0%	40.0%	33.3%	402.5**	30.0%	725.0**
	S3M2	14.3%	33.3%	28.6%	50.0%	33.3%	75.0%	33.3%	489.1**	42.9%	834.4**
	S3M3	20.0%	16.7%	25.0%	100.0%	33.3%	40.0%	35.0%	478.6**	42.9%	574.0**
S1M3	S2M1	30.0%	28.6%	9.1%	20.0%	33.3%	50.0%	50.0%	714.3**	37.5%	352.3**
	S2M2	44.4%	33.3%	20.0%	33.3%	50.0%	33.3%	61.1%	364.8**	57.1%	168.3**
	S2M3	40.0%	16.7%	11.1%	33.3%	50.0%	40.0%	34.8%	473.0**	33.3%	1,082.9**
	S3M1	40.0%	33.3%	9.1%	25.0%	25.0%	60.0%	33.3%	515.8**	30.0%	158.7**
	S3M2	33.3%	12.5%	25.0%	50.0%	50.0%	60.0%	33.3%	623.4**	42.9%	206.6**
	S3M3	28.6%	0.0%	10.0%	33.3%	50.0%	60.0%	24.0%	609.1**	42.9%	256.9**
S2M1	S2M2	33.3%	28.6%	33.3%	50.0%	25.0%	50.0%	52.6%	694.7**	50.0%	235.2**
	S2M3	18.2%	25.0%	42.9%	50.0%	66.7%	25.0%	55.0%	564.0**	50.0%	573.8**
	S3M1	30.0%	12.5%	33.3%	16.7%	16.7%	50.0%	55.6%	417.0**	27.3%	390.9**
	S3M2	25.0%	25.0%	25.0%	25.0%	25.0%	50.0%	39.1%	802.0**	37.5%	649.3**
	S3M3	13.3%	0.0%	22.2%	20.0%	66.7%	50.0%	29.2%	839.7**	57.1%	244.4**
S2M2	S2M3	18.2%	27.3%	42.9%	100.0%	33.3%	16.7%	42.9%	459.5**	28.6%	1,183.1**
	S3M1	30.0%	14.3%	33.3%	25.0%	50.0%	33.3%	35.0%	500.8**	27.3%	288.2**
	S3M2	36.4%	28.6%	11.1%	50.0%	33.3%	33.3%	47.6%	386.2**	22.2%	621.1**
	S3M3	13.3%	0.0%	22.2%	33.3%	33.3%	33.3%	30.4%	551.5**	57.1%	260.3**
S2M3	S3M1	55.6%	27.3%	42.9%	25.0%	20.0%	16.7%	52.6%	269.4**	10.0%	1,140.7**
	S3M2	14.3%	36.4%	14.3%	50.0%	33.3%	40.0%	37.5%	527.7**	33.3%	1,265.1**
	S3M3	20.0%	16.7%	28.6%	33.3%	100.0%	75.0%	45.5%	375.9**	60.0%	701.5**
S3M1	S3M2	23.1%	12.5%	11.1%	33.3%	20.0%	60.0%	36.4%	526.2**	30.0%	300.0**
	S3M3	12.5%	0.0%	10.0%	25.0%	20.0%	33.3%	26.1%	533.3**	30.0%	263.5**
S3M2	S3M3	42.9%	12.5%	28.6%	50.0%	33.3%	60.0%	43.5%	336.2**	42.9%	367.4**
	Min	8.3%	0.0%	9.1%	16.7%	16.7%	16.7%	23.8%		10.0%	
	Max	62.5%	50.0%	42.9%	100.0%	100.0%	75.0%	61.1%		66.7%	
	Average	28.2%	18.4%	21.0%	41.3%	39.9%	46.1%	38.8%		40.3%	
	St.Dev	12.6%	12.7%	11.1%	21.2%	18.4%	17.7%	10.1%		12.9%	

Note: * significant at $\alpha = 0.05$; ** significant at $\alpha = 0.01$

Table 4. Similarity indices for plankton and benthos composition between periods within treatments

Treatment	Plankton						Benthos					
	I - II		I - III		II - III		I - II		I - III		II - III	
	SI	Pearson's Chi-Square	SI	Pearson's Chi-Square	SI	Pearson's Chi-Square	SI	Pearson's Chi-Square	SI	Pearson's Chi-Square	SI	Pearson's Chi-Square
S1M1	12.5%	127.7	50.0%	103.1	12.5%	141.0	33.3%	27.9	33.3%	458.9	20.0%	498.2
S1M2	11.1%	251.6	20.0%	348.6	14.3%	117.1	33.3%	67.6	25.0%	148.2	25.0%	422.8
S1M3	10.0%	223.6	0.0%	363.0	11.1%	219.8	50.0%	5.2	20.0%	1,137.0	25.0%	692.8
S2M1	10.0%	231.7	9.1%	807.4	0.0%	728.0	40.0%	46.8	20.0%	386.8	25.0%	241.7
S2M2	11.1%	307.2	9.1%	449.3	0.0%	258.0	33.3%	54.0	20.0%	946.7	20.0%	1154.6
S2M3	13.3%	288.8	10.0%	187.1	27.3%	168.1	100.0%	0.2	66.7%	557.1	66.7%	620.5
S3M1	0.0%	345.0	8.3%	431.7	42.9%	107.3	40.0%	95.9	16.7%	929.4	14.3%	809.7
S3M2	7.7%	462.3	0.0%	501.0	0.0%	171.0	50.0%	71.1	25.0%	686.9	20.0%	609.9
S3M3	7.1%	367.0	23.1%	243.9	0.0%	153.0	33.3%	138.6	20.0%	542.9	50.0%	272.3
Min	0.0%		0.0%		0.0%		33.3%		16.7%		14.3%	
Max	13.3%		50.0%		42.9%		100.0%		66.7%		66.7%	
Average	9.2%		14.4%		12.0%		45.9%		27.4%		29.6%	
St.Dev	4.0%		15.4%		14.9%		21.4%		15.5%		17.2%	

Note: ‡ correlation is not significant

Table 5. Similarity indices for plankton and benthos composition between periods across all treatments

Periods		Plankton		Benthos	
		SI	Pearson's Chi-Square	SI	Pearson's Chi-Square
I	II	34.5%	1,665.3	60.0%	140.5
	III	51.7%	2,462.9	33.3%	5,601.3
II	III	48.0%	1,245.4	33.3%	5,255.0
	Min	34.5%		33.3%	
	Max	51.7%		60.0%	
	Average	44.7%		42.2%	
	St.Dev	9.1%		15.4%	

Note: *: significant at α = 0.05; **: significant at α = 0.01

The result of the analysis of similarity indices for plankton and benthos between pairs of treatments is presented in Table 3. For plankton, similarity index analysis for the first observation period showed that only for the pair of treatments S1M1 and S1M3 was similarity high, while in the second and third observations there were no high values for the indices of similarity between pairs of treatments. Analysis of similarity indexes for plankton between pairs of treatments determined across all three periods showed high similarity only between treatments S1M3 and S2M2. This indicated that similarity in composition of plankton between treatments was low. The application of various pond settings, involving the species composition and population of mangrove had significant effect on the composition of plankton.

Overall, the total number of benthos species identified in the ponds was far less than the number of plankton species (Table 1); some treatments had only one benthos species at particular sampling times The similarity index results in Table 3 show that in several cases there was absolute similarity between pairs of treatments: namely, in the first observation period, between S1M1 and S3M2; between S1M2 and S3M3; and between S2M2 to S2M3; and in the second observation period between S2M3 and S3M3. In the third observation period there were no pairs of treatments that showed absolute similarity in their benthos composition. Apart from absolute similarity, there was no high values for similarity index in the first observation period, while in the second and third periods respectively five and six high similarity indices were recorded. Analysis across all three observation periods revealed only two high similarity indices between pairs of treatments: namely, between S1M1 and S1M3; and between S1M1 and S3M3.

In general, the results indicated that the distribution of benthos across the treatments was low. This suggests that there were significant differences in sediment conditions between the silvofishery treatments. The statistical analysis showed that the treatments had significant effects on the composition of both plankton and benthos in the silvofishery ponds. According to the chi-square analysis, the compositions of plankton and benthos during the research were significantly different. Thus, the likelihood of plankton and benthos compositions among treatments were low.

Similarity index comparison between periods within treatments showed generally low similarity for plankton (Table 4). Moderate similarity for plankton was the highest level recorded in the analysis: i.e. between the first and third observation period for treatment S1M1; and between the second and third observation period for S3M1. Within some treatments, comparison between observation periods revealed 0% similarity: i.e. between first and second period for treatment S3M1; between first and third periods for treatments S1M3, S3M2 and S2M1; and between second and third periods for S2M2, S3M2 and S3M3. These 0% similarity index values mean that the plankton composition of the compared observation periods was completely different within the particular treatments. The Chi-square analysis confirmed that there was no significant similarity of plankton composition between observation periods within particular treaments.

For benthos composition, too, pairwise similarity indices calculated between obervation periods within treatments revealed negligible similarity between the periods (Table 4). Only within treatment S2M3 was there consistent high similarity in benthos over time. Statistical analysis showed that there was no significant differnece in the similarity index for benthos between the first and second observation periods in the treatment S2M3. However, it needs to be noted that among all the treatments, S2M3 had the lowest total number of benthos species; only three species compared to at least five species for the other treatments (see Table 2). Low values for similarity indices of benthos between periods within treatments revealed that even for benthos composition as for plankton there was significant change over time. This suggests that the sediment conditions in the silvofishery treatments were changing across the three observation periods of the research.

Analysed across all nine treatments the pairwise similarity indices between the three obervation periods showed that plankton composition similarity was low between the first and second periods but had moderate between the first and third, and between the second and third period (Table 5). This suggests that the absence of particular plankton species may have been caused by movement towards another place. The higher similarity values between first and third and between second and third observation periods suggest that several plankton species might have moved out of the silvofishery ponds prior to the second observation period but soon after re-entered the system.

For benthos, the similarity indices between observation periods across treaments (Table 5) declined from 60% between observation period I and observation period II, to 33% between I and II, and 33% between II and III. This suggests that several benthos species moved or were removed from the silvofishery pond. However, the number of species was consistent among periods which indicated the replacement of plankton specieses. The Chi-square analyses for pairwise similarity indices of plankton and benthos across treatments showed that none of the three observation periods were similar in species composition.

Discussion

Seasonal change is common for plankton composition as it responds to hydro-oceanographic changes (Ahmed et al. 2016). In our study, change in plankton composition over the periods of observation as well as variation between the nine treatments in the silvofishery ponds indicated that there was significant fluctuation in the water quality of the ponds. Plankton distribution is known to be affected by water temperature, CO_2 concentration, chloride concentration, water clarity, total dissolved solids (TDS), pH and dissolved oxygen concentration (Ganai and Parveen 2014). Variations in environment conditions affect the relative abundance of plankton species. According to our identification of plankton species, the dominance of particular species changed between the periods of observation. Change in species dominance of plankton in aquatic ecosystem is commonly observed phenomenon especially in response to seasonal change. Seasonal change causes alteration in temperature, pH, dissolved solids and dissolved nutrients in aquatic systems (Kocer and Sen 2014). The utilization of land and water such as for agricultural activity, tourism, residential, fish pens, etc are also considered to effect the composition of plankton (Baloloy et al. 2016). Thus, different land use also effect the composition of plankton.

The domination of *Diatoma* sp. in the first observation period suggests that the water may have been enriched with nutrients. Diatom abundance and distribution is correlated with the concentration of nutrients (Jakovljevic et al. 2016). Thus, in our study, the absence of *Diatoma* sp. in the second and third period suggested the likelihood of decreasing nutrient concentration in the treatment ponds.

On the other hand, *Gyrosigma* sp. was the most distributed plankton species in the third observation period. Increasing distribution of *Gyrosigma* sp. showed that environmental conditions within the treatments had changed. Perhaps due to water movement, since *Gyrosigma* sp. has been reported to prefer lotic (i.e. flowing) water and has low adapability to impounded water conditions (Alhassan 2015).

In general, the silvofishery ponds in our study in Semarang appeared to in a relatively good condition as indicated by the presence of *Cocconeis* sp., *Cyclotella* sp., *Fragillaria* sp. and *Navicula* sp. These plankton species are considered to be indicators of good levels of dissolved oxygen concentration (Kim et al. 2015). These types of dominant plankton species suggest that the water in the ponds is enriched with nutrients and has good water circulation. Research by other workers has shown the presence of such species in flowing water systems with good oxygen concentration levels (Wu et al. 2011; Yuce and Gonulol 2016).

The distribution of benthos species suggest that there was no significant change in sediment quality in the silvofishery ponds during the period of our study. The domination of *Pyramidella* sp. persisted across the three observation occasions. *Pyramidella* sp. is known to be a sensitive benthic organism (Shokat et al. 2010), thus its persistent across time in or study indicates that the environment quality was favourable in the ponds. *P. sulcata* (also known as *P. maculata*) has a wide habitat range including offshore areas (Willan et al. 2015; Leopardas et al. 2016), estuaries (Takarina and Adiwibowo 2010) and young mangrove ecosystems (Chen and Ye 2011). On the other hand, *P. ventricosa* is mostly found in seagrass beds (Kusnadi et al. 2008).

The presence of *Cerithidea cingulata* in the ponds indicates the effect of mangrove development on the environment. The species *C. cingulata* is adapted to habitats with a large tidal range, abundant silt and vegetation (Itsukushima et al. 2017). *Cerithidea* is known to be a mangrove-associated benthic species (Zvonareva et al. 2015). Thus, the presence of *C. cingulata* in the second observation period indicates that mangrove vegetation has impacted the pond ecosystem. Other research has shown showed that *C. cingulata* tends to move to shaded mangrove areas during warm seasons (Lorda and Lafferty 2012). It is to be noted that extracts of *C. cingulata* have been shown to have potential for antimicrobial activity against human and fish pathogens. Thus, it is possible that *C. cingulata* has beneficial biological effects in aquatic environments.

The presence of *N. luridus* observed in our study is also often related to mangrove habitats. Even though the main habitat of *N. luridus* is in seagrass beds (Paramasivam et al. 2014), it has nevertheless also been observed in other habitats, including harbors and mangrove patches (Monolisha and Edward 2015). The presence of *T. telescopium* also emphasizes the impact of the mangrove plantation. Sites associated with mangrove vegetation have been identified as the habitat of *T. telescopium*, even though it is known to be adapted to a variety of habitats (Yap 2014). Other research has suggested that *T. telescopium* prefers habitats that include muddy sediment and have low light intensity (Zaman and Jahan 2013). Thus, ecosystems with vegetation, such as silvofishery systems, should be favorable environments for the the species.

The changing numbers of plankton species in our study indicated that there were changes in the quality of the pond environments. Plankton abundance and composition reacts rapidly to changes in nutrient concentration and the aquatic environment (Arhonditsis et al. 2003). Thus, plankton is an appropriate indicator for measuring short-term environment quality changes and trends in nutrient levels (Karydis 2009). The fluctuating plankton species in our research suggested that the nutrient levels were changing dynamically. The high number of plankton species of the first observation period might be caused by better nutrient availability compared to the second and third observation periods, while the second observation might be the lowest condition.

Low benthos diversity indicates that a decline in the quality of aquatic environments (Sihombing et al. 2017). In our study the number of benthos species increased from the first observation period through to the third. Thus, the silvofishery ponds in the studied site perhaps experienced an improvement in water quality over time. The improvement in the benthos composition suggests a benefit derived from the mangrove vegetation in the silvofishery ponds.

High similarity indices in resident organisms between different locations could be caused by linkages between the sites or by similar habitat types (Sihombing et al. 2017). On the otherhand, Differences among the similarity indices suggest the possibility of different levels of eutropication in the pond ecosystems (Arhonditsis et al. 2003). Changing ecosystem conditions stimulate the presence of opportunistic species with rapid growth until the limit is reached.

Mangrove plays an important role in coastal ecosystems due to its high productivity. Mangrove provides nutrient cycling and pollutant filtering which results in improved water quality (Schade-Poole and Möller 2016). The existence of mangrove plants significantly effects physical and chemical parameters of the environment, such as temperature, total suspended solids (TSS), turbidity, salinity, dissolved oxygen (DO), soil organic matter, and N and P concentrations (Hastuti and Budihastuti 2016). Environment suitability and nutrient availability are likely to affect the diversity and growth of plankton and benthos within silvofishery pond. Thus, mangrove composition might affect the nutrient concentration which in turn affects plankton composition. Benthic organisms seem to prefer sheltered, shallow intertidal habitats (Colen et al. 2014) typical of well established silvofishery ponds. Change of sediment texture due to increasing sedimentation caused by mangrove trapping might also increase habitat suitability for benthic community improvement (Picanço et al. 2014).

Plankton species richness in the different pond treatments was varied across the three observation periods. The highest species richness at the first observation period was in treatment S3M3; in the second observation period, highest species richness was recorded in treatment S2M3; while in the third observation species richness was quite well distributed over the treatments S1M1, S1M3, S2M1, S2M2 and S3M1. This suggested that the trend over time in water quality was towards a more balanced condition. The fact that highest plankton species richness at the first and second observations was recorded in treatments S3M3 and S2M3 respectively, suggests that a mixture of mangrove species, may provide better water quality than a single mangrove species in the early development of silvofishery ponds. It is possible that a mixture of mangrove species provides improved nutrient availability for plankton.

On the other hand, benthos species richness of benthos in the early development of silvofishery pond was greater in those treatments with the single mangrove species *Avicennia marina*: treatment S2M1 in the first observation period; and treatment S3M1 in the second observation period. In the third observation period, benthos species richness was highest in those treatments having *Rhizophora mucronata* either as a single species or in mixture with *A. marina*; namely, treatments S1M3, S2M2, S3M1, S3M2 and S3M3. This might indicate changes in sediment structure or benthic nutrient supply.

The effect of mangrove variation on plankton and benthos species richness could be the result of variation in litter production and decomposition. The litter decomposition rate of *Avicennia* species is generally higher than that of *Rhizophora* species (Hossain and Hoque 2008; Siska and Kusmana 2016). Thus, more dissolved nutrients might be produced from *Avicennia* mangrove, while *Rhizophora* mangrove might produce more suspended nutrients. This is supported by the reserch findings of Sakho et al. (2015) who have reported that below-ground sediment structure in *Rhizophora* trees contains more silt than *Avicennia* trees, which contain more sand and clay.

Plankton and benthos composition are believed to be useful indicators of environment health in aquatic ecosystems to supporting aquaculture activities. Several plankton species are considered to be a natural feedstock for aquatic organisms of economic imortance (Budihastuti et al. 2013). However, there must be matched environmental conditions to support both the plankton and the dependent organism in the food chain. Organisms and environment within an ecosystem will change over time in response to ecosystem disturbances and services (Brander et al. 2016). In order to formulate appropriate aquaculture management plans, thorough consideration of potential change in the supporting ecosystems is required

In conclusion, the composition of plankton and benthos within silvofishery ponds in Coastal Semarang, was found to vary according to different mangrove plantation treatments and different observation occasions over time. There was notable fluctuation in species richness across time and between ponds with different treatments. Species richness of plankton tended to decrease while benthos tended to increase over time. High similarity indices between treatments were recorded for benthos community due to its low species richness. The differences in plankton and benthos species richness between the various mangrove treatments suggest that the two main mangrove species in the silvofishery research site each have different effects on the aquatic environment of the ponds: it is likely that *Avicennia marina* produces improvement in the water quality; while *Rhizophora mucronata* appers to produce sediment quality improvement.

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