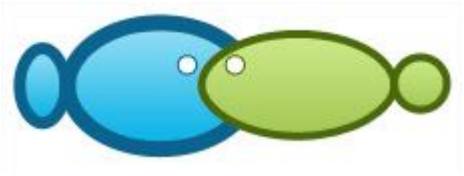

Biodiversity and spatial distribution of molluscs in Tangerang coastal waters, Indonesia

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Abstract. Tangerang coastal water is considered as a degraded marine ecosystem due to anthropogenic activities such as mangrove conversion, industrial and agriculture waste, and land reclamation. Those activities may affect the marine biodiversity including molluscs which have ecological role as decomposer in bottom waters. The purpose of this study was to describe the biodiversity and distribution of molluscs in coastal waters of Tangerang, Banten Province- Indonesia. Samples were taken from 52 stations from April to August 2014. Sample identification was conducted following the website of World Register of Marine Species and their distribution was analyzed by Canonical Correspondence Analysis (CCA) to elucidate the significant environmental factors affecting the distribution. The research showed 2194 individual of molluscs found divided into 15 species of bivalves and 8 species of gastropods. In terms of number, *Lembulus bicuspidatus* (Gould, 1845) showed the highest abundance with density of 1100-1517 indv m^{-2}, probably due to its ability to live in extreme conditions such as DO < 0.5 mg L^{-1}. The turbidity and sediment texture seemed to be key parameters in spatial distribution of molluscs.
Key Words: bivalve, ecosystem, gastropod, sediment, turbidity.

Introduction. Coastal waters are a habitat for various aquatic organisms including macroinvertebrates such as molluscs, crustaceans, polychaeta, olygochaeta and echinodermata. These organisms have slow movements or remain idle/sessile that their existence can be directly influenced by anthropogenic activities (Shin et al 2004). Molluscs are among natural marine and fisheries resources in Indonesia which can be found in coral reef ecosystems, mangroves, beaches with sand, mud and rock substrate. According to LIPI (The Indonesian Institute of Science) molluscs in Indonesia are amounted to 15,000 species (Kartika & Mu 2014).

According to Brusca & Brusca (1990), molluscs are commonly found in Aplacopora, Caudofoveata, Monoplacopora, Polyplacopora, Cephalopoda, Scaphoda, Gastropoda and Bivalve. The two largest classes of mollusc phyla are gastropods and bivalves (Dharma 2005). The existence of molluscs is very important in the marine community, and around 15-25% of macroinvertebrates are mollusc organisms (Sabelli et al 1990; Sabelli & Taviani 2014). In addition, molluscs play an important role in maintaining biodiversity and sustainability of marine ecosystems (Zenetos 1997).

The distribution and abundance of macroinvertebrates (mollusc) are important factors in ecological management (Aldea et al 2009). The abundance of molluscs has been playing a role in maintaining biodiversity and sustainability of an ecosystem and they are also beneficial for economic activities (Kartika & Mu 2014). Molluscs exploitation for economic activities is one of the causes of their biodiversity and abundance declining in that area. Economically, molluscs are exploited for regional and export market as nutritious food sources, jewelry, ornaments, and medicines (Lescinsky et al 2002; Venkatesan 2010). Molluscs are mostly traded in several countries such as Tanzania (Gössling et al 2004), Philippines (Salamanca & Pajaro 1996) and Mexico (Garza et al 2012). Molluscs exploitation for ornamental purposes, especially from gastropods and

bivalves, in Indonesia is found in Bali (Nijman et al 2015; Nijman & Lee 2016), Pangandaran (Nijman et al 2016) and Jakarta (Sancia et al 2009; Widianwari 2013). In addition, the decreasing of biodiversity and abundance of molluscs is also caused by tourism activities (Zahedi 2008) and decreasing of water quality (Wardiatno et al 2017). Molluscs, as macroinvertebrate biota, have very limited movement and relatively stay on one particular substrate (Barnes & Hughes 2004). It makes these animals more sensitive to environmental disturbances especially changes in water and sediment quality (Smorfield & Gage 2000; Shin et al 2004; Manoharan et al 2011) and anthropogenic activities (Zahedi 2008), therefore, the biodiversity and distribution of molluscs in coastal waters will vary from one area to another. For example, mollusc biodiversity in the bay of Jakarta has decreased since 1997-2013 (Kastoro et al 2007, 1997; Sancia et al 2009; Widianwari 2013). Previous research on molluscs on the coast of Banten was carried out by Kastoro & Aswandy (1989) who found that there were 14 species of molluscs in that area. Therefore, human and industrial developments in Tangerang region will have an impact on the abundance and biodiversity of moluscs.

Tangerang coastal waters are directly adjacent to Jakarta Bay which has many community activities including industry, fisheries, housing and tourism. These activities have negative impacts such as coastal erosion, pollution and organic waste accumulation. Therefore, Tangerang coastal waters area belongs to one of the coastal areas with a high level of vulnerability. Pollutants which enter the Tangerang coastal waters area are not only organic materials but also toxic substances (poisons) that are harmful to aquatic biota (Al-Hakim 2010). However, researches on the degradation of molluscs in coastal waters area of Tangerang are still limited. The most recent study related to molluscs degradation in Tangerang coastal waters was carried out by Kastoro & Aswandy (1989). Therefore, further study on the diversity of molluscs in Tangerang coastal waters are required to find out the actual condition. Hence the present study was performed.

Material and Method

Research location. The research was conducted from April to August 2014 in coastal waters of Tangerang, Tangerang Regency, Banten Province, Indonesia. Research site was located on $5^{o}50'16.91"S$ – $6^{o}12'44.59"S$ and $105^{o}54'33.45"E$ – $106^{o}43'39.62"E$. There are 52 observation stations which spread into 3 different locations, namely Kronjo (K) with 15 stations, Cituis (C) with 15 stations and Tanjung Pasir (T) with 22 stations (Figure 1).

Sampling and identification of molluscs. Mollusc samples were taken at each station as many as 3 replications using the Van Veen grab with the jaws of 0.04 m^2. The sample was filtered by modified macrozoobentos filter with mesh size of 0.5 mm to separate the molluscs from the mud (substrate). Samples were preserved with formaldehyde solution with a concentration of 10%. Small-sized samples were observed in the laboratory by using binocular microscope, while larger-sized samples were observed by using a magnifying glass. Mollusc identification was performed by means of comparing the morphology of samples with the standard mollusc identification book in Indonesia (Dharma 2005) and writing nomenclature following the World Register of Marine Species (WoRMS: http://www.marinespecies.org/index.php). All mollusc specimens were identified at the Bogor Agricultural University BIOMIKRO Laboratory.

Data analysis. Water samples from each station were analyzed to see the water quality parameters (temperature, clarity, salinity, acidity (pH), turbidity and dissolved oxygen (DO)). Organic carbon and sediment particle size (sand, mud) were analyzed using the "wet sieving" method (Buchanan 1984). Molluscs biodiversity was analyzed according to the Shannon-Wiener index (H'), species richness indices (J') and species dominance (D). Spatial distribution of molluscs was analyzed by using silimilarity index and canonical correspondence analysis (CCA) (Braak & Verdonschot 1995) with the help of MINITAB v15.1.2-EQUiNOX software.

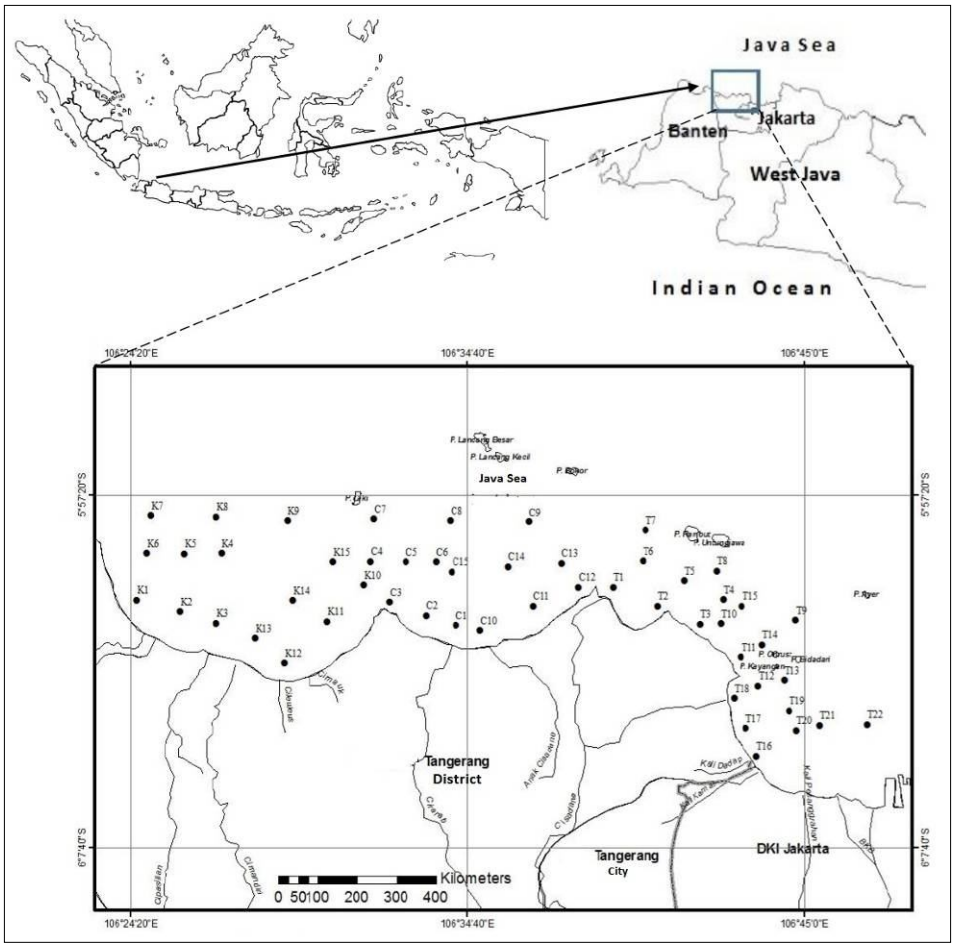

Figure 1. GIS location of sampling sites in Tangerang Coastal Waters, Banten Province, Indonesia. K=Kronjo location (K1-K15), C=Cituis location (C1-C15) and TJ=Tanjung Pasir location (T1-T22).

Results

Water quality and sediment parameters. The results of water quality measurements for each station can be seen in Table 1. The results showed that temperature, pH and salinity of each samples taken from every station were not significantly different. However, DO and turbidity parameters were significantly different in each location. DO and turbidity value in Tanjung Pasir locations have a wide range value at several stations with by 0.5-10.5 mg L^{-1} and 0.4-21.6 NTU. Whereas in Kronjo and Cituis locations have wide range differences in values only on turbidity parameters by 0.8-43.6 NTU and 0.8-13 NTU respectively. Based on the composition of the sediment size, the highest sand composition in sediment was found in the Cituis location with a value of 45.7%, while the lowest sand composition in sediment was found in the Kronjo location with a value of 19.5%. On the contrary, the highest mud concentration was found at Kronjo's location by 80.5% and the lowest mud concentration was found on the Cituis location with a value of 54.3%.

The value DO in the Tanjung Pasir location was ranged by 0.5-10.6 mg L^{-1}. Based on this range, it can be inferred that there are several stations with a very low DO values, namely T12 = 4.0 mg L^{-1}, T16 = 2.5 mg L^{-1} and T17 = 0.5 mg L^{-1}. These stations are located in the easternmost of Tanjung Pasir location which is adjacent to the Jakarta Bay, precisely in Muara Angke and Muara Kamal.

The highest composition of sand was found in Cituis locations by 41-50.7%, while the sediment in Kronjo and Tanjung Pasir location was dominated by mud substrates with a range of 45.0-86.85% and 17-85.8% respectively. The organic C content varies between locations. The highest organic C content was found in Tanjung Pasir location by

0.68-2.88% with an average of 1.73%, while organic C content found in Cituis location was ranged from 0.38-2.66% with an average of 1.35%. Meanwhile, the lowest organic C content was found in Kronjo by 0.14-2.43% with an average of 1.13% (Figure 2).

Table 1

Condition of physio-chemical environmental factors in the research location

Parameters	Unit	Location					
		Kronjo (K)		Cituis (C)		Tanjung Pasir (T)	
		x	r	x	r	x	r
Water quality							
Temperature	°C	30.0±5.1	29.7-30.6	30.4±3.6	30.0-30.7	30.9±1.2	30.3-31.5
pH		8.2±1.3	8.1-8.3	8.3±1.9	8.1-8.4	8.3±1.1	7.1-8.5
Dissolved oxygen	mg L^{-1}	7.3±2.7	6.5-8.3	7.7±1.4	6.8-8.9	8.1±2.7	0.5-10.6
Salinity	‰	29.3±1.7	28.6-30.3	29.3±5.3	27.5-30.2	28.8±2.9	12.2-30.3
Turbidity	NTU	11.6±2.1	0.8-43.6	9.6±3.6	0.8-130	3.7±2.6	0.4-21.6
Sediment parameters							
Sand	%	19.5±4.5	13-25	45.7±10.7	36-62	32.0±10.6	18-44
Mud	%	80.5±4.5	75-87	54.3±10.7	38-64	68.0±10.6	56-82
C-organic	%	1.2±0.1	1.1-1.3	1.3±0.2	1.0-1.4	1.6±0.1	1.6-1.7

note: x = average; r = range.

The diversity and ecological indices of molluscs. There are 2194 of moluscs found on 52 stations located on the Coastal Waters of Tangerang, Banten province. These moluscs are classified into 23 species belonging to 15 families. Bivalve class was found in 15 species and gastropods by 8 species (Table 2). There are 9 species of bivalves and 6 species of gastropods found in Kronjo, 3 species of bivalve and 3 species of gastropods found in Cituis and 9 species of bivalve and 4 species of gastropods found in Tanjung Pasir locations.

Table 2

List of species recorded in the study area

Family	Species*	K	C	T	Habitat
	BIVALVIA				
Archidae	*Tegillarca granosa* (Linnaeus, 1758)	+			md,Cz, Sz
Astartidae	*Astarte sulcata* (da Costa, 1778)	+			md, Cz
Cardiidae	*Cerastoderma edule* (Linnaeus, 1758)			+	md, Cz
Lucinidae	*Codakia punctata* (Linnaeus, 1758)	+++	+	++	md, Cz,Sz
Mytilidae	*Brachidontes erosus* (Lamarck, 1819)			+	md, Cz
	Perna viridis (Linnaeus, 1758)			+	md, Cz, Inv
Nuculanidae	*Lembulus bicuspidatus* (Gould, 1845)	++		+++	md, sn, Cz, Sz
Pharidae	*Ensis ensis* (Linnaeus, 1758)			+	md, Cz
	Phaxas pellucidus (Pennant, 1777)	+			md, Cz
	Pharella javanica (Lamarck, 1818)			+	md, Cz
	Siliqua radiate (Linnaeus, 1758)	+			md, sn, Cz
Tellinidae	*Quidnipagus palatam* (Iredale, 1929)		+	++	md, sn, Cz, Sz
	Tellina radiata (Linnaeus, 1758)	+			md, sn, Cz
	Tellinides timorensis Lamarck, 1818	+	+	+	md, sn, Cz, Sz
Veneridae	*Dosinia dilecta* (A. Adam, 1856)	+			md, sn, Cz
	GASTROPODA				
Clavatulidae	*Turricula javana* (Linnaeus, 1767)	+		+	md, Cz
Conidae	*Conus radiates* (Gmelin, 1791)		+		sn, Cz
Nasariidae	*Nassarius conoidalis* (Deshayes, 1832)	+		+	md, sn, Cz, Sz
	Nassarius dorsatus (Roding, 1798)	+	+	+	md, Cz
Naticidae	*Natica fasciata* (Roding, 1798)	+	+		md, Cz, Sz
	Notocochilis tigrina (Roding, 1798)	+			md, Cz
Triphoridae	*Costatophora princeps* (G. B. Sowerby III, 1904)			+	md, Cz
Turritellidae	*Turritella terebra* (Linnaeus, 1758)	+			md, sn, Cz

Location (K = Kronjo; C = Cituis; T = Tanjung Pasir); Habitat (md = mud; cl = clay; and sn = sand); Zone (Cz = coastal zone; Sz = sea zone); Inv = invasive species molluscs); and + = recorded; ++ medium recorded; +++ = high recorded; *identification by Dharma (2005) and nomenclature name by WoRMS: http://www.marinespecies.org/index.php.

Based on Tables 2 and 3, it can be seen that the station located in Kronjo has the highest composition of molluscs with 15 species and abundance with 1245 ind m^{-2}. In addition to that, the lowest composition of molluscs was found in Cituis location by 6 species and abundance 156 ind m^{-2}. Meanwhile, number of individual and dominance index showed in Tanjung Pasir location with 3231 individual from 22 station and dominance index 0.72 (Table 3). Among all the species caught in this research, *Codakia punctata* and *Lembulus bicuspidatus* were dominating by 36.69% and 33.06% respectively. *C. punctata* was found in almost all stations in Kronjo location, whereas *L. bicuspidatus* was found in T12, T17 and T18 stations in Tanjung Pasir locations. In addition, the density in these stations was high but the number of species was low (Figure 2).

Table 3

The ecological indices of each location

Index	*Kronjo*	*Cituis*	*Tanjung Pasir*
Number of individuals	1185	123	3231
Number of species	15	6	13
Abundance (ind m^{-2})	1245	156	822
Shannon-Wiener index (H')	1.91	1.29	2.29
Dominance index (D)	0.34	0.53	0.72

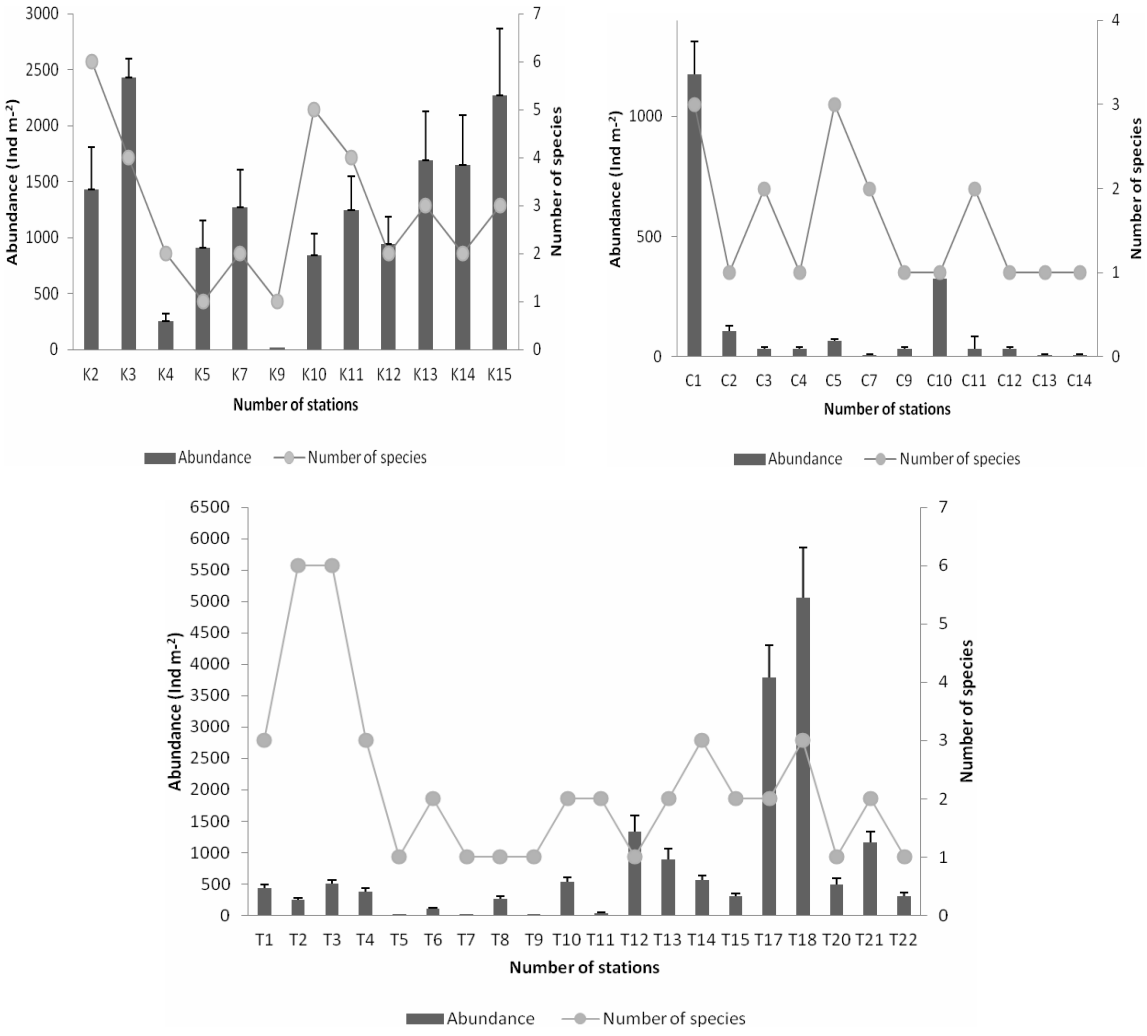

Figure 2. Avarage of abundance and number of species molluscs at every station (2.K = Kronjo site, 2.C = Cituis site, and 2.T = Tanjung Pasir site).

Stations K3, K13, K15 (Figure 2.K), C1, C10 (Figure 2.C), T2, T12, T17, T18 (Figures 2.T) which adjacent to the river were found to have high mollusc densities and high deviation values. On the other hand, no molluscs were found in stations K1, K6, K8 (Figure 2.K), C6, C8, C15 (Figure 2.C), and T16 (Figures 2.T), but there are other invertebrates found in that area (Figure 1). Based on zoning classification, 16 species of identified molluscs were only found in the coastal zone, while 7 species were found in both the coastal and marine zone namely *Tegillarca granosa, C. punctata, L. bicuspidatus, Quidnipagus palatam* and *Tellinides timorensis* from bivalve class and *Nassarius conoidalis* and *Natica fasciata* from the gastropod class.

Spatial distribution pattern of molluscs. Evaluation of molluscs spatial distribution in Tangerang coastal waters was determined by canonical correspondence analysis (CCA) and cluster analysis. The distribution of molluscs based on cluster analysis was conducted based on the abundance of molluscs in every station which spread into 5 main groups (Figure 3). Group I has 9 stations located in Kronjo's location (Figures 1 and 3). Based on the species abundance in group I, it was dominated by two bivalve species namely *Codakia punctata* and *Lembulus bicuspidatus*. Both species were found in stations located in Kronjo with high abundance. Group II is dominated by stations in the Tanjung Pasir location (16 stations) and 2 stations in the Cituis (Figures 1 and 3), stations in group II were dominated by 4 families of molluscs namely Nuculanidae, Telinidae, Pharidae and Cardiidae. The group III is stations at Cituis location (8 stations) (Figure 3). Species which dominating around stations in this group are gastropod (Turritelidae phyllum, Turritella terebra species). Stations C3, C12 and T9 were grouped into group IV due to the unique species found in these stations which are not found in other stations. And Group V is only occupied by T5 station because there is only one species found in this station, namely *Ensis ensis*.

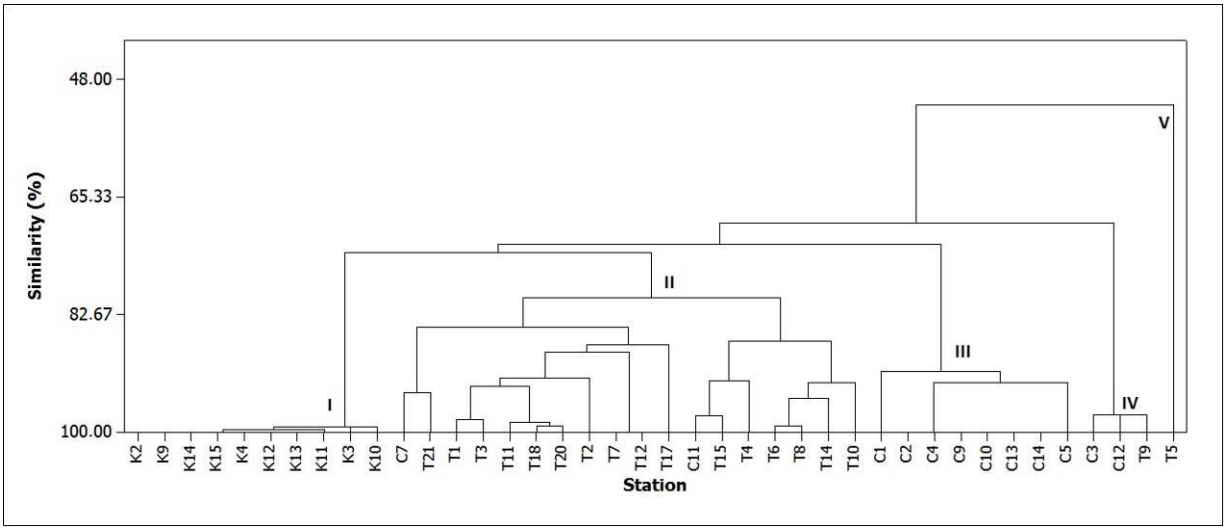

Figure 3. Dendogram of species association.

The result of CCA analysis showed that turbidity parameters are the main parameters affecting the presence of molluscs (Figure 4). The CCA diagram shows that 14 species of molluscs were gathering around turbidity parameter. Meanwhile, there are 4 species namely *Nassarius conoidalis, Perna viridis, Dosinia dilecta* and *Costatophora princeps* with cosmopolitan nature. However, *Codakia punctata* is close to the mud substrate.

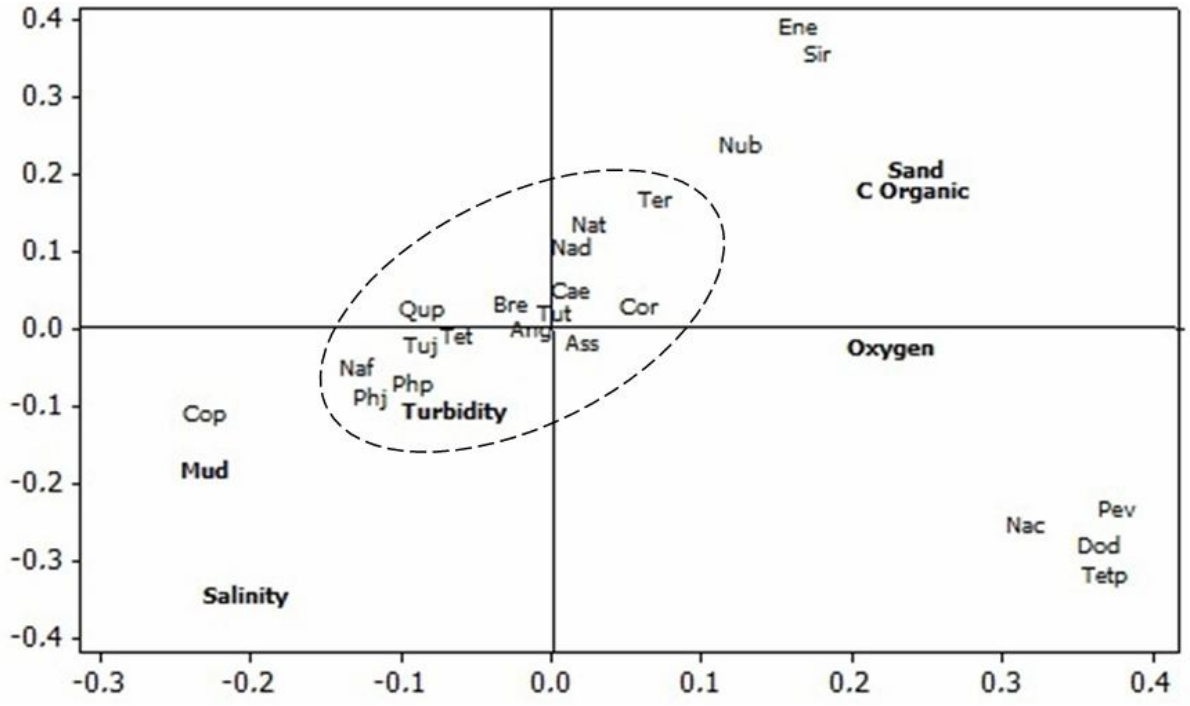

Figure 4. Biplot of CCA performed on abundance of species and environmental variable in the study area. Ang = *Tegillarca granosa,* Ass = *Astarte sulcata,* Bre = *Brachidontes erosus,* Cae = *Cardium edula,* Cop = *Codakia punctata,* Dod = *Dosinia dilecta,* Ene = *Ensis ensis,* Pev = *Perna viridis,* Phj = *Pharella javanica,* Php = *Phaxas pellucidus,* Sir = *Siliqua radiata,* Qup = *Quidnipagus palatam,* Ter = *Tellina radiata,* Nub = *Lembulus bicuspidatus,* Tet = *Tellinides timorensis,* Cor = *Conus radiates,* Nac = *Nassarius conoidalis,* Nad = *Nassarius dorsalis,* Naf = *Natica fasaciata*, Nat = *Notocochilis tigrina,* Tetp = *Costatophora princeps,* Tuj = *Turicula javana,* Tut = *Turritella terebra*.

Discussion. Tangerang coastal area is characterized by industrial, fishery, residence and tourism activities (Sahidin et al 2014). These activities have negative impacts such as coastal erosion, pollution and organic waste. Therefore, the coastal area in Tangerang is classified as one of coastal areas in Indonesia with high level of vulnerability. The flow that enters the coast of Tangerang is not only organic matter, which is rich in nutrients, but also toxic substances (poisons) that are harmful to aquatic organisms (Yonvitner et al 2012). Based on topography, Tangerang coast borders the coast of Jakarta. Riyadi et al (2012) stated that Jakarta coastal area is highly polluted and this condition will impact the surrounding areas including western part of Tangerang coastal area. Pollution status in Tangerang coastal area is classified as medium-heavy polluted with disturbed ecological status (Wardiatno et al 2017; Sahidin et al 2018). In addition, Tangerang coastal waters are contaminated by heavy metals such as cadmium (Cd), copper (Cu), mercury (Hg), and lead (Pb) (Hariyadi et al 2017). Therefore, these conditions will impact the diversity and distribution of molluscs especially gastropods and bivalves.

Molluscs' distribution is shown in certain living habitats, certain areas and certain times. The lowest density of both gastropod and bivalve was found at Cituis location with coarse sand as the characteristics of substrate. Sand substrates is badly related to the density and species biodiversity of macrozoobenthos (Lizarralde & Pittaluga 2010; Gholizadeh et al 2012; Sahidin et al 2014), including molluscs (Joydas & Damodaran 2009; Rahmawati et al 2015). Low density of molluscs in sand substrates is caused by the inability of molluscs, especially gastropods, to attach in the substrates. Substrate type is important to pick place for gastropods to survive from the continuous wave action that can move substrate particles (Nybakken 1992; Irma & Sofyatuddin 2012; Pyron & Brown 2015). Meanwhile, Kronjo and Tanjung Pasir have mud substrates. Mud substrate can bind organic matter in the sediments. Organic matter is a food source for Gastropoda and Bivalvia. Texture of substrate and organic content in sediments are important factors in benthic community structures (Kari 2002; Sahidin et al 2014), including molluscs.

Bivalvia class can grow and multiply well on mud substrates which contain large amounts of organic matter, especially infauna (Dauer et al 2000; Nybakken & Bertness 2005; Sundaravarman et al 2012; Yolanda et al 2015).

Stations T12, T17, and T18 have high average density, but low number of species (Figure 2). The results of DO measurement values on these three stations are very low, ranging from 0.5 to 4.3 mg L^{-1} (Table 2), the DO value is below the quality standard for the life of marine biota based on Ministry of Environment decree of Indonesia No. 51 Year 2004 about sea quality standards with DO values > 5 mg L^{-1}. Rumahlatu & Leiwakabessy (2017) state that the relationship between DO and molluscs, especially gastropods, are very tight, the higher DO values correlate positively with the high abundance and diversity of molluscs. The oxygen parameter is very important for the metabolism of aquatic organisms. Low DO will cause death in some aquatic organisms due to hypoxia. It will also cause disruption of growth and reproduction in molluscs, and will also increase the susceptibility to disease (McClain & Rex 2001; Weisberg et al 2008). Low DO levels will result in the loss of the mollusc community at these stations. However, the result showed that *L. bicuspidatus* was dominating in T12, T17, and T18 stations in a very large number with the abundance in range of 1100-1515 ind m^{-2}. *L. bicuspidatus* is a Bivalvia species that is small, opportunistic and tolerant of low DO (Zettler et al 2009; Sahidin et al 2018).

Stations K3, K13, K15, C1, C10, T2, T12, T17, T18 (Figures 1 and 2) which are adjacent to the river mouth are found to have high molluscs densities and high deviation values. This means that molluscs composition at that stations is very dynamic or easily to change in a short period. The dynamics of molluscs at these stations happened due to changes in material input such as organic matter, nutrients and pollutants at certain times. River estuary is a gathering place for pollutants from both organic and inorganic materials derived from anthropogenic activities carried by rivers (Al Hakim 2010; Martin et al 2011; Riyadi et al 2012; Wardiatno at al 2017) and toxic materials such as heavy metals which will be sedimentated (Abrahim & Parker 2008). Therefore, the high oxygen consumption at these locations happens for organic matter decomposition. This decomposition activity will result in fluctuations in DO in water which have an effect on the biodiversity and abundance of aquatic organisms (Rumahlatu & Leiwakabessy 2017; Wardiatno et al 2017). *C. punctata* was found in many of these stations, whereas *L. bicuspidatus* was found in T12, T17 and T18 stations located in Tanjung Pasir. In addition, these stations have a high average density of molluscs but low number of species (Figure 2). According to Mikkelsen (2011), bivalves tend to settle in one place and form a cluster. These marine organisms can inhabit various places because they have a mechanism of adaptation that is good enough for their survival.

The distribution of aquatic organisms including molluscs is strongly influenced by water quality parameters. Based on the results of the CCA analysis (Figure 4), the turbidity is the most closely correlated with the abundance of the molluscs species found in these waters. There are 14 species out of 23 species that gather close to the turbidity parameter. This condition is most likely caused by respiratory blockade on aquatic organisms, the increasing of predators and germs, and depleting in DO in the waters (Heral & Berthome 1991; Hamsiah et al 2016).

Conclusions. The parameters of the turbidity and sediment texture in this study are found to be the key parameters in the spatial distribution of molluscs (gastropods and bivalves) in coastal waters of Tangerang, Banten, Indonesia. *Lembulus bicuspidatus* is an extreme species of mollusc found in the water with DO concentrations < 0.5 mg L^{-1} at stations T12, T16 and T17 with density of 1100-1517 individual m^{-2}.

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