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Original Paper

DIATOM STRATIGRAPHY OF MANGROVE ECOSYSTEMS ON THE NORTHERN COAST OF CENTRAL JAVA

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ABSTRACT

The natural mangrove ecosystems along the Northern Coast of Central Java were very limited in extent, even had replanted almost twenty years ago. Naturally, the upper layer of sediment are the latest deposition (superposition). Environmental condition recently are recorded in the top sediment layer, and can be used to reconstruct past condition (the present is the key to the past). The potential use of diatoms to reconstruct palaeoecology is well established. Diatoms are microscopic algae that form siliceous frustules which make them well preserved in sediment. Diatoms and their assemblages are very useful as integrated indicators of environmental changes because their distribution is closely linked to water quality parameters as well as their affinities to several physical habitats. This research was conducted in order to determine the changes of mangrove ecosystem in the Northern Coast of Central Java based on diatom stratigraphy. Sediment samples from mangrove sites were taken from Pekalongan, Brebes, Semarang, Demak and Rembang. Diatom analysis, consist of digestion, preparation, and identification. The diatom stratigraphy was performed by Software of C2 1.5.1. Stratigraphycally, the mangrove ecosystems along the Northern Coast of Central Java were previously more influenced by freshwater rather than the marine sources which dominate today.

Keywords : Diatom; palaeoreconstruction; stratigraphy; mangrove; Central Java

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INTRODUCTION

One of Millennium Developing Goals (MDGs) is towards environmental conservation. As a maritime nation, Indonesia has 17,508 islands with a beach area of 81,000 km^2, of which 42,500 km^2, or 4.25 million hectares are mangrove forests rich in diversity (Aizpuru *et al*., 2001). However, recently, this area has reduced sharply to 2.49 million hectares (60%) by which 59% located in Papua and only 11% in Java. Anwar and Gunawan (2007) stated that the rate of mangrove forest reduction was 530,000 ha/year; meanwhile the rate of rehabilitation area was only 1,973 ha/year (Departmen Kehutanan, 2004). The expansion of settlement and agriculture seem to be the major causes of that reduction (Noor, *et al*., 1999) as well as the exapansion of marine aqua culture, logging, reclamation/sedimentation, and environmental pollution (Setyawan and Winarno, 2006).

The unique biological resources, including mangrove ecosystems, is one of five potency that elevate Indonesia to one of the largest five countries in the world after China, India, USA, and Uni-Europe, as stated in Indonesia's vision towards 2030.

Mangrove forests make a significant contribution to human welfare. Ecologically, mangrove ecosystems function as nutrient sources; increase fisheries productivity; reduce sea water intrution, increase mosquito population, reduce heavy metal pollution; habitat for wildlife, such as mammals, reptiles and birds (Anwar and Gunawan, 2007); reduce wave's energy and reduce tsunami effect (Pratikno, *et.al.*, 2002; Istiyanto, *et.al.,* 2003). Economically, mangrove forests provide elementary materials for fuel, houses material, chip material, tanin for shoes and bag industries, palm roof, medicine, agriculture, aquaculture,

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and tourism (Quarto, 2002; Anwar and Gunawan, 2007). However, these values had been degraded along the Northern Coast of Central Java owing to anthropogenic activities had expanded sharply, such as over exploitation mangrove forest for fishery, logging, pollution and habitat degradation have threatened its existence. The expansion of aquaculture was the main factor reducing mangrove forest (Setyawan and Winarno, 2006). Reclamation for domestic settlement is the main reason for the loss of mangrove ecosystems in Semarang. This condition had induced sea water intrusion of 4 – 6cm/year. Consequently, flooding frequently threatens Semarang (Suara Merdeka, 2004).

An environmental problem that requires a serious consideration in Indonesia, particularly in Central Java, is sea water intrusion which induces a condition termed *rob*. This term refers to the onset of high sea level permeating the ground water that often induces flooding even without rainfall or runoff. Much effort had been spent on the prevention and conservation of mangrove forests, through replantation and rehabilitation, to develop cooperation between institutions, both nationally even internationally, as well through public involvement. However, the mangrove ecosystem in Central Java is still far from performing their function as a coastal barrier of wave action and to prevent aquaculture from inundation during high tide. Many reforestation programmes of mangrove ecosystems have failed, due to the poor matching of the plant with the environment (Setyawan and Winarno, 2006).

Each zone provides a specific habitat, particularly for the ecosystem mangrove, which is site specific and depends on the geographical location, both vertically or horizontally. Limited data on the previous condition of mangrove ecosystems, and data on its palaeoecology, are among the main problems concerning to the failure of rehabilitation. This type of data is very important in establishing the baseline condition to guide prevention and conservation measures, and even the replantation program. Therefore, a first step that should be undertaken before implementing a replantation program is the reconstruction the past condition. This can be done using diatom paleoecology.

Diatoms are a powerful bioindicator of environmental changes as they have short life cycles, reproduction rapidly, represent many species most of which are sensitive to the environmental change and they respond rapidly. Furthermore, they are easily sampled and prepared as well as identified, and are inexpensive to sample and analyse (John, 2000; Dixit, *et. al.,* 2001; Gell, *et al.,* 2007; Reid and Ogen, 2009). Relevant to this study, diatoms have been used to identified late holocene tsunamis at Swantown Marsh, Whidbey Island, Washington (Williams and Hutchinson, 2000), to reconstruct the palaeoecology on Walden Pond, Massachusetts, USA (Koster, *et al.,* 2005), to describe diatom assemblages from tsunami sandy deposits in Thailand (Kokocinski, *et al.*, 2009).

In Indonesia, diatoms have been used to map river water quality in seven rivers along the Northern Coast of Central Java (Soeprobowati, *et al.,* 1999; 2001), to analyse for the impact of urbanization on Pekalongan (Soeprobowati and Rahardian, 2003), to reconstruct ecological changes in Rawapening Lake of Central Java (Soeprobowati, *et al.,* 2005).

This research is conducted in order to reconstruct the palaeoecology of mangrove ecosystems along the Northern Coast of Central Java based on fossil diatom communities. It is anticipated that this research will provide insights into the ecological condition of the past, to enable the reforestation to be developed towards ecological conditions similar to the past.

MATERIALS AND METHODS

Sampling

There are five littoral regions supporting mangrove ecosystems along the Northern Coast of Central Java, i.e. Randusanga (Brebes), Sigandu (Pekalongan), Kemijen (Semarang), Surodadi (Demak) and Kaliuntu (Rembang). Each region consists of two sites (**Fig. 1**). Triplicate sediment samples were taken from each site using modified core barrel (4 cm in diameter 50 cm in length; Willard and Holmes, 1999). This activity was done during the lowest tides. Each sediment core was then subsampled at 2 cm intervals. Samples code consists of sampling sites (B for Brebes, P for Pekalongan, S for Semarang, D for Demak and R for Rembang). The number after site code means the sediment layers: 1 for 0-2 cm; 2 for 2-4 cm; 3 for 4-6 cm, etc.

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Fig.1. Sampling Sites in the five survey regions : Randusanga Brebes (B), Sigandu Pekalongan (P), Kemijen Semarang (S), Surodadi Demak (D) and Kaliuntu Rembang (R).

Diatom Analysis

Diatoms were separated from the sediment by adding a strong acid and potassium dichromate. This suspension was heated and allowed to settle. Distilled water was added after supernatant was discharged. This was done repeatedly until the pH was neutral (7). The washed frustules were mounted in enthelan and examined by optical microscope at 400 – 1,000 magnification. In each sample, an average of 100 valves was identified in order to establish the relative abundance of the species (Round, 1993).

Data Analysis

The cluster analysis was done using Programme PAST - Palaeontological Statistics, ver 0.99 produced by Hammer, Harper, Ryan, *at al.,* (2004). The biostratigraphy was done by Software of C2 1.5.1 (Juggins, 2003).

Results And Discussion

Vertical diatom composition in the mangrove ecosystem from 5 sites along Northern Coast of Central Java were tend to differ that reflected environmental changes. Generally, all mangrove ecosystems at the research sites have a circumneutral to alkaline pH, indicated by the presence of *Cyclotella, Staurosira construens* Ehrenberg, *Fragilaria. capucina* Desmazieres, *Nitzschia palea* (Kutzing) W. Smith (Rosen, *et al.*, 2000) *Fragilaria* sp., *Cocconeis placentula* Ehrenberg and *Rhoicosphenia abbreviata* (C.Agardh) Lange-Bertalot (Gell, *et al*., 1999; Forel and Grafel, 2002), although the presence of *Fragilariforma virescens* (Ralfs) D.M. Williams and Round suggests lower more acid conditions at times.

Mangrove ecosystem in Pekalongan were mesotrophic that indicated by the abundance of *Cyclotella, Nitzschia,* and *Synedra ulna* (Nitzsch) Ehrenberg in all layers (Round, 1993). It seems that mesotrophic conditions have prevailed for a long time in Pekalongan possibly since the development of textile industries in Pekalongan **(Fig.2)**. Aquatic ecosystems are regarded as mesotrophic whenever the total nitrogen concentration is 500-1500 µg/L (Barus, 2002). This assessment is supported by the water quality data, particularly that of total nitrogen concentration, which was in the range of 407.6-524.8µg/L, at the lower end of the mesotrophic range.

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Cyclotella meneghiniana Kutzing in Brebes (**Fig. 3**) and Semarang (**Fig. 4**) tend to to increase as the sediment layers were younger. This trend was also found for *Thalasiosira* sp. From Brebes and Demak (**Fig. 5**). *Coscinodiscus* was found to be abundant in Demak (**Fig. 5**). Based on the presence of those species, as well as *Eunotia* and *Aulacoseira distans* (Ehrenberg) Simonsen (Forel and Grafel, 2002), the mangrove ecosystems of Brebes and Demak were considered to be in a mesotrophic condition.

The abundance of *S. ulna* (Nitzsch) Ehrenberg was highest in Rembang (**Fig. 6**), and moderately high in the Semarang and Demak layers of 14-20 cm. *S. ulna* (Nitzsch) Ehrenberg is a widely tolerant species and found almost in all freshwater ecosystems in Indonesia, both in lotic ecosystem (rivers) and even in lentic ecosystems (lakes). Whenever its relative abundance exceeds 60% organic pollution is indicated (Soeprobowati and Rahardian, 2003; Soeprobowati, *et.al.,* 1999, 2001, 2005). The population of *S. ulna* (Nitzsch) Ehrenberg, at almost in all sites, was quite high suggesting the freshwater inputs have affected the mangrove ecosystem significantly.

Along with *S. ulna* (Nitzsch) Ehrenberg, the presence of *Cymbella and Meridion circulare* (Greville) C. Agardh indicate the influence of freshwater flows to the mangrove ecosystem. *Coscinodiscus* is a mesohalobous species (0.2 - 30 ‰), whereas *S. ulna* (Nitzsch) Ehrenberg is oligohalobous species with the salinity of 0.02 ‰ (Gell, *et al*., 1999).

Based on the dendrogram from the cluster analysis using Bray-Curtis similarity (**Fig. 7**), for diatom species with relative abundance of more than 2%, it can be reconstructed that there are four groups of sites. Ecologically, the mangrove ecosystem of Pekalongan is similar to Semarang (about 50%, called Group I); Rembang is grouped with Brebes and Demak in the layers of 8, 9, and 10 (Group III). Ecologically, the mangrove ecosystem in Rembang relatively more stabile than other sites, indicated by the Bray-Curtis similarity of more than 50%. This result was supported with the research conducted in 1998, that based on rivers' diatom, Karanggeneng River (Rembang) was relatively unpolluted river (Soeprobowati, *et al.,* 1999). Rembang has 30% similarity with Demak in past (layers 8-10) and Brebes (layers 3-6). The diatom flora of the mangrove ecosystem in Demak is distinctive compared with the other sites, particularly in the recent sediments (Group IV). This site may be distinctive on the basis of the success of mangrove rehabilitation.

Saltwater intrution had occur in the Northern Coast of Central Java (Suara Merdeka, 2004). Some region in Semarang had land subsidence elevation 10 cm per year, that induce widening sea water intrution (Kodoatie cited in BBC Indonesia, 2007). The sites that previosily dominated by freshwater change to the saltwater. Any restoration program needs to consider the past condition represented by the paleoenvironmental record. The unsuccessful replantation program might be correlated to the unsuitable of the plants in the replanting. The prevalence of freshwater in the system suggests that the plants selected should be more tolerant of freshwaters and not merely marine conditions.

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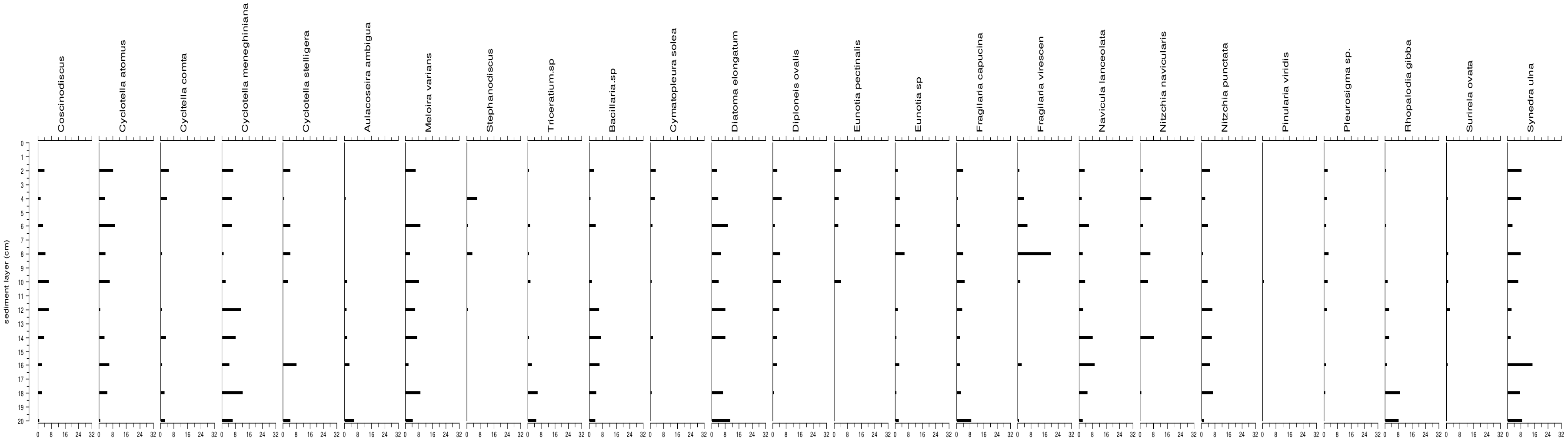

Fig. 2. Biostratigraphy based on the relative abundance of dominant diatoms in mangrove ecosystem of Sigandu Pekalongan.

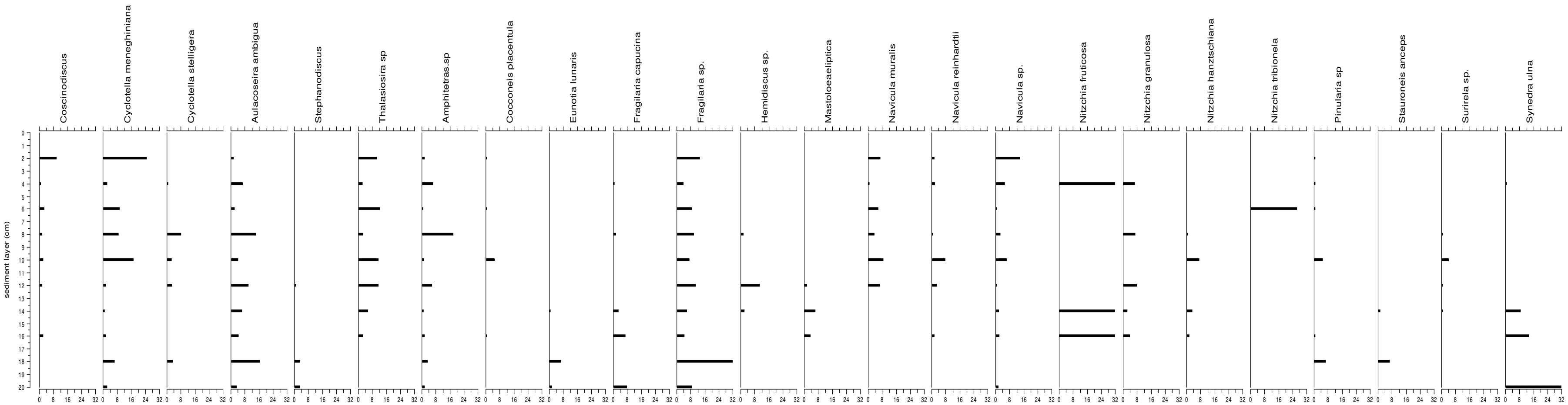

Fig. 3. Biostratigraphy based on the relative abundance of dominant diatoms in mangrove ecosystem of Randusanga Brebes.

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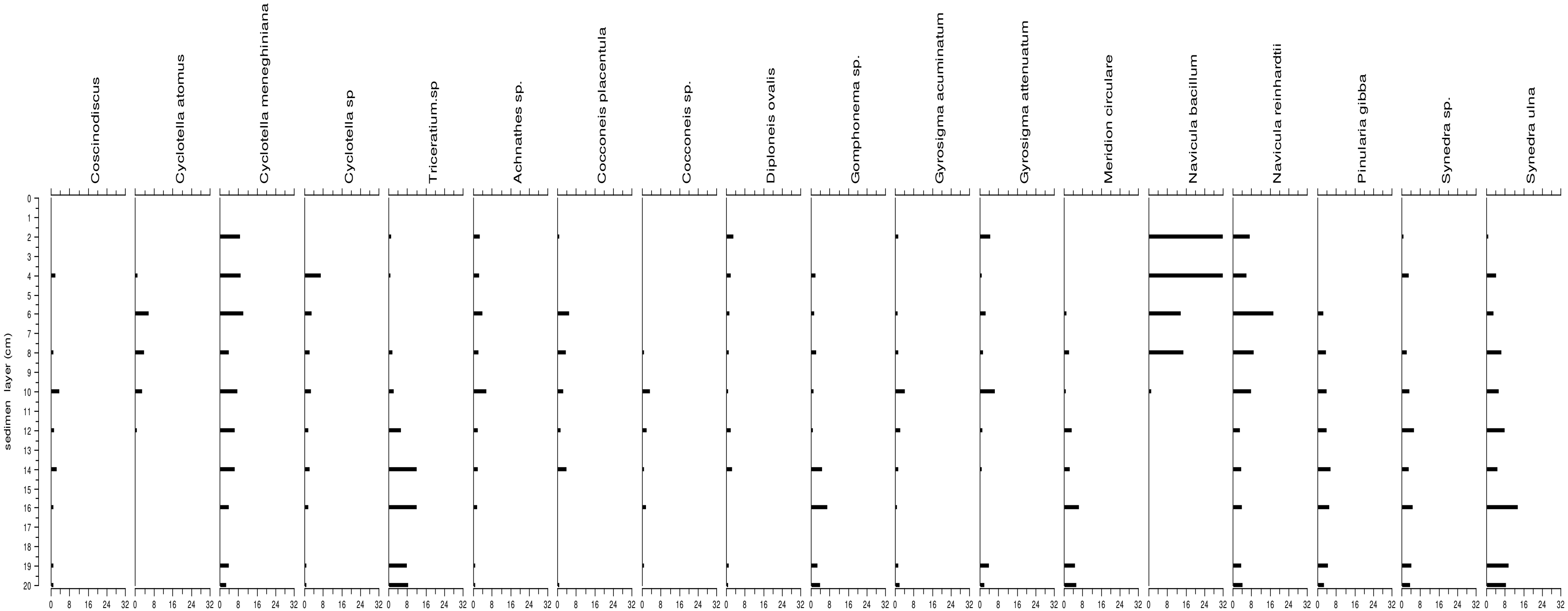

Fig. 4. Biostratigraphy based on the relative abundance of dominant diatoms in mangrove ecosystem of Kemijen Semarang.

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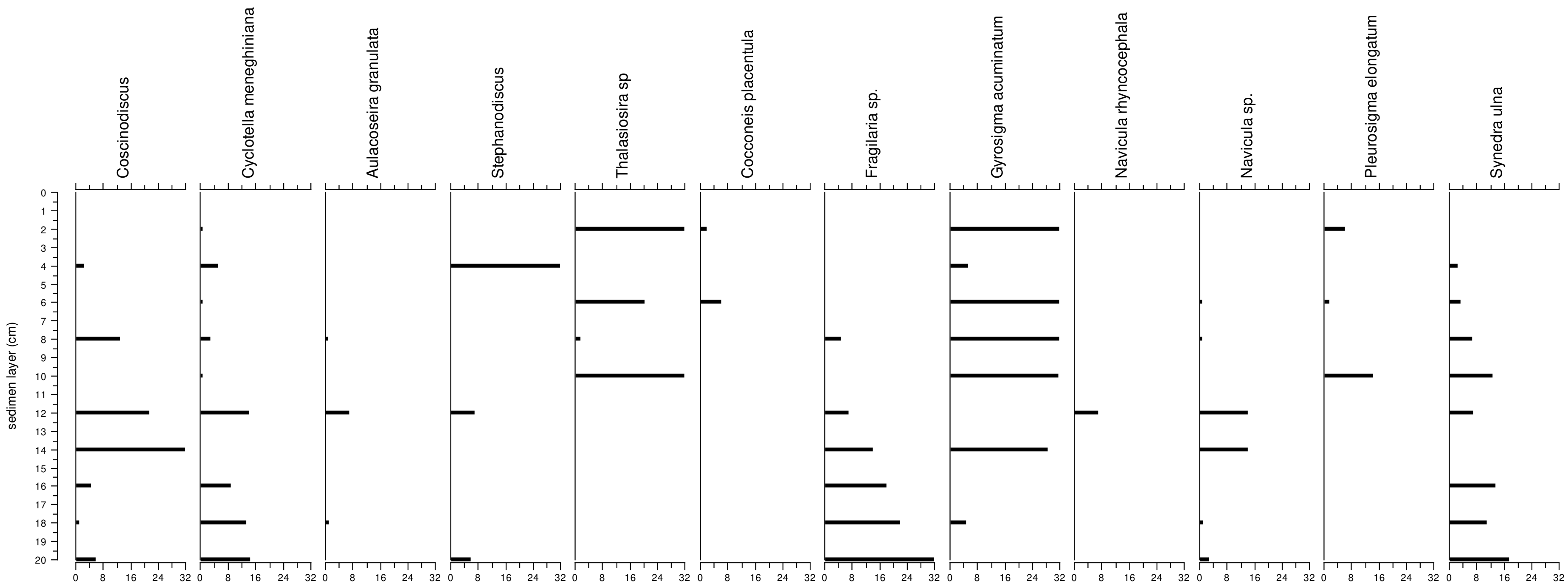

Fig 5. Biostratigraphy based on the relative abundance of dominant diatoms in mangrove ecosystem of Gandhong Demak.

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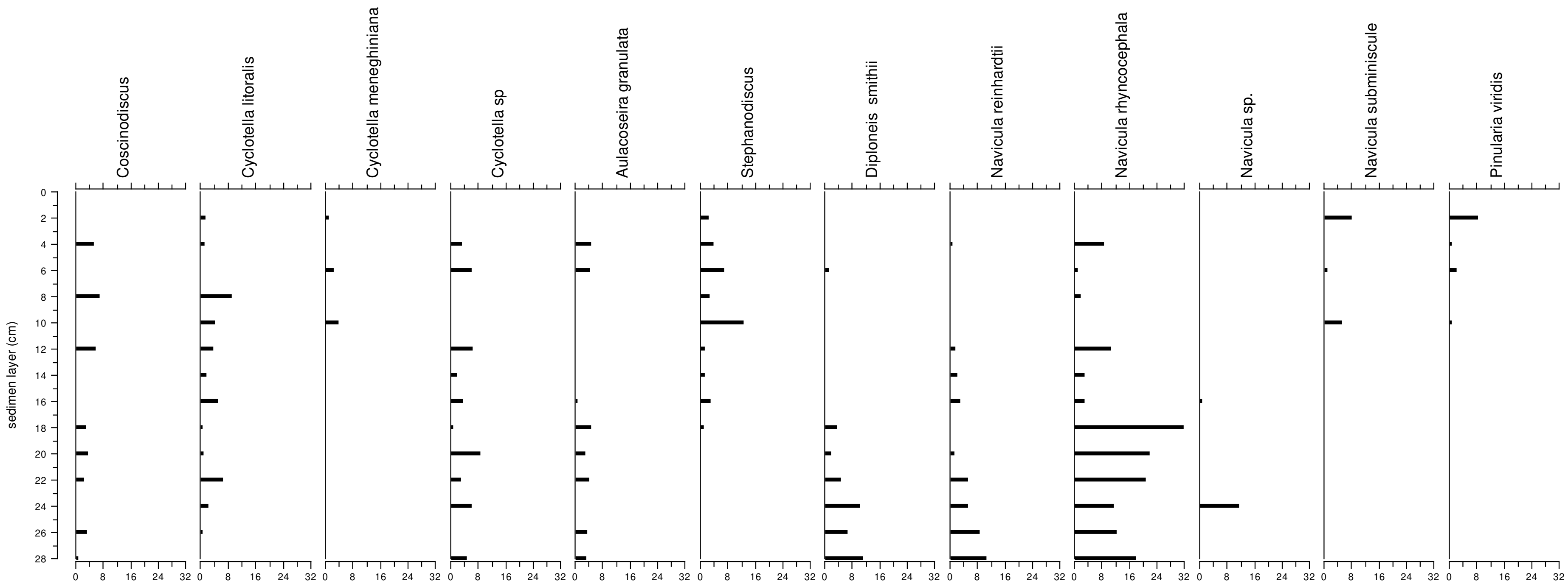

Fig. 6. Biostratigraphy based on the relative abundance of dominant diatoms in mangrove ecosystem of Kaliuntu Rembang.

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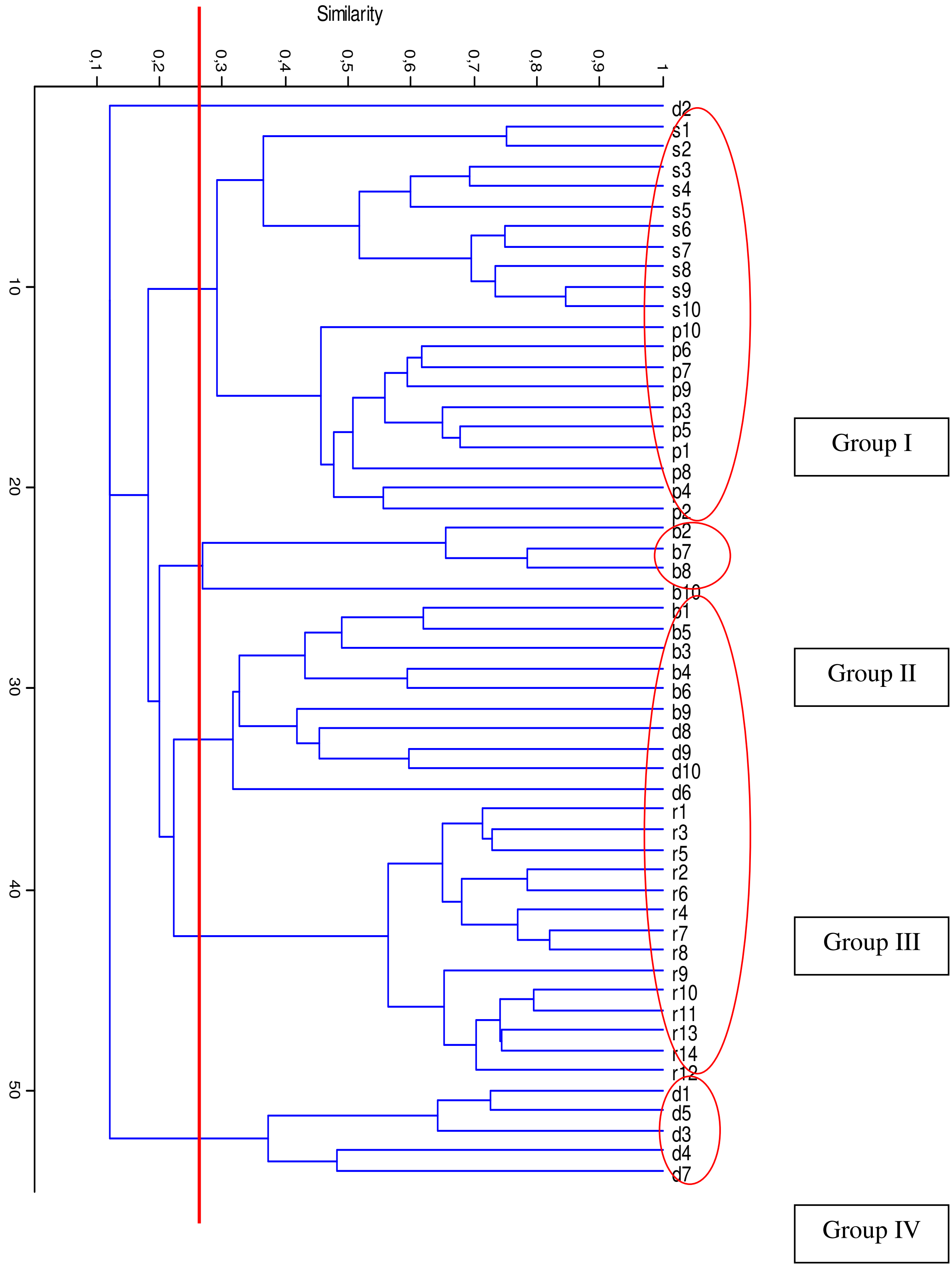

Fig. 7. Groups of biostartigraphy (the relative abundance of more than 2% diatoms) from Cluster Analysis with Bray-Curtis Similarity Pair Group.

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CONCLUSION

The diatom stratigraphy from mangrove ecosystem along Northern Coast of Central Java indicate that in the past freshwater were more dominated in the sites that recently dominated by saltwater.

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