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Diversity model of Pliocene-Pleistocene nannofossil of Kendeng Zone

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Abstract. Quantitative analyses of Pliocene-Pleistocene calcareous nannofossils from the Kendeng Zone, East Java have been performed on 181 samples collected from 4 river sections (Ngawi, Bojonegoro, Nganjuk and Jombang). The research method consists of field study and quantitative statistical analysis. Field study is to measure sections of the 4 selected sections. The samples taken include fine-grained rock (marl, shale) and carbonaceous. The sample preparation has been carried out using smears slide method. Quantitative analysis uses nannotex determination and diversity index. The river sections that have been selected consist of a continuous sediment sequence from Pliocene Kalibeng to Pleistocene Sonde Formation. The results of quantitative analysis indicate the following model of diversity nannofossil Kendeng Zone: (1) Bengawan Solo River section, Ngawi, has an average 46 specieses; Diversity Index (H′)=0.053, Homogeneity (E)=0.009, aged NN12-NN20 (Early Pliocene-Middle Pleistocene); (2) Kedungsumber River section, Soko Area, Distric of Temayang, Bojonegoro, has an average 26 specieses and Diversity Index (H′)=0.035; and Evennes/Homogeneity index (E)=0.006; and age NN12-NN20 (Early Pliocene-Early Pleistocene); (3) Kaliasin River section, Pinggir area, Distric of Lengkong, Nganjuk, has an average 40 specieses and Diversity Index (H′) = 0.050; and Evennes/Homogeneity index (E)=0.009 and NN12-NN20 (Early Pliocene-Early Pleistocene); (4) Kalibeng River section, Kedungringin Area,Distric ofPlandaan, Jombang hasan average 33 specieses, Diversity Index (H′)=0.043 and Evennes/Homogeneity index (E)=0.007, aged NN12-NN19 (Early Pliocene-Early Pleistocene).This nannofossil diversity model indicate that there is a paleoclimate change in Pliocene-Pleistocene of Kendeng zone; and methods applied by the present study has not been used by previous researchers.

Keywords: diversity, nannofossil, Pliocene-Pleistocene, Kendeng zone.

1. Introduction

Nannofossil (calcareous nannoplankton) is included in Haptophyta and found in the photic zone of the oceans [1, 4]. Their presence and distribution are affected by many factors, particularly, temperature and available amount of nutrients [6]). Whilst the usage of nannofossils as a tool for Cenozoic biostratigraphic analysis is well established and widely recognized, their application in paleoecological studies is still limited issue [2, 22] and Guerreiro et al., 2013 in [1].

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The diversity of nannofossil is strongly influenced by paleoecological changes such as salinity, temperature, paleobathymetric, PH, etc. Nannofossil has been proved very important and is used as indicator of paleoecology, biostratigraphy, stratigraphic sequence and hydrocarbon exploration. During Pliocene-Pleistocene, the earth had global climate change occurring as Glacial Ice Age, so that the decrease of sea water reaching 100-125 m. Climate change is causing changes in the diversity of marine fauna species indicated by the decline in the number of marine fauna species including nannoplankton. Nannoplankton diversity declined dramatically during the late Pliocene and early Pleistocene [5], Aubry, 2007 in [16]. Cenozoic nannofosil data suggest that cold climates tend to encourage a decrease in nannofossils diversity. This study aims to determine the model of nannofossil diversity at the Pliocene-Pleistocene (Glacial Ice) in Kendeng zone. The resulted model can be used to identify paleoclimate change, transgression-regression phases, stratigraphic sequence and basin development in the Kendeng zone. Measurement of species diversity is important in some sciences and has evolved mainly within paleoecology[12].

2. Method

2.1. Study Area

The research area consists of four selected locations in the Kendeng Zone, East Java Basin. The locations are (1) Bengawan Solo River section, District of Ngawi; (2) Kedungsumber River section, Soko Area, Distric of Temayang, Bojonegoro; (3) Kaliasin River section, Pinggir area, Distric of Lengkong, Nganjuk; and (4) Kalibeng River section, Kedungringin Area,Distric ofPlandaan, Jombang. All sections concist of Kalibeng and Klitik/Sonde Formations (Figure 1).

Figure 1. (A).Study Area in East Java Province; (B). Selected locations for measuring section in Ngawi, Bojonegoro, Nganjuk and Jombang. [19, 23]

2.2. Analysis Tools

The research method consist of field mapping and microscope-based quantitative statistical analysis. Measuring section of 4 selected sections and representative sampling have been conducted during the field mapping, as well as taking rock samples consisting of fine-grained rock (marl, shale) and carbonaceous. Sample preparation for the fossils uses smear slide method. Nannofossils were determined under two light microscope technique (parallel light and crossed nicols) at magnification of 1000x. Species was identified using standar taxonomy as described by Gartner, 1981, Perch-Nielsen,and the Nannotax3 website [10,24]

The selected sections is expected to have a continuous sediment sequence from Early Pliocene to Early Pleistocene, from older to younger, namely: Kalibeng Formation to Sonde Formation (consisting of Klitik and Atasangin Members). The parameters measured were the average number of species of nannofossils in each section, the number of species in each sample (random but representative) and levels of nannofossils species in diversity in the 4 sections (Ngawi, Bojonegoro, Nganjuk and Jombang area). Quantitative analysis uses nannotex determination while diversity index analysis was based on Shannon Index and and Simpton Index [11,18,25]

Formula of Diversity

Diversity Index:

- A diversity index is a mathematical measure of species diversity in a given community.
- Diversity Index is determined based on the species richness (the number of species) and species abundance (the number of individuals per species).
- The diversity index that will be used by the present study is the Diversity Index by Shannon-Weiner (1949), and Simpson Index.

Calculation of Nannofossil Diversity Index[4, 9, 10]:

To calculate the diversity of nannofossil used Shannon Index Diversity and Simpton Index. Shannon Index is an index of statistical information, which means it assumes all species (nannofossils) are represented in samples and samples randomly (rock samples). In this index, *Pi* is the proportion (*ni/N*) of an individual of a particular species found (*ni*) divided by (*N*) the total number of individuals found, *ln* is the natural *log*, Σ is the sum of the calculations, and *S* is the number of species. The index formula (1, 2) is as follows :

$$\text{Shannon Index}(H') = \sum_{i=1}^{s} Pi \ln Pi \quad (1)$$

$$Pi = \frac{ni}{N} \quad H' = -\sum \frac{ni}{N} ln \frac{ni}{N} \quad (2)$$

Simpson Index is the dominance index because it gives more weight to the common or dominant species. In this case, some rare species with only a few representatives will not affect diversity. In this index same of Shannon index (3) :

$$\text{Simpton Index } (D) = \frac{1}{\sum_{i=1}^{s} Pi^2} \quad (3)$$

Evennes Index / Homogeneity Indek (*E*) [25], the formula (4, 5) is a follows :

$$E = \frac{H'}{Hmax} = -\Sigma \left(\frac{Pi\ Ln\ Pi}{Hmax}\right) \quad (4)$$

$$H_{max} = S \log S \longrightarrow (E) = -\Sigma \left(\frac{Pi\ Ln\ Pi}{S \log S}\right) \quad (5)$$

The Range of Diversity :

The range of Diversity Index (Shannon - Weiner) [11, 18, 25] :

$H' < 2.3026$	: Small diversity and low community stability
$2.3026 < H' < 6.9078$	: Medium diversity and moderate community stability
$H' > 6.9078$	: High diversity and high community stability

The Range of Homogeneity [11, 25]:

$E < 0.4$	: Small population
$0.4 < E < 0.6$	: Moderate population
$E > 0.6$	: High population

3. Result

3.1. Geological Setting

North east Java region based on tektonofisiography of Java Island divided into four units tektonofisiografi, successively from south to north are: Kendeng Zone, Randublatung Zone, Rembang Zone and Shelf of Java Sea (Figure 2).

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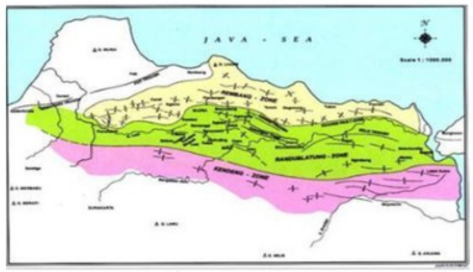

Figure 2. Physiography map of Northeast Java (Van Bemmelen, 1949) in [3].

Regional Stratigraphy of Kendeng Zone, North East Java Basin indicates the age of the rock outcrops found in this zone ranges from Oligocene to Pleistocene [17]. The sequence of litostratigraphy units in the Kendeng Zone are characterized by the composite lithology and age as presented in Figure 3

The Kendeng zone is an anticlinorium situated between the North East Java hinge belt and the axis of the central trough of Java. It appears to be a distinct geological unit from the standpoints of structure, lithostratigraphy and tectonics [17]. From late Oligocene to Holocene, sediments were deposited within this area under dominant regressive conditions which prevailed at first in the West then progressively extended eastwards and finally resulted in the emersion of the entire Kendeng zone . Volcanoes were almost permanently active in the western and southern adjacent areas during this period. Stratigraphy Regional of Kendeng Zone, North East Java Basin [17]. Outcrops found in this zone from Oligocene to Pleistocene. The sequence litostratigraphy units in the Kendeng Zone, characterized by the composite lithology and age, is presented in Figure 3 [7, 17].

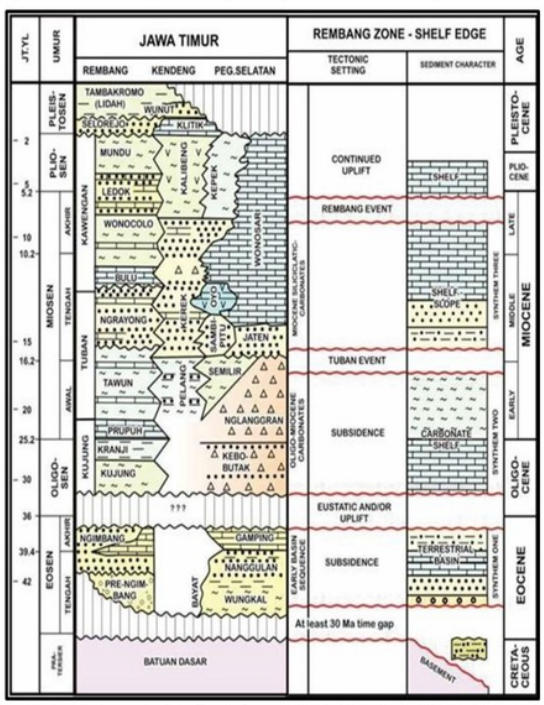

Figure 3. Regional Stratigraphy East Java (modified from Smyth *et al*., 2005) [17].

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Local stratigraphy of research area consists of Kalibeng Formation and Klitik/Sonde Formation. Lithology of the Kalibeng Formation consists of the dominant marl, massive, containing abundant many foraminifera and nannofossil, some calcareous sandstone are found as intercalation layers (Figure 4A, 4B). The thickness of Kalibeng Formation ≥ 650 meters, relative age of this formation is Early Pliocene (NN12-NN18), based on last appearance of *Discoaster brouweri*. The Kalibeng Formation is deposited at the deep water environment, a lower bathyal (200-2000 meters) depth based on apperance of *Gyroidina soldanii*.

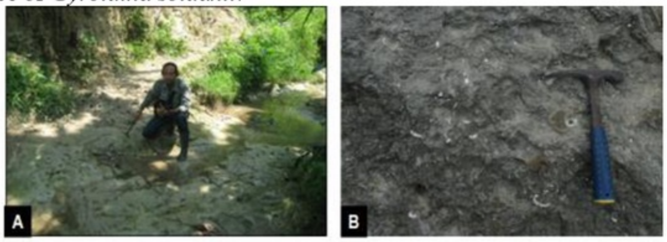

Figure 4. (A) Marl and calcarenite intercalation (Bojonegoro) and (B) masive marl of Kalibeng Formation (Nganjuk) (photo by Team PUPT).

Lithology of the Klitik/Sonde Formation consists of the dominant limestones, calcarenites, marl (Figure 5C, 5D) containing abundant foraminifera and few of nannofossil. The thickness of Klitik/ Sonde Formatian about 100 meters, age of this formation is Late Pliocene to Pleistocene (NN14-NN21), based on first appearance of *Pseudoemiliania lacunosa* and *Gephyrocapsa oceanica*. The Klitik Formation is deposited at the shallow water environment, bathymetric of the neritic (20-100meter) based on appearance of benthonic *Ammonia beccarii, Amphystegina lessonii,* and larger foraminifera.

Figure 5. (C,D) Limestone and calcarenite of Klitik Formation of Ngawi (photo by Andika)

Regional Structure of Java

The main structure of Java Island are three main structural patterns, namely the Meratus Pattern (NE-SW trend), Sunda trend (N-S Trend) and Java pattern (E-W trend) (Figure 6) [15]. In East Java, this pattern is indicated by faults and folds in the Kendeng Zone. The structure of Sumatra is mainly found in West Java, whereas in Eastern Central Java this structure is no longer visible. The Java pattern (East-West) in the East Java basin is older than the Early Miocene, and is called SAKALA trend (Figure 6) in [20].

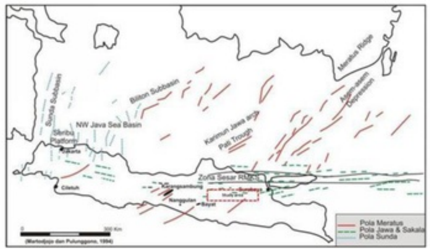

Figure 6. Structural pattern of Java Island [16], (RMKS = Rembang-Madura-Kangean-Sakala) [21].

3.2. Discussion

The species diversity of nannofossils in the study area will be determined by comparing the results from the four selected sections. Data from the selected sectionsof Ngawi, Bojonegoro, Nganjuk and Jombang were collected for determining genus and species of Pliocene-Pleistocene nannofossils of Kendeng Zone (NN12-NN21). The abundance (number of individuals) and variety and number of species found in samples from Kalibeng and Sonde Formation is presented in the following Table-1.

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Table 1. Number of species from Kalibeng and Klitik /Sonde Formation from Ngawi-Bojonegoro-Nganjuk-Jombang Sections of Kendeng Zone

1.Bengawan Solo River section, Ngawi					2.Kedungsumber River section, Bojonegoro					3. Kaliasin River section, Nganjuk					4. Kalibeng River section, Jombang				
NN12-NN20 (Early Pliocene - Early Pleistocene)					NN12-NN20 (Early Pliocene - Early Pleistocene)					NN12-NN20 (Early Pliocene - Early Pleistocene)					NN12-NN21 (Early Pliocene - Early Pleistocene)				
No	Code sample	Σ sp	$\overline{\sum}$ sp	Age	No	Code of sample	Σ sp	$\overline{\sum}$ sp	Age	No	Code sample	Σ sp	$\overline{\sum}$ sp	Age	No	Code sample	Σsp	$\overline{\sum}$ sp	Age
1	U.69	4	0,004	KlitikFm (NN19-NN20)	1	VW.5	5	0,016	Sonde Formation (NN 14 - NN20)	1	S30	4	0,011	Klitik Fm. (N19 -	1	D.33	7	0,021	Klitik/Sonde Fm (NN19 – NN21)
2	U.68	2	0,002		2	VW.6	3	0,010		2	S29	1	0,003		2	D.32	6	0,018	
3	U.67	1	0,001		3	VW.8B	4	0,013		3	S28	1	0,003		3	D.31	2	0,006	
4	U.66	3	0,003		4	VW.9A	2	0,006		4	S27	7	0,019		4	D.30	6	0,018	
5	U.65	0	0,000		5	VW.9B	6	0,019		5	S26	9	0,025		5	D.29	9	0,027	
6	U.64	0	0,000		6	VW.10	1	0,003		6	S25	7	0,019		6	D.28	7	0,021	
7	U.63	7	0,006		7	VW.12	7	0,022		7	S24	5	0,014		7	D.27	4	0,012	
8	U.62	6	0,006		8	VW.17	9	0,029		8	S23	12	0,033		8	D.26	8	0,024	
9	U.61	6	0,006		9	VW.22	4	0,013		9	S22	10	0,028		9	D.25	15	0,045	Kalibeng Formation (NN12-NN18)
10	U.60	11	0,010	Kalibeng Formation (NN13 - NN18)	10	VW.25	9	0,029		10	S21	12	0,033	Kalibeng Formation (NN12 – NN18)	10	D.24	13	0,039	
11	U.59	17	0,016		11	VW.26	6	0,019		11	S20	14	0,039		11	D.23	15	0,045	
12	U.58	15	0,014		12	VW.27	5	0,016		12	S19	15	0,041		12	D.22	13	0,039	
13	U.57	20	0,019		13	VW.33	8	0,026		13	S18	15	0,041		13	D.21	17	0,050	
14	U.56	19	0,018		14	VW.35	8	0,026		14	S17	13	0,036		14	D.20	16	0,047	
15	U.55	22	0,020		15	VW.36	7	0,022		15	S16	17	0,047		15	D.19	11	0,033	
16	U.54	20	0,019		16	VW.38	8	0,026		16	S15	19	0,052		16	D.18	16	0,047	
17	U.53	22	0,020		17	VW.42	7	0,022		17	S14	20	0,055		17	D.17	19	0,056	
18	U.52	28	0,026		18	VW.44	9	0,029		18	S13	25	0,069		18	D.16	13	0,039	
19	U.51	21	0,019		19	VW.45	7	0,022		19	S12	19	0,052		19	D.15	15	0,045	
20	U.50	29	0,027		20	VW.52	3	0,010		20	S11	17	0,047		20	D.14	9	0,027	
21	U.49	20	0,019		21	VW.55	1	0,003		21	S10	19	0,052		21	D.13	12	0,036	
22	U.48	26	0,024		22	VW.57	3	0,010	Kalibeng Formation (NN12 – NN14)	22	S9	20	0,055		22	D.12	2	0,006	
23	U.47	22	0,020		23	VW.60	0	0,000		23	S8	14	0,039		23	D.11	11	0,033	
24	U.46	21	0,019		24	VW.61	0	0,000		24	S7	14	0,039		24	D.10	5	0,015	
25	U.45	19	0,018		25	VW.62	4	0,013		25	S6	17	0,047		25	D.9	7	0,021	
26	U.44	22	0,020		26	VW.63	4	0,013		26	S5	17	0,047		26	D.8	15	0,045	
27	U.43	25	0,023		27	VW.64	5	0,016		27	S4	20	0,055		27	D.7	7	0,021	
28	U.42	17	0,016		28	VW.65	11	0,035				363	0,074		28	D.6	6	0,018	
29	U.41	17	0,016		29	VW.66	5	0,016							29	D.5	13	0,039	
30	U.40	26	0,024		30	VW.70	7	0,022							30	D.4	8	0,024	
31	U.39	28	0,026		31	VW.71	11	0,035							31	D.3	10	0,030	
32	U.38	21	0,019		32	VW.72	9	0,029							32	D.2	5	0,015	
33	U.37	21	0,019		33	VW.73	6	0,019							33	D.1	15	0,045	
34	U.36	24	0,022		34	VW.76A	1	0,003									337	0,098	
35	U.35	17	0,016		35	VW.77	2	0,006											
36	U.34	29	0,027		36	VW.79	0	0,000											
37	U.33	10	0,009		37	VW.80	0	0,000											
38	U.32	28	0,026		38	VW.81	1	0,003											
39	U.31	13	0,012		39	VW.82	0	0,000											
40	U.30	22	0,020		40	VW.83	4	0,013											
41	U.29	22	0,020		41	VW.84	3	0,010											
42	U.28	18	0,017		42	VW.85	1	0,003											
43	U.27	20	0,019		43	VW.86	5	0,016											
44	U.26	28	0,026		44	VW.87	2	0,006											
45	U.25	17	0,016		45	VW.89	2	0,006											
46	U.24	15	0,014		46	VW.90	3	0,010											
47	U.23	22	0,020		47	VW.91	0	0,000											
48	U.22	26	0,024		48	VW.92	4	0,013											
49	U.21	23	0,021		49	VW.93	0	0,000											
50	U.20	18	0,017		50	VW.94	0	0,000											
51	U.19	20	0,019		51	VW.95	0	0,000											
52	U.18	19	0,018		52	VW.96	18	0,058											
53	U.17	17	0,016		53	VW.98	10	0,032											
54	U.16	18	0,017		54	VW.99	11	0,035											
55	U.15	17	0,016		55	VW.104	8	0,026											
56	U.14	28	0,026		56	VW.110	11	0,035											
57	U.13	24	0,022		57	VW.118	7	0,022											
58	U.12	18	0,017		58	VW.125	7	0,022											
59	U.11	15	0,014		59	VW.129	9	0,029											
60	U.10	14	0,013		60	VW.134	4	0,013											
					61	VW.143	15	0,048											
		1080	0,056				312	0,0196											

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Table 2. Distribution of nannofossils species, Diversity Index (*H'*) and Homogeneity (*E*), From Ngawi-Bojonegoro-Nganjuk-Jombang Sections of Kendeng Zone

No.	Spesies	NGAWI			BOJONEGORO			NGANJUK			JOMBANG		
		ni	H'	E	ni	H'	E	ni	H'	E	ni	H'	E
1	*Amaurolithus delicatus*	6	0,01	0,00	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
2	*Amaurolithus tricorniculatus*	7	0,01	0,00	0	0,00	0,00	4	0,01	0,00	0	0,00	0,00
3	*Calcidiscus leptoporus*	66	0,08	0,01	4	0,01	0,00	7	0,02	0,00	6	0,02	0,00
4	*Calcidiscus macintyrei*	73	0,09	0,02	0	0,00	0,00	10	0,03	0,01	0	0,00	0,00
5	*Ceratolithus acutus*	3	0,01	0,00	0	0,00	0,00	5	0,02	0,00	2	0,01	0,00
6	*Ceratolithus armatus*	0	0,00	0,00	0	0,00	0,00	3	0,01	0,00	0	0,00	0,00
7	*Ceratolithus rugosus*	54	0,07	0,01	3	0,01	0,00	5	0,02	0,00	0	0,00	0,00
8	*Ceratolithus telesmus*	1	0,00	0,00	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
9	*Coccolithus pelagicus*	49	0,06	0,01	25	0,06	0,01	32	0,08	0,01	173	0,22	0,04
10	*Coccolithus pliopelagicus*	6	0,01	0,00	0	0,00	0,00	11	0,03	0,01	273	0,28	0,05
11	*Discoaster sp.*	5	0,01	0,00	0	0,00	0,00	2	0,01	0,00	0	0,00	0,00
12	*Discoaster surculus*	52	0,07	0,01	12	0,03	0,01	79	0,14	0,03	39	0,08	0,01
13	*Discoaster tamalis*	0	0,00	0,00	19	0,00	0,00	0	0,00	0,00	2	0,01	0,00
14	*Discoaster triradiatus*	5	0,01	0,00	1	0,00	0,00	9	0,03	0,00	2	0,01	0,00
15	*Discoaster tristellifer*	67	0,08	0,01	28	0,06	0,01	31	0,07	0,01	148	0,20	0,03
16	*Discoaster variabilis*	63	0,08	0,01	0	0,00	0,00	24	0,06	0,01	16	0,04	0,01
17	*Emiliania Huxleyi*	2	0,00	0,00	4	0,01	0,00	11	0,03	0,01	4	0,01	0,00
18	*Gephyrocapsa caribbeanica*	4	0,01	0,00	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
19	*Gephyrocapsa oceanica*	7	0,01	0,00	10	0,03	0,00	26	0,06	0,01	2	0,01	0,00
20	*Helicosphaera carteri*	10	0,02	0,00	0	0,00	0,00	0	0,00	0,00	2	0,01	0,00
21	*Helicosphaera kamptneri*	0	0,00	0,00	0	0,00	0,00	5	0,02	0,00	0	0,00	0,00
22	*Helicosphaera sellii*	30	0,04	0,01	0	0,00	0,00	11	0,03	0,01	22	0,05	0,01
23	*Phontosphaera japonica*	38	0,05	0,01	1	0,00	0,00	3	0,01	0,00	0	0,00	0,00
24	*Phontosphaera sp.*	2	0,00	0,00	0	0,00	0,00	8	0,03	0,00	11	0,03	0,01
25	*Ponthosphaera multipora*	11	0,02	0,00	0	0,00	0,00	29	0,07	0,01	68	0,12	0,02
26	*Pseudoemiliania lacunosa*	32	0,05	0,01	0	0,00	0,00	13	0,04	0,01	12	0,03	0,01
27	*Pseudoemiliania ovata*	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00	5	0,02	0,00
28	*Reticulofenestra haqqi*	34	0,05	0,01	6	0,02	0,00	18	0,05	0,01	2	0,01	0,00
29	*Reticulofenestra minuta*	2	0,00	0,00	1	0,00	0,00	9	0,03	0,00	3	0,01	0,00
30	*Reticulofenestra minutula*	26	0,04	0,01	13	0,04	0,01	24	0,06	0,01	61	0,11	0,02
31	*Reticulofenestra pseudoumbilicus*	3	0,01	0,00	9	0,03	0,00	13	0,04	0,01	3	0,01	0,00
32	*Rhabdosphaera clavigera*	171	0,16	0,03	27	0,06	0,01	40	0,09	0,02	5	0,02	0,00
33	*Scapholithus fossilis*	71	0,09	0,01	0	0,00	0,00	5	0,02	0,00	0	0,00	0,00
34	*Scyphosphaera apsteini*	45	0,06	0,01	0	0,00	0,00	3	0,01	0,00	0	0,00	0,00
35	*Scyphosphaera aranta*	19	0,03	0,01	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
36	*Scyphosphaera globulata*	162	0,15	0,03	13	0,04	0,01	37	0,08	0,01	14	0,04	0,01
37	*Scyphosphaera pulcherrima*	0	0,00	0,00	0	0,00	0,00	31	0,07	0,01	6	0,02	0,00
38	*Scyphosphaera ventriosa*	0	0,00	0,00	8	0,02	0,00	38	0,09	0,01	23	0,05	0,01
39	*Sphenolithus abies*	329	0,24	0,04	332	0,31	0,05	251	0,28	0,05	22	0,05	0,01
40	*Sphenolithus neoabies*	514	0,30	0,05	593	0,37	0,06	134	0,20	0,04	35	0,07	0,01
41	*Syracosphaera* sp.	179	0,16	0,03	57	0,11	0,02	52	0,11	0,02	29	0,06	0,01
42	*Thoracosphaera albatrosiana*	7	0,01	0,00	12	0,03	0,01	0	0,00	0,00	2	0,01	0,00
43	*Thoracosphaera saxea*	6	0,01	0,00	0	0,00	0,00	5	0,02	0,00	0	0,00	0,00
44	*Umbilicosphaera jafari*	12	0,02	0,00	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
45	*Discoaster* sp.	13	0,02	0,00	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
46	*Discoaster surculus*	9	0,02	0,00	1	0,00	0,00	0	0,00	0,00	0	0,00	0,00
47	*Discoaster tamalis*	5	0,01	0,00	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
48	*Discoaster triradiatus*	9	0,02	0,00	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
49	*Discoaster tristellifer*	463	0,28	0,05	293	0,30	0,05	368	0,33	0,06	483	0,35	0,06
50	*Discoaster variabilis*	416	0,27	0,05	321	0,31	0,05	290	0,30	0,05	444	0,34	0,06
51	*Emiliania Huxleyi*	37	0,05	0,01	0	0,00	0,00	9	0,03	0,00	11	0,03	0,01
52	*Gephyrocapsa caribbeanica*	0	0,00	0,00	3	0,01	0,00	0	0,00	0,00	0	0,00	0,00
53	*Gephyrocapsa oceanica*	24	0,04	0,01	10	0,03	0,00	11	0,03	0,01	0	0,00	0,00
53	*Helicosphaera carteri*	0	0,00	0,00	0	0,00	0,00	5	0,02	0,00	5	0,02	0,00
	Total	3149	0,05	0,01	1806	0,04	0,01	1671	0,05	0,01	1935	0,04	0,01

Quantitative analysis of nannofossils have been performed on 4 stratigraphic measurement sections. The results of analysis show that Kalibeng and Sonde Formations are deposited in Early Pliocene to Early Pleistocene (NN12-NN21) and there are 18 genus and 54 specieses identified (Table-3). The

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diversity models of nannofossil Pliocene-Pleistocene resulted from the four selected sections are summarized as follows and shown in Figure 7.

- Bengawan Solo River section, District of Ngawi: Age NN12-NN20 (Early Pliocene-Middle Pleistocene), 46 specieses identified, average number of species (0,056), Diversity Index (H′)=00.53and Evennes/Homogeneity Indek (E)=0.009.
- Kedungsumber River section, Soko Area, Distric of Temayang, Bojonegoro: Age NN12-NN20 (Early Pliocene - Early Pleistocene), 26 specieses identified, average number of species (0.196), Diversity Index (H′) = 0.035 and Evennes/Homogeneity Indek (E)= 0.006.
- Kaliasin River section, Pinggir area, Distric of Lengkong, Nganjuk: Age NN12-NN20 (Early Pliocene - Early Pleistocene), 40 specieses identified and average number of species (0.074), Diversity Index (H′) = 0.050 and Evennes/Homogeneity Indek (E)= 0.009.
- Kalibeng River section, Kedungringin Area,Distric of Plandaan, Jombang: AgeNN12-NN19 (Early Pliocene-Early Pleistocene), 33 specieses identified, average number of species (0.098), Diversity Index (H′) = 0.043 and Evennes/Homogeneity Indek (*E*)= 0.007.

From the results shown above, the Diversity Index of nannofossils in the study area is H′=0.035-0.050. This values is considered as "Small diversity and low community stability" (where H′< 2.3026). this means small diversity and low community stability. The Range of Evennes/Homogeneity is E=0.006-0.009), and it can be considered as "small population" (with *E*< 0.4). this means small population. The smaller the index value of diversity (*H′*) then the uniformity index (*E*) will also be smaller, indicating the dominance of a particular species against other species. Based on table 2, a model of diversity model of each section, has been constructed. The model is used to know the pattern of development of species diversity, to performed paleoecological analysis on Pliocene to Pleistocene (Figure 7).

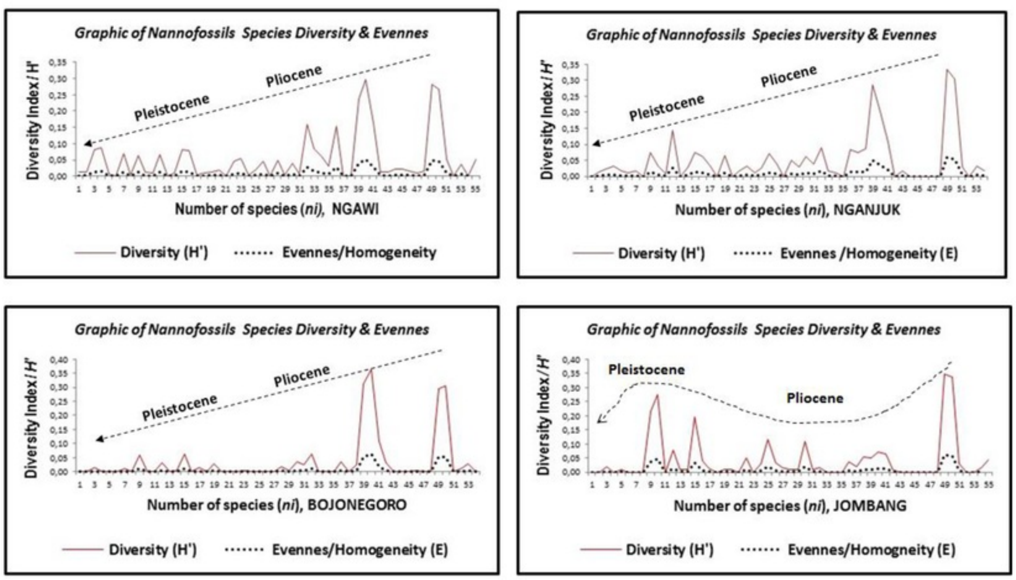

Figure 7. Diversity model of nannofossils species Pliocene-Pleistocene from Ngawi-Bojonegoro-Nganjuk-Jombang Sections of Kendeng Zone.

Based on four diversity models of nannofossil shown in Figure 4, showen that there is a decreasing pattern of diversity index from Pliocene to Pleistocene and Jombang section have a different pattern. This means that there is a decrease of species diversity from Pliocene to Pleistocene. This diversity model is expected to determine paleoclimate change in Pliocene-Pleistocene of Kendeng zone. The low diversity index is strongly influenced by changes in paleoecology, climate change and ecosystem stability. The uniformity index (E) is low which means the ecosystem is in a less stable condition. This is probably due to climate change in Pliocene-Pleistocene globally, volcanic or tectonic.

4. Conclusions

Presence of nannofossil is affected by many factors and used as a tool for Cenozoic biostratigraphic analysis and application in paleoecological. Research area that consists of four selected locations (Ngawi, Bojonegoro, Nganjuk and Jombang sections) in the Kendeng Zone, is composed by Kalibeng and Klitik/Sonde Formations with Early Pliocene to Early Pleistocene (NN12-NN21).

Total number species of the Kalibeng Formation more abundance than Klitik/Sonde Formation, this is because Kalibeng Formation composed of lithology dominated by fine-grain clastic sediment (marl), deposited of the open marine (Bathyal), whilst Klitik/Sonde Formation is deposited in shallow marine (neritic) and lithology dominanted by limestone.

Diversity Index of nannofossils is H'=0.035-0.050, indicating "small diversity and low community stability". The Range of Evennes/Homogeneity is E=0.006-0.009, showing "small population".The smaller the index value of diversity (H') then the uniformity index (E) will also be smaller, indicating the dominant of a species against other species.

Based on the graphic of diversity model shown in Figure 7, there is a decreasing pattern of Diversity index from Pliocene to Pleistocene in the three selected locations while the Jombang section have a different pattern. With the similar results of the three locations, it means that there is a decrease of species diversity from Pliocene to Pleistocene. This diversity model can be used to determine paleoclimate change in Pliocene-Pleistocene of Kendeng zone. The low diversity index is strongly influenced by changes in paeoecology, climate change and ecosystem stability. The uniformity index (E) is low, this means the ecosystem is in a less stable condition. It is probably due to climate change in Pliocene-Pleistocene globally

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