

# Diversity model of Pliocene- Pleistocene nannofossil of Kendeng Zone

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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 nannotax 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 of Plandaan, Jombang has an 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.

### 1. Introduction

Nannofossil (calcareous nannoplankton) is included in Haptophyta and found in the photic zone of the oceans [1, 4]. Their presence and distribution is 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].

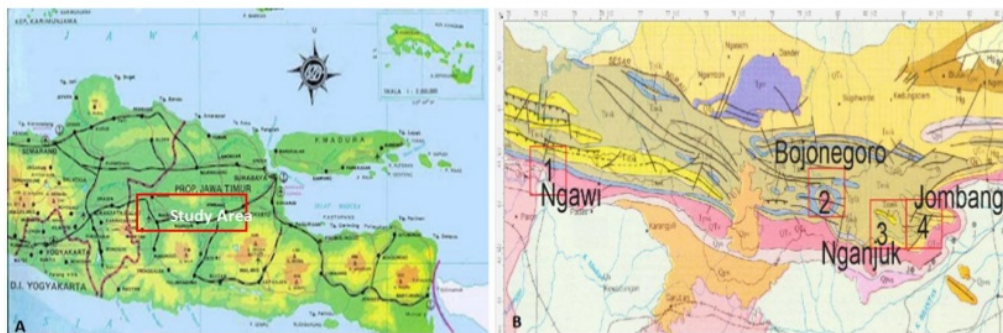
The diversity of nannofossil is strongly influenced by paleoecological changes such as salinity, temperature, paleobathymetric, PH, etc. Nannofossil has been proved very important and is used as indicator of paleoecology, biostratigraphy, stratigraphic sequence and hydrocarbon exploration. During Pliocene-Pleistocene, 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 nannofossil 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, District of Temayang, Bojonegoro; (3) Kaliasin River section, Pinggir area, District of Lengkon, Nganjuk; and (4) Kalibeng River section, Kedungringin Area, District of Plandaan, Jombang. All sections consist 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]

### 2.1. 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 1000 x. 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 nannotax determination while diversity index analysis was based on Shannon Index and and Simpton Index [11,18,25]

### 2.2. 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 Simpson 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,  $P_i$  is the proportion ( $n_i/N$ ) of an individual of a particular species found ( $n_i$ ) divided by ( $N$ ) the total number of individuals found,  $\ln$  is the natural log,  $\Sigma$  is the sum of the calculations, and  $S$  is the number of species. The index formula (1, 2) is as follows :

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

$$P_i = \frac{n_i}{N} \quad H' = -\sum_{i=1}^s \frac{n_i}{N} \ln \frac{n_i}{N} \tag{2}$$

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) :

$$\text{Simpson Index } (D) = \frac{1}{\sum_{i=1}^s p_i^2} \tag{3}$$

Evennes Index / Homogeneity Index ( $E$ ) [25], the formula (4, 5) is as follows :

$$E = \frac{H'}{H_{max}} = -\frac{\sum (P_i \ln P_i)}{H_{max}} \tag{4}$$

$$H_{max} = S \log S \rightarrow (E) = -\frac{\sum (P_i \ln P_i)}{S \log S} \tag{5}$$

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

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

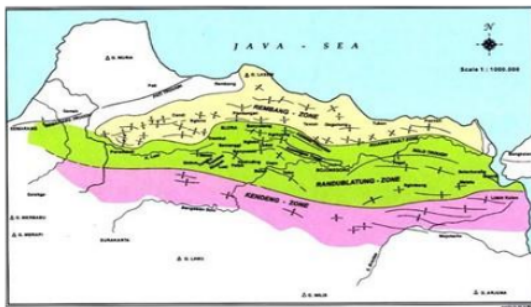


Figure 2. Physiography map of Northeast Java (Van Bemmelen, 1949) in [3]

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. 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. Outcrops found in this zone from Oligocene to Pleistocene. The sequence lithostratigraphy units in the Kendeng Zone, characterized by the composite lithology and age, is presented in Figure 3 [7, 17].

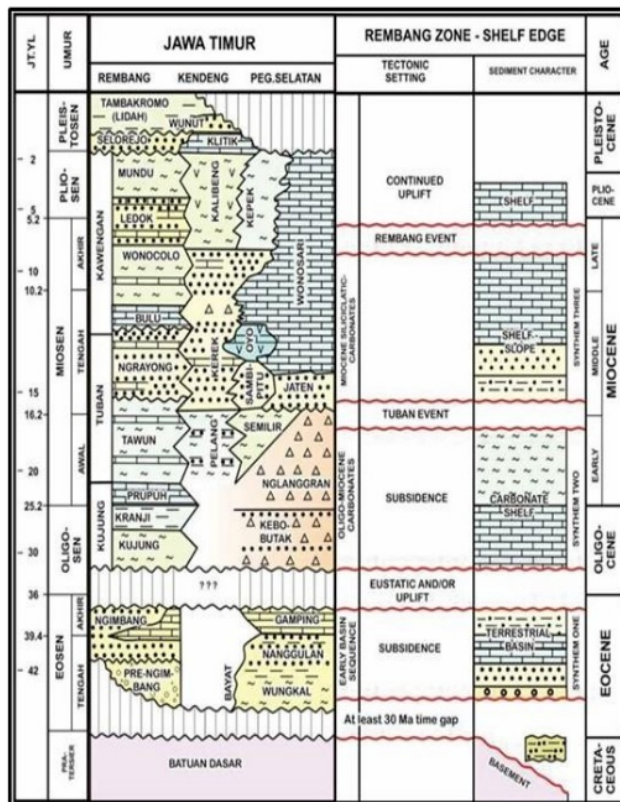
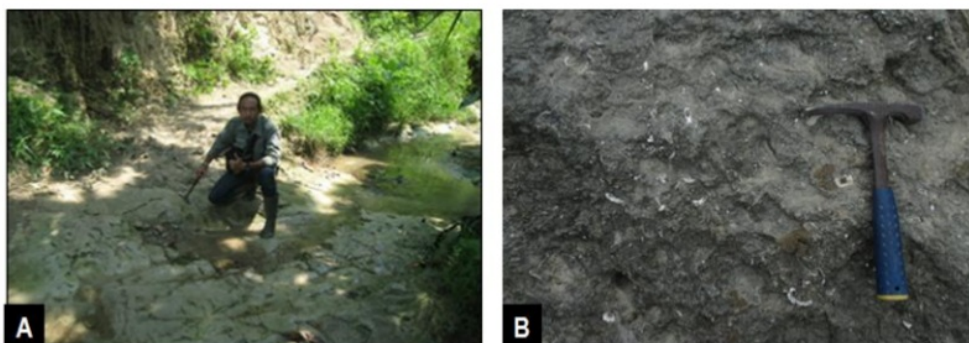


Figure 3. Regional Stratigraphy East Java (modified from Smyth *et al.*, 2005) [17]

Local stratigraphy of research area consists of Kalibeng Formation and Klitik/Sonde Formation. Lithology of the Kalibeng Formation consists of the dominant marl, massive, contains many foraminifera and nannofossil, there are calcareous sandstone (Figure 4A, 4B). The thickness of Kalibeng Formation  $\geq 650$  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, of the lower bathyal (200-2000meter) based on appearance of *Gyroidina soldanii*.



**Figure 3.** (A) Marl and calcarenite (Bojonegoro) and (B) masive marl of Kalibeng Formation (Nganjuk) (photo by Team PUPT)

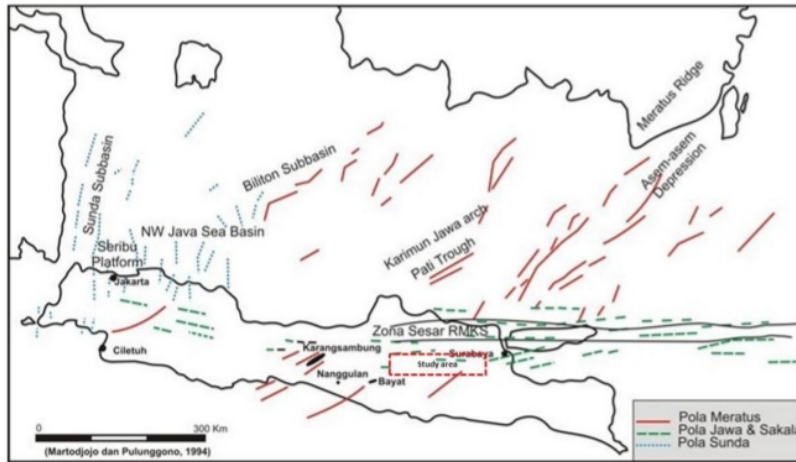
Lithology of the Klitik/Sonde Formation consists of the dominant limestones, calcarenites, marl (Figure 3C, 3D) contains foraminifera and few of nannofossil. The thickness of Klitik/Sonde Formation about 100 meters, age of this formation is Late Pliocene to Pleistocene (NN14-NN21), based on first appearance of *Pseudoemiliana 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 3.** (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 4) [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 direction (Figure 4) in [20].



**Figure 4.** 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 sections of 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.**

**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 NN12-NN20 (Early Pliocene - Early Pleistocene)					2. Kedungsumber River section, Bojonegoro NN12-NN20 (Early Pliocene - Early Pleistocene)					3. Kaliasin River section, Nganjuk NN12-NN20 (Early Pliocene - Early Pleistocene)					4. Kalibeng River section, Jombang NN12-NN21 (Early Pliocene - Early Pleistocene)				
No	Code sample	Σ sp	Σ sp	Age	No	Code of sample	Σ sp	Σ sp	Age	No	Code sample	Σ sp	Σ sp	Age	No	Code sample	Σ sp	Σ sp	Age
1	U.69	4	0,004	Klitik Fm (NN19-NN20)	1	VW.5	5	0,016	Sonde Formation (NN 14 - NN20)	1	S30	4	0,011	Klitik Fm. (NN19 - NN21)	1	D.33	7	0,021	
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	
10	U.60	11	0,010	10	VW.25	9	0,029	10	S21	12	0,033	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	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												



**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	<i>Amaurolithus delicatus</i>	6	0,01	0,00	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
2	<i>Amaurolithus tricorniculatus</i>	7	0,01	0,00	0	0,00	0,00	4	0,01	0,00	0	0,00	0,00
3	<i>Calcidiscus leptoporus</i>	66	0,08	0,01	4	0,01	0,00	7	0,02	0,00	6	0,02	0,00
4	<i>Calcidiscus macintyreii</i>	73	0,09	0,02	0	0,00	0,00	10	0,03	0,01	0	0,00	0,00
5	<i>Ceratolithus acutus</i>	3	0,01	0,00	0	0,00	0,00	5	0,02	0,00	2	0,01	0,00
6	<i>Ceratolithus armatus</i>	0	0,00	0,00	0	0,00	0,00	3	0,01	0,00	0	0,00	0,00
7	<i>Ceratolithus rugosus</i>	54	0,07	0,01	3	0,01	0,00	5	0,02	0,00	0	0,00	0,00
8	<i>Ceratolithus telesmus</i>	1	0,00	0,00	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
9	<i>Coccolithus pelagicus</i>	49	0,06	0,01	25	0,06	0,01	32	0,08	0,01	173	0,22	0,04
10	<i>Coccolithus pliopelagicus</i>	6	0,01	0,00	0	0,00	0,00	11	0,03	0,01	273	0,28	0,05
11	<i>Discoaster sp.</i>	5	0,01	0,00	0	0,00	0,00	2	0,01	0,00	0	0,00	0,00
12	<i>Discoaster surculus</i>	52	0,07	0,01	12	0,03	0,01	79	0,14	0,03	39	0,08	0,01
13	<i>Discoaster tamalis</i>	0	0,00	0,00	19	0,00	0,00	0	0,00	0,00	2	0,01	0,00
14	<i>Discoaster triradiatus</i>	5	0,01	0,00	1	0,00	0,00	9	0,03	0,00	2	0,01	0,00
15	<i>Discoaster tristellifer</i>	67	0,08	0,01	28	0,06	0,01	31	0,07	0,01	148	0,20	0,03
16	<i>Discoaster variabilis</i>	63	0,08	0,01	0	0,00	0,00	24	0,06	0,01	16	0,04	0,01
17	<i>Emiliania Huxleyi</i>	2	0,00	0,00	4	0,01	0,00	11	0,03	0,01	4	0,01	0,00
18	<i>Gephyrocapsa caribbeanica</i>	4	0,01	0,00	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
19	<i>Gephyrocapsa oceanica</i>	7	0,01	0,00	10	0,03	0,00	26	0,06	0,01	2	0,01	0,00
20	<i>Helicosphaera carteri</i>	10	0,02	0,00	0	0,00	0,00	0	0,00	0,00	2	0,01	0,00
21	<i>Helicosphaera kampneri</i>	0	0,00	0,00	0	0,00	0,00	5	0,02	0,00	0	0,00	0,00
22	<i>Helicosphaera sellii</i>	30	0,04	0,01	0	0,00	0,00	11	0,03	0,01	22	0,05	0,01
23	<i>Phontosphaera japonica</i>	38	0,05	0,01	1	0,00	0,00	3	0,01	0,00	0	0,00	0,00
24	<i>Phontosphaera sp.</i>	2	0,00	0,00	0	0,00	0,00	8	0,03	0,00	11	0,03	0,01
25	<i>Ponthosphaera multipora</i>	11	0,02	0,00	0	0,00	0,00	29	0,07	0,01	68	0,12	0,02
26	<i>Pseudoemiliania lacunosa</i>	32	0,05	0,01	0	0,00	0,00	13	0,04	0,01	12	0,03	0,01
27	<i>Pseudoemiliania ovata</i>	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00	5	0,02	0,00
28	<i>Reticulofenestra haqqi</i>	34	0,05	0,01	6	0,02	0,00	18	0,05	0,01	2	0,01	0,00
29	<i>Reticulofenestra minuta</i>	2	0,00	0,00	1	0,00	0,00	9	0,03	0,00	3	0,01	0,00
30	<i>Reticulofenestra minutula</i>	26	0,04	0,01	13	0,04	0,01	24	0,06	0,01	61	0,11	0,02
31	<i>Reticulofenestra pseudoumbilicus</i>	3	0,01	0,00	9	0,03	0,00	13	0,04	0,01	3	0,01	0,00
32	<i>Rhabdosphaera clavigera</i>	171	0,16	0,03	27	0,06	0,01	40	0,09	0,02	5	0,02	0,00
33	<i>Scapholithus fossilis</i>	71	0,09	0,01	0	0,00	0,00	5	0,02	0,00	0	0,00	0,00
34	<i>Scyphosphaera apsteini</i>	45	0,06	0,01	0	0,00	0,00	3	0,01	0,00	0	0,00	0,00
35	<i>Scyphosphaera aranta</i>	19	0,03	0,01	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
36	<i>Scyphosphaera globulata</i>	162	0,15	0,03	13	0,04	0,01	37	0,08	0,01	14	0,04	0,01
37	<i>Scyphosphaera pulcherrima</i>	0	0,00	0,00	0	0,00	0,00	31	0,07	0,01	6	0,02	0,00
38	<i>Scyphosphaera ventriosa</i>	0	0,00	0,00	8	0,02	0,00	38	0,09	0,01	23	0,05	0,01
39	<i>Sphenolithus abies</i>	329	0,24	0,04	332	0,31	0,05	251	0,28	0,05	22	0,05	0,01
40	<i>Sphenolithus neoabies</i>	514	0,30	0,05	593	0,37	0,06	134	0,20	0,04	35	0,07	0,01
41	<i>Syracosphaera sp.</i>	179	0,16	0,03	57	0,11	0,02	52	0,11	0,02	29	0,06	0,01
42	<i>Thoracosphaera albatrosiana</i>	7	0,01	0,00	12	0,03	0,01	0	0,00	0,00	2	0,01	0,00
43	<i>Thoracosphaera saxea</i>	6	0,01	0,00	0	0,00	0,00	5	0,02	0,00	0	0,00	0,00
44	<i>Umbilicosphaera jafari</i>	12	0,02	0,00	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
45	<i>Discoaster sp.</i>	13	0,02	0,00	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
46	<i>Discoaster surculus</i>	9	0,02	0,00	1	0,00	0,00	0	0,00	0,00	0	0,00	0,00
47	<i>Discoaster tamalis</i>	5	0,01	0,00	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
48	<i>Discoaster triradiatus</i>	9	0,02	0,00	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
49	<i>Discoaster tristellifer</i>	463	0,28	0,05	293	0,30	0,05	368	0,33	0,06	483	0,35	0,06
50	<i>Discoaster variabilis</i>	416	0,27	0,05	321	0,31	0,05	290	0,30	0,05	444	0,34	0,06
51	<i>Emiliania Huxleyi</i>	37	0,05	0,01	0	0,00	0,00	9	0,03	0,00	11	0,03	0,01
52	<i>Gephyrocapsa caribbeanica</i>	0	0,00	0,00	3	0,01	0,00	0	0,00	0,00	0	0,00	0,00
53	<i>Gephyrocapsa oceanica</i>	24	0,04	0,01	10	0,03	0,00	11	0,03	0,01	0	0,00	0,00
53	<i>Helicosphaera carteri</i>	0	0,00	0,00	0	0,00	0,00	5	0,02	0,00	5	0,02	0,00
<i>Total</i>		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

diversity models of nannofossil Pliocene-Pleistocene resulted from the four selected sections are summarized as follows and shown in Figure 4.

- 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 ( $H'$ )=00.53 and 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: Age NN12-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 is 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 is 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, then to made a model of diversity model of each section, to know the pattern of development of species diversity, to performed paleoecological analysis on Pliocene to Pleistocene (Figure 4).

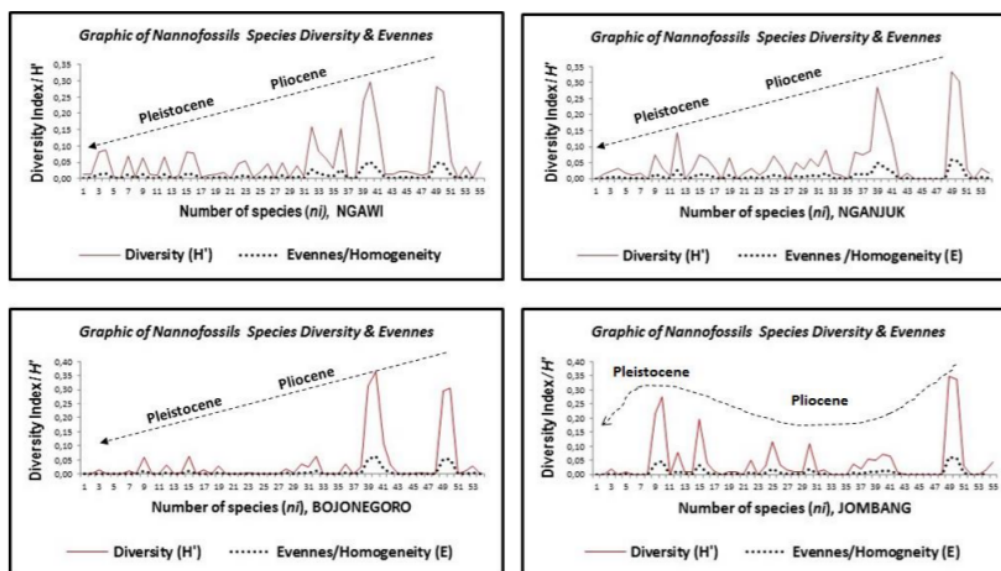


Figure 4. Diversity model of nannofossils species Pliocene-Pleistocene from Ngawi-Bojonegoro-Nganjuk-Jombang Sections of Kendeng Zone.

Based on fourth diversity model of nannofossil in Figure 4, shown 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, this 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 nanofossil 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 caused is Kalibeng Formation deposited of Pliocene and the lithology dominant of fine-grain clastic sediment (marl), deposited of the open marine (Bathyal), whilst Klitik/Sonde Formation deposited of Pleistocene, shallow marine (neritic) and dominant lithology is limestone.

Diversity Index of nanofossils is  $H'=0.035-0.050$ , indicating "small diversity and low community stability". The Range of Evenness/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, indicate the dominant of a species against other species.

Based on the graphic of diversity model shown in Figure 4, 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 paleoecology, 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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# Diversity model of Pliocene-Pleistocene nannofossil of Kendeng Zone

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