ENVIRONMENTAL CONTROL OF NANNOPLANKTON AND FORAMINIFERA ASSEMBLAGES IN MADURA WATERS

by :

Vijaya Isnaniawardhani[1)]

(Manuscript received October 08, 2008)

ABSTRACT

Nannoplankton is widely used for determining age of sediments following the other microorganism foraminifera since the late 1960s; and it was started being used for marine geography study in the year of 1984. This topic interests to be done in Indonesia as one of the tropic region.

The research covered a study about environment using nannoplankton and it is compared with the same study using foraminifera. Methods of the study include: (1) collecting secondary data and samples; (2) collecting field data record; (3) laboratory analyses upon sediment samples to determine the content of nannoplankton and foraminifera (micropaleontology analyses), the texture and composition of minerals (by means of grain size, petrology megascopic and microscopic analyses) (4) intergrating all of the analyses result.

Madura waters can be divided into four zones, among all : (I) inner shelf (water depth less than 30 m) in Madura Strait, (II) inner shelf in open marine north of Madura, (III) outer shelf (water depth 30 to 80 m) in Madura Strait, and (IV) outer shelf in open marine north of Madura.

Inner shelf in the Madura Strait (Zone I) is characterized by less than 1% sediment of nannoplankton (are made up of ***Gephyrocapsa oceanica****); rare assemblages of benthic foraminifera only (****Ammonia*** **spp.,** *arenaceous carbonate test taxa such as :* ***Ammobaculites*** **spp.,** ***Textularia agglutinans, Haplophragmoides*** **spp.**, *and milliolidae). Inner shelf open marine north of Madura (Zone II) yielded few nannoplankton assemblages, dominated by* ***Gephyrocapsa oceanica*** *with low number of* ***Emiliania huxleyi, Helicosphaera carteri, H. pavimentum, H. walichii*** *and* ***Pontosphaera*** **spp***; common foraminifera assemblages consist of rare planktic* ***Globigerinoides ruber, G. trilobus sacculiferus, G. conglobatus*** *with one or two dominant benthic (****Elphidium*** **spp,** ***Ammonia*** **spp.,** ***Pseudorotalia*** **spp.,** ***Asterorotalia*** **spp.***). Outer shelf of Madura Strait (Zone III) assigned by common nannoplankton assemblages, dominated by* ***Gephyrocapsa oceanica*** *and* ***Emiliania huxleyi*** *with few to common* ***Helicosphaera carteri, H. pavimentum, H. wallichii, Pontosphaera*** **spp.,** ***Calcidiscus leptoporus, Umbellosphaera irregularis*** *and* ***Umbilicosphaera*** **spp.***; common benthic foraminifera assemblages* ***Elphidium*** **spp,** ***Ammonia*** **spp.,** ***Cibicides*** **spp.,** ***Pseudorotalia*** **spp.,** *and* ***Asterorotalia*** **spp.** *with rare planktic* ***Globigerinoides ruber, G. trilobus sacculiferus,*** *and* ***G. conglobatus****. In the outer shelf open marine north of Madura (Zone IV), it is recorded abundant of nannoplankton* ***Gephyrocapsa oceanica, Emiliania huxleyi,***

1. Faculty of Geology, University of Padjadjaran, Bandung

Helicosphaera carteri, H. pavimentum, H. wallichii, Pontosphaera* spp., *Discoaster* spp., *Calcidiscus leptoporus, Umbellosphaera irregularis, Umbilicosphaera* spp.; the presence of moderate divers and abundance of planktic foraminifera ***Globigerina calida, Pulleniatina obliquiloculata, Orbulina universa, Hastigerina aequilateralis*** with common abundance benthic ***Bolivina* spp., *Bulimina* spp., *Cibicides* spp., *Pseudorotalia* spp., *Asterorotalia* spp., *Lenticulina* spp., *Cassidulina* spp., *Siphonina* spp.***, the presence of ***Uvigerina* spp.*** are noted.

The most significant physical environment parameter of each zone controlling appearance of marker species and abundancy of microorganism assemblages are bathymetry, salinity, temperature, pH and sediment due to fluvial supply.

Keywords : nannoplankton, foraminifera, environment, marker species, Madura Waters

SARI

Nannoplankton telah digunakan secara luas untuk penentuan umur sedimen di samping mikroorganisme lain, foraminifera, sejak tahun 1960-an; dan mulai digunakan untuk studi geografi laut pada tahun 1984. Kajian ini menarik untuk dilakukan di Indonesia yang termasuk daerah tropis.

Studi ini mempelajari perubahan lingkungan berdasarkan analisis nannoplankton, dibandingkan dengan foraminifera yang umum dipakai untuk kegunaan sejenis. Metode penelitian mencakup : (1) pengumpulan data sekunder dan sampel; (2) pengambilan data lapangan; (3) pekerjaan laboratorium meliputi analisis mikropaleontologi dan petrologi ; serta (4) integrasi seluruh hasil analisis.

Perairan Madura dapat dibedakan menjadi empat zona, yaitu: (I) Paparan dalam (kedalaman muka air laut kurang dari 30 m) di Selat Madura; (II) Paparan dalam pada laut terbuka di Perairan Utara Madura; (III) Paparan luar (kedalaman muka air laut 30 hingga 80 m) di Selat Madura; dan (IV) Paparan luar pada laut terbuka di Perairan Utara Madura.

*Paparan dalam di Selat Madura (Zona I) dicirikan oleh kumpulan nannoplankton kurang dari 1% total sedimen (***Gephyrocapsa oceanica***); foraminifera bentik jarang (***Ammonia* spp.,** *cangkang gamping pasiran seperti* ***Ammobaculites* spp., *Textularia agglutinans, Haplophragmoides* spp.***, dan miliolida). Paparan dalam di laut terbuka (Zona II) dicirikan oleh nannoplankton kurang melimpah yang didominasi oleh* ***Gephyrocapsa oceanica*** *dengan beberapa* ***Emiliania huxleyi, Helicosphaera carteri, H. pavimentum, H. walichii, Pontosphaera* spp***; foraminifera cukup melimpah dengan plankton ***Globigerinoides ruber, G. trilobus sacculiferus, G. conglobatus*** dalam jumlah jarang serta satu atau dua jenis bentik yang dominan (***Elphidium* spp, *Ammonia* spp., *Pseudorotalia* spp., *Asterorotalia* spp.***). Paparan luar di Selat Madura (Zona III) dicirikan oleh nannoplankton dalam jumlah yang umum, didominasi oleh* ***Gephyrocapsa oceanica*** *dan* ***Emiliania huxleyi*** *dengan beberapa* ***Helicosphaera carteri, H. pavimentum, H. wallichii, Pontosphaera* spp., *Calcidiscus leptoporus, Umbellosphaera irregularis, Umbilicosphaera* spp.***; foraminifera bentik jumlahnya umum seperti* ***Elphidium* spp, *Ammonia* spp., *Cibicides* spp., *Pseudorotalia* spp.,** *dan* ***Asterorotalia* spp.** *dengan foraminifera planktik seperti* ***Globigerinoides ruber, G. trilobus sacculiferus,*** *dan* ***G. conglobatus*** *dalam jumlah jarang. Di paparan luar laut terbuka (Zona IV) teridentifikasi nannoplankton yang melimpah seperti* ***Gephyrocapsa oceanica,***

Emiliania huxleyi, Helicosphaera carteri, H. pavimentum, H. wallichii, Pontosphaera* spp.*, Discoaster* spp.*, Calcidiscus leptoporus, Umbellosphaera irregularis, Umbilicosphaera* spp.*;* *dan beragam jenis foraminifera planktik seperti* ***Globigerina calida, Pulleniatina obliquiloculata, Orbulina universa *dan* ***Hastigerina aequilateralis*** *serta foraminifera bentik seperti* ***Bolivina* spp.*, Bulimina* spp.*, Cibicides* spp.*, Pseudorotalia* spp.*, Asterorotalia* spp.*, Lenticulina* spp.*, Cassidulina* spp.*, Siphonina* spp.** *dan* ***Uvigerina* spp.** *dalam jumlah yang umum.*

Parameter lingkungan fisik yang paling berpengaruh dalam mengontrol kehadiran spesies penunjuk (indikator) dan kelimpahan kumpulan mikroorganisma adalah: batimetri, salinitas, temperatur, pH dan sedimen.

Katakunci : nannoplankton, foraminifera, lingkungan, spesies penunjuk, Perairan Madura

INTRODUCTION

Since the lates 1960s, nannoplankton has been used in the geological study particulary to determine the age of sediment. In the last few years, the study of nannoplakton has been developed especially among others in geographical determination. McIntyre, et al., 1970; Winter, et al., 1979; Wang and Samtleben, 1983; Okada, 1984; Okada, 1992; Baumann, et al., 2001; and Gibbs, 2001 recognized lateral oceanographic condition changes based on the qualitative and quantitative analyses (appearance of marker species, amount- and number- of spesies) of nannoplankton assemblages.

In Indonesia, the use of nannoplankton to determine the age of sediment has succesful results. However, studies of marine geography and environment in using nannoplankton has never been done.

Madura Waters has been selected as the study area as a lot of secondary data and surface and core- samples can be used; this area is marked by the abundance of both nannoplankton and foraminifera as well.

This research is herein intended to determine the environmental control of nannoplankton and foraminifera assemblages in waters near Madura.

MATERIAL AND METHOD

Nannoplankton and foraminifera assemblages were studied in twenty six shallow marine surface sediment samples from Madura Strait and twenty four samples from open marine water north of Madura. The fifty samples collected by Marine Geological Institute (MGI) were obtained from the area between coordinates 5°48′00″ S to 8°00′00″ S and 112°24′00″ E – 114°30′00″ E.

The actual research was done in several stages, namely :

1. collection of secondary data and shallow samples (seabed surface sediment from grab sampler and sediment from the uppermost part of core samples from one metre of gravity corer
2. collecting field data record (physical oceanographyc factors measurement)
3. laboratory analyses upon sediment samples to determine the content of nannoplankton and foraminifera (micropaleontology analyses), the texture and composition of minerals (by means of grain size, petrology megascopic and microscopic analyses).

The samples were prepared using nannoplankton smear slide and foraminifera residue preparation methods. The nannoplankton slides were examined using a light microscope of 1000 magnification in both cross-polaried and phased light for contrast. Foraminifera examined using a slab microscope of 40 magnification.

4. Intergrating all of analyses result

The taxonomy of nannoplankton is referred to Perch-Nielsen (1985), planktic foraminifera is referred to Bolli and Saunders (1985), and benthic foraminifera is referred to van Marle (1991).

RESULT

Twenty-three nannoplankton taxa, sixteen planktic- and thirty-four benthic-foraminifera were identified in the sediment samples. Few reworked occur in each samples. Nannoplankkton taxa in the surface sediment samples of Madura Waters are among all : Family Braarudosphaeraceae Deflandre (1947): ***Braarudosphaera bigelowii*** (Grand and Braarud, 1935) Deflandre (1947); Family Calciosoleniaceae Kamptner (1927): ***Scapholithus*** spp; Family Ceratolithaceae Norris (1965): ***Ceratolithus cristatus*** Kamptner (1950); Family Cocolithaceae Poche (1913): ***Coccolithus pelagicus*** (Wallich, 1877) Schiller (1930), ***Calcidiscus leptoporus*** (Murray and Blackman, 1989) Loblich and Tappan (1978) and ***Umbilicosphaera*** spp; Family Discoasteraceae Tan (1927): ***Discoaster*** spp.; Family Helicosphaeraceae Black (1971): ***Helicosphaera carteri*** (Wallich, 1877) Kamptner (1954), ***Helicosphaera hyalina*** Gaarder (1970), ***Helicosphaera pavimentum*** Okada and Mc Intyre (1977), ***Helicosphaera wallichii*** (Lohmann, 1902) Boudreaux and Hay (1969), ***Helicosphaera*** spp.; Family Pontosphaeraceae Lemmermann (1908): ***Pontosphaera discopora*** Schiller (1925) and ***Pontosphaera japonica*** (Takayama, 1967) Nishida (1971), Family Princiaceae Hay and Mohler (1967): ***Emiliania huxleyi*** (Lohmann, 1902) Hay and Mohler in Hay et al. (1967), ***Gephyrocapsa oceanica*** Kamptner (1943), ***Gephyrocapsa*** spp., ***Pseudoemiliania lacunosa*** (Kamptner, 1963) Gartner (1963), and ***Reticulofenestra*** spp; Family Rabdosphaeraceae Lemmermann (1908): ***Rabdosphaera*** spp., Family Sphenolithaceae Deflandre in Grasse (1952) ***Sphenolithus*** spp.; Family Syracosphaeraceae Lemmermann (1908): ***Syracosphaera*** spp.; Family Thoracosphaeraceae Schiller (1930): ***Thoracosphaera*** spp; and Insertae sedis: ***Umbellosphaera irregularis*** Paasche in Markali and Paasche (1955). Planktic foraminifera assemblages in the sediment consist of: ***Globigerina bermudezi*** Seiglie, ***Globigerina calida*** Parker, ***Globigerina*** **spp.**, ***Globigerinoides ruber*** (d'Orbigny), ***Globigerinoides trilobus trilobus*** (Reuss), ***Globigerinoides trilobus immaturus*** LeRoy, ***Globigerinoides trilobus sacculifer*** Brady, ***Globigerinoides*** **spp.**, ***Globorotalia humerosa*** Takayanagi dan Saito, ***Globorotalia menardii cultrata*** (d'Orbigny), ***Globorotalia tumida tumida*** (Brady), ***Globorotalia ungulata*** Bermudez, ***Globorotalia*** **spp.**, ***Hastigerina aequilateralis*** (Brady), ***Hastigerina siphonifera*** (d'Orbigny), ***Orbulina*** **spp.** D'Orbigny (1839) and ***Pulleniatina*** **spp**. Cushman (1927). Hyaline benthic foraminifera taxa were identified among all: Family Almaenidae Myatlyuk, 1959: ***Annomalinella*** **spp.**; Family Amphistiginidae Cushman, 1927: ***Amphistegina*** **spp.**; Family Bagginidae Cushman (1927): ***Cancris*** **spp.**; Family Bolivinidae Glaessner, 1937: ***Bolivina***

spp.; Family Cassidulinidae d'Orbigny, 1839: ***Cassidulina*** **spp.**; Family Cibicididae Cushman, 1927: ***Cibicides*** **spp.**; Family Elphidinae Galloway, 1933: ***Elphidium crispum*** (Linnaeus) and ***Elphidium*** **spp.**; Family Eponinidae Hofker, 1951: ***Eponides*** **spp.;** Family Lagenidae Reuss, 1862: ***Fissurina*** **spp.** and ***Lagena*** **spp.;** Family Nodosariidae Ehrenberg, 1838: ***Dentalina*** **spp.** and ***Nodosaria*** **spp.;** Family Reussella Cushman, 1933: ***Reusella*** **spp.;** Family Rotaliidae Ehrenberg, 1839: ***Ammonia becarii*** (Linnaeus) s.l., ***Asterorotalia*** **spp.** and ***Pseudorotalia*** **spp.**; Family Sphaeroidinidae Cushman, 1927: ***Sphaeroidina bulloides*** d'Orbigny and ***Sphaeroidina*** **spp.**; Family Uvigerinidae Haeckel, 1894: ***Uvigerina*** **spp.**; Family Vaginulinidae Reuss, 1860: ***Lenticulina costata*** (Fichtel and Moll) and ***Lenticulina*** **spp.** Arenaceous test benthic foraminifera can be identified among all: Family Textulariidae Ehrenberg, 1839: ***Textularia*** **spp.**; Family Haplophragmoididae Maync, 1952: ***Haplophragmoides*** **spp.**; and Family Lituolidae De Blainville, 1827: ***Ammobaculites*** **spp.** Porceleneous test benthic or Family Miliolidae Ehrenberg, 1839 in the samples are: ***Flintina*** **spp.,** ***Pyrgo*** **spp.,** ***Qunqueloculina seminulum*** (Linnaeus), ***Quinqueloculina*** **spp.,** ***Spiroloculina communis*** Cushman and Todd, ***Spiroloculina depresa*** d'Orbigny, ***Spiroloculina*** **spp.,** ***Triloculina tricarinata*** d'Orbigny and ***Triloculina*** **spp.**

The distribution and the abundance pattern of nannoplankton & foraminifera assemblages are shown in **Table 1**.

Megascopically and microscopically, sediment can be classified into: clay, silty clay, sandy clay, clayey silt, silt, sandy silt, clayey sand, silty sand, and fine-, medium-, coarse- grained sand. The shape of material sediment can be differentiated into rounded to well rounded (0,7-0,9), subrounded to rounded (0,5-0,7), subangular to subrounded (0,3-0,5); the sphericity of sediment can be differentiated into high to very high (0,7-0,9), average to high (0,5-0,7) and low to average (0,3-0,5) (shown in **Table 2**). The sediment textural analyses result is compiled by Masria (1991), Astjario, et al. (1991), Arifin, et al. (1992) and Astjario, et al. (1998), as shown in **Figure 1.**

According to Ingle (1980), marine biofasies is divided into: inner shelf (0 - 50 m; 0 – 150 ft), outer shelf (50 – 150 m; 150 – 470 ft), upper bathyal (150 – 500 m; 460 – 1560 ft), upper middle bathyal (500 – 1500 m; 1560 – 4700 ft), lower middle bathyal (1500 – 2000 m; 4700 – 6250 ft), and lower bathyal (2000 m + ; 6250 ft+).

Based on bathymetry and physical oceanographic parameters including sediment (type, texture and mineral composition) Madura waters can be divided into four zones, among all : (I) inner shelf (water depth less than 30 m) in strait, (II) inner shelf in open marine, (III) outer shelf in strait, and (IV) outer shelf (water depth 30 - 80 m) in open marine. The difference of condition were signed by the characteristic distribution and the abundance pattern of nannoplankton & foraminifera assemblages in restricted and open marine in Madura Waters. (**Table 3** and **Figure 2**).

In water depth less than 30 meters (inner shelf) in the Madura Strait (Zone I), the zone is being indicated by various grain-size sediment (clay to sand), low salinity, low sea surface temperature (29,3° C) and pH = 6,0-7,3; the assemblages of nannoplankton is less than 1% of sediment, and are made up of the only species, ***Gephyrocapsa oceanica***; the benthic foraminifera noted included

Table 1. Distribution of Nannoplankton And Foraminifera Assembalges in The Surface Sediment of Madura Waters

NANNOPLANKTON

ZONATION	SAMPLE	DEPTH	*Braarudosphaera bigelowii*	*Scapolithus*	*Ceratolithus cristatus*	*Coccolithus pelagicus*	*Calcidiscus leptoporus*	*Umbilicosphaera*	*Helicosphaera carteri*	*Helicosphaera hyalina*	*Helicosphaera pavimentum*	*Helicosphaera wallichii*	*Helicosphaera* spp.	*Pontosphaera discopora*	*Pontosphaera japonica*	*Emiliania huxleyi*	*Gephyrocapsa oceanica*	*Gephyrocapsa* spp.	*Rabdosphaera*	*Syracosphaera*	*Thoracosphaera*	*Umbelosphaera irregularis*	Others
Inner shelf in Madura Strait (Zone I)	GB - 38	5,00																					
	GB - 43	11,00																					
	GB - 17	7,50																					
	GB - 18	6,00																					
	GB - 29	5,00																					
	GB - 21	6,50																					
	GB - 20	5,50																					
	GB - 32	10,00																					
	GB - 19	4,50																					
	GB - 30	7,00																					
	GB - 31	7,50																					
	SG - 28 (SBY)	5,00																					
	SG - 20 (SBY)	5,00																					
	SG - 02 (SBY)	9,00																					
	SG - 47 (SBY)	10,00																					
	SG - 30 (SBY)	5,00																					
	SG - 04 (SBY)	5,00														1	3	1					
	SG - 06 (SBY)	4,00																					
	SG - 09 (SBY)	4,00																					
	SG - 10 (SBY)	5,00															3						
	SG - 04 (S)	7,50														1	3	1					
	SG - 05 (S)	8,00															4						
	PGC - 26	12,00		1					1		1	1				4	2			1			1
	BSK - 38	15,60		1					1		1	1		1	1	2	2			2			2
Inner shelf in open marine north of Madura (Zone II)	GM - 10	27,00		3		3			2		2	3	2	2	2	28	47			2			15
	GM - 21	25,00		3				2	1		3	2		2	2	53	28		1	2			11
	GM - 16	23,00	1	1			1	1		1		2	1	2	1	16	53						7
	GB - 24	29,00								1				1			4	2				1	
Outer shelf in Madura Strait (Zone II)	PGC - 02	42,00		15		2					14	1					4		1			1	7
	PGC - 05	42,00		23					2		2	3		3	2	24	32		1	3			12
	PGC - 03	56,00		4		3			4		4	3	2	2	3	48	36			4			21
	PGC - 09	54,00		3					3		1	2		2	4	43	33			4			20
	P - 32	37,00	1	18			2	1	8	1	28	8	1	26	7	56	37	2		25	2	2	26
	P - 30	35,00		1					1		2	2		2	3	22	27			2			8
	P - 22	32,00	1	28	1	1	5	1	26		13	26	1	8	28	54	26	2		25		2	6
	BSK - 04	72,00	1	47			4	6	20	2	74	28	4	29	32	76	88	4		18		4	35
	P - 27	28,00		1					5		17		1	16	11	13	18	2		1			9
	P - 15	40,00	1	36		2	2	4	28		23	27	1	33	27	52	52	2	2	28	1	2	26
	P - 24	23,00	1	26			1	2	23		25	24	1	27	27	51	50	1		1		2	24
	BSK - 16	55,00		3					3		4	3		2	3	62	37		3	4			19
	BSK - 01	52,50	1	34	2	3	5	4	34		32	31	4	25	28	48	47	3		9		3	43
Outer shelf in open marine north of Madura (Zone IV)	GM - 18	69,00	1	2					3		3	4		4	2	34	48			2			46
	GM - 01	69,00		9		3	9	3	18	9	29	18	16	15	2	39	55	4		24	2		42
	GM - 11	63,00	1	7			3	3	10	2	28	8	3	29	11	64	54	1		31	1	1	37
	GM - 31	61,00	1	31	1	2	7	3	25		26	28	3	27	39	26	54	1		16		2	31
	GM - 32	57,00	1	26			2	2	8	1	25	26	2	26	28	51	52	2		26		1	26
	GM - 15	73,00	2	37		4	4	3	27		17	34	3	39	47	73	57	3	1	44	4	1	38
	GM - 04	55,00				5	5	1	2		2	1	1	26	1	53	54			1		1	52
	GM - 13	77,00		6	2	4	3	4	21	4	3		22	21	4	46	63	4	2		3		18
	GM - 29	42,00	1	4		2	2	2			2	2	3	8		24	62		2	4			20

PLANKTIC FORAMINIFERA

ZONATION	SAMPLE	DEPTH	*Globigerina bermudezi*	*Globigerina* spp.	*Globigerinoides ruber*	*Globigerinoides trilobus immaturus*	*Globigerinoides trilobus sacculiferus*	*Globigerinoides trilobus trilobus*	*Globigerinoides* spp.	*Globorotalia humerosa humerosa*	*Globorotalia menardii*	*Globorotalia tumida tumida*	*Globorotalia ungulata*	*Globorotalia* spp.	*Hastigerina aequilateralis*	*Hastigerina siphonifera*	*Orbulina universa*	*Pulleniatina* spp
Inner shelf in Madura Strait (Zone I)	GB - 38	5,00																
	GB - 43	11,00																
	GB - 17	7,50																
	GB - 18	6,00																
	GB - 29	5,00																
	GB - 21	6,50																
	GB - 20	5,50																
	GB - 32	10,00																
	GB - 19	4,50																
	GB - 30	7,00																
	GB - 31	7,50																
	SG - 28 (SBY)	5,00																
	SG - 20 (SBY)	5,00																
	SG - 02 (SBY)	9,00																
	SG - 47 (SBY)	10,00																
	SG - 30 (SBY)	5,00																
	SG - 04 (SBY)	5,00																
	SG - 06 (SBY)	4,00																
	SG - 09 (SBY)	4,00																
	SG - 10 (SBY)	5,00																
	SG - 04 (S)	7,50																
	SG - 05 (S)	8,00																
	PGC - 26	12,00																
	BSK - 38	15,60																
Inner shelf in open marine north of Madura (Zone II)	GM - 10	27,00			2			1										
	GM - 21	25,00			1											1		
	GM - 16	23,00			1											1		
	GB - 24	29,00					1			2							1	
Outer shelf in Madura Strait (Zone II)	PGC - 02	42,00		5		2	2	3	3				2	3			3	2
	PGC - 05	42,00		8	5	2			2		1			4	2			1
	PGC - 03	56,00		3	2			3								4		
	PGC - 09	54,00		2	2				2		1	2		2			2	1
	P - 32	37,00	2	3	3			2	1		4					1		1
	P - 30	35,00	1	9	1	1		1	1									
	P - 22	32,00		9	4	1			1		1			3				1
	BSK - 04	72,00		12	3	2		2		2								2
	P - 27	28,00		2					2									
	P - 15	40,00		3	3	2				1	2					3		2
	P - 24	23,00		4	1	1		1	1									
	BSK - 16	55,00		5	3											3		
	BSK - 01	52,50	3	7	5	3					3					3		
Outer shelf in open marine north of Madura (Zone IV)	GM - 18	69,00	5		17	13			6	9	4		2	3			2	
	GM - 01	69,00	4		5	7	1	8	3	1	7		1			1	2	1
	GM - 11	63,00	3		7			6	3		6			1		1		1
	GM - 31	61,00	2		6	2					2					1		
	GM - 32	57,00		2					2		2	2		1			1	
	GM - 15	73,00			14	9	1	4	4	4	7	3	2	4	1	4	3	4
	GM - 04	55,00	2		5	1		1								1		2
	GM - 13	77,00	3	6	8			4		4		2	5	2	2	3	6	3
	GM - 29	42,00			3	1		2								3		

BENTHIC FORAMINIFERA — HYALIN

ZONATION	SAMPLE	DEPTH	*Amphistegina* spp.	*Anomalinella* spp.	*Asterorotalia* spp.	*Bolivina* spp.	*Cancris* spp.	*Cassidulina* spp.	*Cibicides* spp.	*Dentalina* spp.	*Elphidium crispum*	*Elphidium* spp.	*Eponides* spp.	*Fissurina* spp.	*Lagena* spp.	*Lenticulina* spp.	*Nodosaria* spp.	*Pseudorotalia* spp.	*Reusella* spp.	*Ammonia becarii*	*Ammonia* spp.	*Sphaeroidina buloides*	*Uvigerina* spp.
Inner shelf in Madura Strait (Zone I)	GB - 38	5,00																					
	GB - 43	11,00																		2			1
	GB - 17	7,50																					
	GB - 18	6,00																					
	GB - 29	5,00																					
	GB - 21	6,50																					
	GB - 20	5,50																					
	GB - 32	10,00																					
	GB - 19	4,50																					
	GB - 30	7,00																					
	GB - 31	7,50																					
	SG - 28 (SBY)	5,00																					
	SG - 20 (SBY)	5,00																					
	SG - 02 (SBY)	9,00																					
	SG - 47 (SBY)	10,00																		1			
	SG - 30 (SBY)	5,00																					
	SG - 04 (SBY)	5,00			1				1									1		1			
	SG - 06 (SBY)	4,00																					
	SG - 09 (SBY)	4,00																					
	SG - 10 (SBY)	5,00											1							2	1		
	SG - 04 (S)	7,50					1		1												1		1
	SG - 05 (S)	8,00													1		1			1			
	PGC - 26	12,00					1		1											2	1		
	BSK - 38	15,60																		1	2		1
Inner shelf in open marine north of Madura (Zone II)	GM - 10	27,00			3						8	3						6		4	1	1	
	GM - 21	25,00			5		2		2		3	2	1	3				5		1		1	
	GM - 16	23,00			4		3		2		3	2			1			3		1		1	
	GB - 24	29,00		2	7		1		3		5	5		1				9		6	1	1	
Outer shelf in Madura Strait (Zone II)	PGC - 02	42,00		1	3		2		7		3	1	5	3	2	2	1	7		2	9		
	PGC - 05	42,00			5		7		6		2	4	13		4		5	6		4	6		
	PGC - 03	56,00			16				16		8	7		2	4	3		8		7	13		
	PGC - 09	54,00		3	7	1	5	3	8	2	4	7	3		5	3		8	4	5	8	3	
	P - 32	37,00		3	2	2	3		7		5	6	10		2	1	2	6	1	2	7		
	P - 30	35,00	3		3		6		6		2	7	3					6	4	2	4		
	P - 22	32,00			1		2		2			3	3					4		2	5	2	1
	BSK - 04	72,00		3	2	2	3		19		9	7	11	2	1	1	3	26	3	7	13	3	1
	P - 27	28,00			1		1		4			3	5					5	1	1	3	1	
	P - 15	40,00		7	3	4	5	4	6		2	11	9	1		3	8	8		4	5	2	
	P - 24	23,00	1		1		3		2			2	2					4			2		
	BSK - 16	55,00			11		11		6		4	9	3	6	3			12	3	9	11	2	2
	BSK - 01	52,50		7	5	2	6		9	1	4	1	9		1	1	2	8	3	3	7	3	
Outer shelf in open marine north of Madura (Zone IV)	GM - 18	69,00		9	8	11	5	4	16	2		4	16	2	9	5	3	13	3	3	6	5	3
	GM - 01	69,00		23	6	9	6	3	19			8	21		4	2	3	27	3	7	13	9	2
	GM - 11	63,00		21	7	5	7		15		6	14	24		6	3	7	25	2	8	14		2
	GM - 31	61,00		7	5	3	3		10	2		2	18		3	2	1	21	2	2	21	3	1
	GM - 32	57,00		4	1	2	2		7		17	12	10	1			6	19	3	4	10	3	1
	GM - 15	73,00		18	12	9	3	3	14			3	15	1	9	2	1	23		11	19	2	3
	GM - 04	55,00		4	3	2	2		6		5	3	14				2	16	4	4		7	1
	GM - 13	77,00		6	14	13	4		17	4	5	6	23			4	2	29	3	3	14	4	4
	GM - 29	42,00			1		2		2		3	4	2					5		2			

BENTHIC FORAMINIFERA — ARENACEOUS / PORCELENEOUS

ZONATION	SAMPLE	DEPTH	*Textularia agglutinans*	*Haplophragmoides* spp.	*Ammobaculites* spp.	*Flintina* spp.	*Pyrgo* spp.	*Quinqueloculina seminulum*	*Quinqueloculina* spp.	*Spiroculina columnis*	*Spiroloculina* spp.	*Triloculina* spp.	Others
Inner shelf in Madura Strait (Zone I)	GB - 38	5,00											
	GB - 43	11,00	1	2	2			1			1		3
	GB - 17	7,50											
	GB - 18	6,00											
	GB - 29	5,00											
	GB - 21	6,50											
	GB - 20	5,50											
	GB - 32	10,00											
	GB - 19	4,50											
	GB - 30	7,00											
	GB - 31	7,50											
	SG - 28 (SBY)	5,00											
	SG - 20 (SBY)	5,00											
	SG - 02 (SBY)	9,00											
	SG - 47 (SBY)	10,00	1	1		1		1	1		1		5
	SG - 30 (SBY)	5,00											
	SG - 04 (SBY)	5,00						1			1		
	SG - 06 (SBY)	4,00											
	SG - 09 (SBY)	4,00											
	SG - 10 (SBY)	5,00	2	3	1				1				
	SG - 04 (S)	7,50		2	3					1			1
	SG - 05 (S)	8,00	2	4	1			1	1		1		1
	PGC - 26	12,00		1	1				1				2
	BSK - 38	15,60	2	2	1			1	2		1		1
Inner shelf in open marine north of Madura (Zone II)	GM - 10	27,00	2		1								8
	GM - 21	25,00	1		2			2	2		2	1	3
	GM - 16	23,00	1	1				4			3	1	2
	GB - 24	29,00	1		2		1		1	1	1	1	2
Outer shelf in Madura Strait (Zone II)	PGC - 02	42,00	3			2	1	3	3		4		13
	PGC - 05	42,00	2		1	3		9	3	2	9	2	4
	PGC - 03	56,00	2		2	3			3		9	3	11
	PGC - 09	54,00	2					5	3	3	2	3	14
	P - 32	37,00	2			1	3	8	1	4	5	4	8
	P - 30	35,00	2					3	3		3	4	3
	P - 22	32,00				3		3	2		2	2	6
	BSK - 04	72,00	3			8		10	7	2	8	14	11
	P - 27	28,00						2	1		2	1	3
	P - 15	40,00	2				4	2	1		2	2	5
	P - 24	23,00	1					2	1			1	
	BSK - 16	55,00	1					5	2	2	5	7	5
	BSK - 01	52,50	3			2	1	2	2	2	3	2	11
Outer shelf in open marine north of Madura (Zone IV)	GM - 18	69,00	1			8	3	3	3	7	3	3	13
	GM - 01	69,00	2			2	2	4	6		1	7	8
	GM - 11	63,00	2			1	1	1	1		3	4	7
	GM - 31	61,00	3			6	2	3	5		4	7	12
	GM - 32	57,00	3		2	11		2	4		4	6	16
	GM - 15	73,00	2				3	1	1		3	9	29
	GM - 04	55,00	2			6		4	3		6	8	17
	GM - 13	77,00	4			17	1	5	2	1	6	10	10
	GM - 29	42,00	4						1			2	5

Table 2. Megascopic, Microscopic and Grain size Analyses of Sediment in Madura Waters

Sample Code/Core	Coordinate		Depth	Megascopic	Microscopic																																		Grain size Analysis				
						Texture								Mineralogy																												
						Size				Shape				Coarse grain																						Fine grain								
								% Grain						Carbonate			Volcanic Material														Others													
	S / Late	East / Lon	(m)	Description	Sediment Type	Range (mm)	Mean (mm)	Sand	Silt	Clay & Mud	Sphericity	Roundness	Sorting	Limestone	Carbonate	Shells/fossil	Igneous Rock	Pyroclastic rock	Feledpars	Quartz	Pyroxenes	Hornblende	Biotite	Mica	Clorde	Ore minerals	Carbon	Lithic (sediment rock	Glaukonit	Carbonate mud	Carbonate minerals	Volcanic material	Lithic (sediment rock)	Clay	Medium - coarse sand	Fine Sand	Silt	Clay	Sediment Type
GM - 18	-5.998	113.805	69.00	Clay, greenish grey, fossil	Clay	<0,005-0,4	<0,005		15	85				1	2	2		1	2	1	1	1	1		1		1	1	5				80	-	60.4	29.9	9.7	Silty san
GM - 01	-6.000	112.612	69.00	Clay, greenish grey, fossil	Silty clay	<0,005-0,8	0.5		33	67				4		7	2	2	3	1	2	2	2	1	1	2		2	2	15				52	-	58.1	21.3	20.6	Silty san
GM - 11	-6.000	113.016	63.00	Clay, greenish grey	Clay	<0,005-0,01	0.04		18	82				1	3	4			2	3	1		1			1		2	6				76	-	62.9	22.9	14.2	Silty san
GM - 31	-6.248	112.476	61.00	Clay, greenish grey, fossil	Clay	<0,005-0,08	<0,005		20	80				2	2	2			5	3						2	2	2	20				60	-	3.6	27.9	68.5	Silty cla
GM - 32	-6.405	113.264	57.00	Clay, greenish grey, fossil	Clay	<0,005-0,1	<0,005		22	78				1	1	8		1	4	2	1	1	1			1	1		30				48	-	6.9	21.9	71.2	Silty cla
GM - 15	-6.418	113.894	73.00	Clay, greenish grey, fossil	Clay	<0,005-0,02	<0,005		20	80				2	1	9			3	1		1				1	1	1	15				65	-	6.8	34.9	58.3	Silty cla
GM - 04	-6.499	112.676	55.00	Clay, greenish grey, fossil	Silty clay	<0,005-0,06	<0,005		26	74				3	5	3			2	1	1	1			1	2	2	4	1	32				42	-	7.9	24.3	67.8	Silty cla
GM - 13	-6.582	114.000	77.00	Clay, greenish grey, fossil	Clay	<0,005-0,01	<0,005		22	78				7	4	3			2	1	1	1				1	1	1	28				50	-	2.4	18.9	78.7	Clay
GM - 10	-6.738	112.478	42.00	Silt, greenish grey, fossil	Silty clay	0,005-0,03	0.01		46	54				8	5	20		1	2	2	1	1			1	2		2		38				16	-	4.6	56.8	38.6	Clayey s
GM - 21	-6.817	112.547	5.00	Silt, greenish grey, fossil	Silty clay	0,005-0,2	>0,2		55	45				10	15	18			3	3	1	2				2			40				5	3.6	30.1	56.6	9.7	Sandy si
GM - 16	-6.827	112.507	11.00	Silt, greenish grey, fossil	Silty clay	< 0,005-0,1	<0,005		52	48				24	4	10			3	6		1				1	1	1	38				10	-	8.8	58.9	32.3	Clayey s
GM - 29	-6.833	112.950	27.00	Clay, greenish grey, fossil	Clay	<0,005-0,01	<0,005		22	78						1	1		8	3	1					1	1	6		8				70	-	4.9	18.6	76.5	Clay
GB - 38	-6.834	113.624	25.00	Clay, greenish grey	Clay	< 0,005-0,01	<0,005	4	18	78						1	1		3	2	1					3	1	8	2	8				70	-	2.5	17.9	79.6	Clay
GB - 43	-6.834	113.891	23.00	Clay, greenish grey	Clay	< 0,005-0,01	<0,005	8	17	75						1	2		6	3	1		1			4	1	6		4				71	-	3.4	19.1	77.5	Clay
GB - 24	-6.845	112.764	29.00	Silt, greenish grey	Sandy silt	<0,002-0,2	0.13	33	59	8	0,5-0,9	0,5-0,9	0,35-0,5			2	2		6	6		1				3	2	10	1	4	1	10	48	4	-	29.6	60.4	10.0	Sandy si
GB - 17	-6.908	112.729	7.50	Silty sand, greenish grey	Silty sand	<0,005-0,2	0.0625	54	36	10	0,3-0,7	0,3-0,7	1-2			17	5	2	6	10	1		1			8	1	2	1	2		6	30	8	-	57.8	24.8	17.4	Silty san
GB - 18	-6.908	112.765	6.00	Silty sand, greenish grey, fossil	Fine sand	0,03-0,2	0.125	100			0,3-0,7	0,3-0,7	0,35-0,5			10	7	2	11	10	2		1			2		48	7					-	55.2	30.9	13.9	Silty san
GB - 29	-6.909	112.692	5.00	Coarse sand, greenish grey, fossil	Coarse sand	0,1-1	0.3	100			0,3-0,7	0,5-0,7	0,35-0,5	3	2	3	3	4	10	2	2	2	2	2	5	4	47	7					-	78.9	12.2	8.9	Sand
GB - 21	-6.909	112.801	6.50	Silty sand, greenish grey, fossil	Silty sand	<0,005-0,1	0.125	60	25	15	0,3-0,7	0,3-0,5	1-2	4	1		3		15	12	2					6	1	14	2		5	20	15	-	59.8	29.2	11.0	Silty san
GB - 20	-6.924	112.783	5.50	Silty sand, greenish grey, fossil	Silty sand	<0,005-0,15	0.125	69	21	10	0,3-0,5	0,3-0,7	>4	4	1	5	2	2	12	10	1		1			6	1	22	2	4	5	12	10	-	58.1	30.7	11.2	Silty san
GB - 32	-6.927	112.719	10.00	Silty sand, greenish grey, fossil	Silty sand	0,01-0,1	0.07	64	36		0,3-0,7	0,3-0,7	1-2			5	11	2	12	3		2				2		27			11	25		3.1	56.2	27.8	12.9	Silty san
GB - 19	-6.939	112.765	4.50	Fine sand, greenish grey, fossil	Fine sand	0,05-0,2	0.15	100			0,3-0,5	0,3-0,5	1-2			17	6	1	14	11	4		1			2	1	41	2					-	60.6	35.8	3.6	Silty san
GB - 30	-6.945	112.703	7.00	Silty sand, greenish grey, fossil	Silty sand	0,005-0,1	0.15	66	34		0,3-0,5	0,3-0,5	2-4			4	6	2	13	7						7		25	2			15	19	-	57.8	34.7	7.5	Silty san
GB - 31	-6.967	112.698	7.50	Medium sand, greenish grey, fossil	Sand	0,03-0,3	0.05	100			0,1-0,3	0,1-0,3	>4		2	10	12	10	10	8	2	4				3		34	5	5				11.8	65.4	13.8	9.0	Sand
SG - 28 (SBY)	-7.190	112.822	5.00	Silty sand, greenish grey	Sand	0,05-0,7	0.15	90	10		0,1-0,5	0,1-0,5	0,35-0,5	12		1	7	1	13	6	7	1			1	4		35	2				10	6.1	56.5	19.2	18.2	Silty san
SG - 20 (SBY)	-7.192	112.785	5.00	Sandy silt, greenish grey	Sandy silt	0,005-0,5	0.125	31	66	3	0,1-0,5	0,1-0,5	1-2	3	1	2	3	1	2	3	1	1	1	2		2		5	4			20	46	3	-	56.0	27.9	12.9	Silty san
SG - 02 (SBY)	-7.195	112.792	9.00	Medium sand, greenish grey	Sand	0,05-0,15	0.125	95	5		0,1-0,5	0,1-0,5	>4	3		4	6	4	13	4	5	4	4			5	2	38	3				5	-	71.1	16.9	7.4	Sand
SG - 47 (SBY)	-7.198	112.705	10.00	Medium sand, greenish grey	Clayey sand	<0,005-0,5	<0,005	57	6	37	0,5-0,7	0,5-0,7	2-4	3		4	4	2	15	7		1	1	1		5	2	11	1	6			6	31	13.5	68.6	16.4	1.5	Sand
SG - 30 (SBY)	-7.214	112.839	5.00	Sandy silt, greenish grey	Sandy silt	<0,005-0,1	<0,005	21	65	14	0,5-0,9	0,3-0,7	1-2	1		6	1		5	1	1					2	2		2	5		20	45	9	5.7	52.9	23.7	17.7	Silty san
SG - 04 (SBY)	-7.219	112.826	5.00	Medium sand, greenish grey	Sand	0,02-0,5	0.2	93		7	0,3-0,7	0,1-0,3	2-4	12		6	9	2	10	6	6	3	2	1	1			32	3				7	-	78.1	14.3	5.5	Sand
SG - 06 (SBY)	-7.251	112.823	4.00	Medium sand, greenish grey	Silty sand	<0,005-0,1	0.062	53	23	24	0,1-0,3	0,1-0,3	1-2	1	8			3	1	5	12	2			1	12	2	4	2	6		6	17	18	-	19.2	58.3	18.3	Sandy si
SG - 09 (SBY)	-7.292	112.860	4.00	Sandy silt, greenish grey	Fine sand	<0,005-0,4	0.2	83	10	7	0,5-0,7	0,3-0,7	1-2	8	1	1	7	3	17	2	9	2	1	1	1	2	18	5	5				10	7	-	21.1	57.2	17.9	Sandy si
SG - 10 (SBY)	-7.309	112.876	5.00	Sandy silt, greenish grey	Sandy silt	0,005-0,35	0.1	34	60	6	0,5-0,9	0,5-0,9	1-2	3		3	4	3	6	4	1	1	1	1		1	1	4	1		23	37	6	-	16.7	55.3	24.1	Clayey s
SG-04(S)	-7.057	114.062	7.50	Clay, greenish grey	Silty clay	<0,005-0,01	<0,005	7	31	62				2	3	4			9	13		1				4	1	1	41				21	-	7.4	12.5	80.1	Clay
SG-05(S)	-7.091	114.079	8.00	Fine sand, greenish grey	Silty clay	<0,005-0,1	<0,005	9	30	61				8	2	3			8	7	1	1	1			4	1	1	29				27	-	10.4	28.8	59.7	Silty cla
PGC-02	-7.242	113.473	42.00	Clayey sand, greenish grey, fossil	Clay	<0,005-0,01	<0,005	5	13	82				2	5	4			1	1		1				2	1	1	58				24	-	2.6	13.7	83.7	Clay
PGC-26	-7.253	113.200	12.00	Fine sand, greenish grey	Clay	<0,005-0,01	<0,005	6	15	79				4	1	5			1	1		1				3	1	3	1	59				20	-	4.1	18.6	77.1	Clay
PGC-05	-7.289	113.427	42.00	Clay, greenish grey, fossil	Clay	<0,005-0,1	<0,005	6	12	82				3	5	6			1	1		1				1			53				30	-	8.9	56.8	34.3	Clayey s
PGC-03	-7.400	113.480	56.00	Clay, dark grey	Clay	<0,005-0,01	<0,005	3	14	83				1	4	5			1	1		1			2	1		1	57				26	-	2.5	17.3	80.2	Clay
PGC-09	-7.403	113.391	54.00	Clay, greenish grey	Clay	<0,005-0,01	<0,005	7	11	87				3	3	2			1			1			1	1	1	1	50				37	-	3.9	16.7	79.4	Clay
P-32	-7.475	113.975	37.00	Clay, greenish grey	Clay	<0,005-0,01	<0,005	5	15	80					1	3	1		2	3	2	1	1	1		1	1	3	40				40	-	3.5	19.3	77.2	Clay
P-30	-7.500	113.045	35.00	Clay, greenish grey	Clay	<0,005-0,01	<0,005	5	17	78					1	5	2	1	2	1	1	1	1	1		4	1	1	32				46	-	2.6	39.6	57.8	Silty cla
P-22	-7.527	113.081	32.00	Clay, dark grey	Clay	<0,005-0,01	<0,005		22	78					1	4	1		4	1	3	1	1	1		3	1	1	10				68	-	4.4	18.8	76.5	Clay
BSK-04	-7.567	113.815	72.00	Clay, greenish grey, fossil	Clay	<0,005-0,01	<0,005	8	14	78						1	2	5	4	2	3	1				3	1						78	-	10.1	26.8	60.6	Silty cla
P-27	-7.571	113.010	28.00	Clay, greenish grey	Clay	<0,005-0,01	<0,005		21	79						1			8	1	3	5	1			1	1	4					75	-	6.7	25.8	67.5	Silty cla
P-15	-7.573	113.220	40.00	Clay, greenish grey	Clay	<0,005-0,01	<0,005	11	14	75						3	1	3	4	2	1	1	1	1	5	1	1	2					73	-	5.1	16.0	78.9	Clay
P-24	-7.608	113.046	23.00	Clay, greenish grey	Clay	<0,005-0,01	<0,005	16	10	74						1	1	1	6	4	2	2	1	1	5	1		1					74	-	6.6	15.0	78.4	Clay
BSK-16	-7.646	113.643	55.00	Silt, grey green	Silty clay	<0,005-0,01	<0,005	14	15	71						1	1	3	6	2	2	1	2	2	2	4	1	1	1				71	1.8	4.2	34.2	59.2	Silty cla
BSK-01	-7.658	113.829	52.50	Silty sand, brownish grey	Silty sand	0,05-0,4	0.1	48	48	4	0,1-0,5	0,1-0,3	1-2			3	9	3	5	2	2	1	2	2	1	8	2	4	4		44	4	4	1.8	10.2	33.7	46.1	Silty cla
BSK-38	-7.754	113.303	15.60	Clay, greenish grey	Clay	<0,005-0,01	<0,005	9	14	77					1	5	1		3	2	1	1	1	1	4	1		1					77	-	4.9	14.7	80.4	Clay

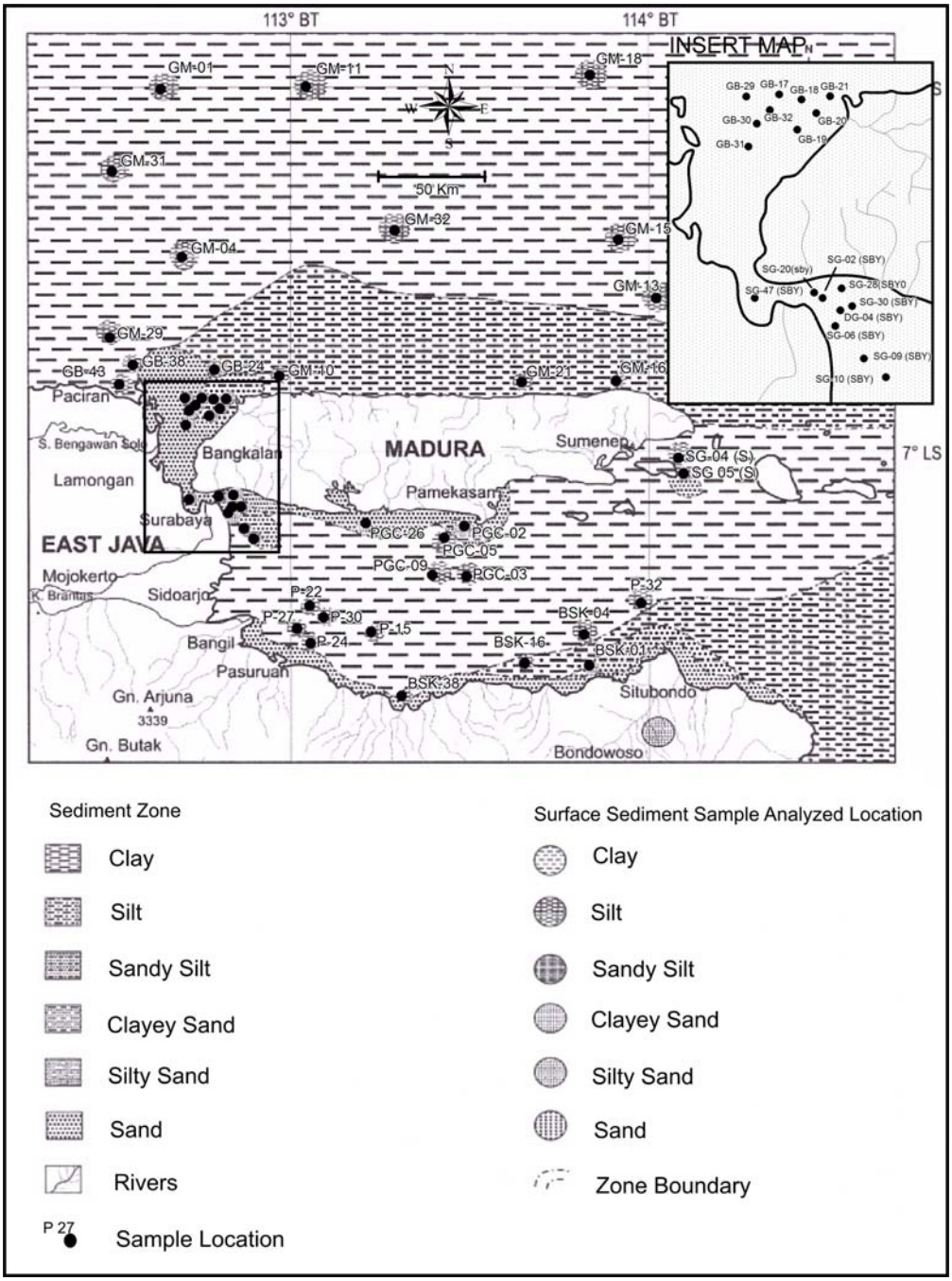

Figure 1. Sea Surface Sediment Map of Madura Waters (modified from Masria, 1991; Arifin et al., 1992 and Astjario et al., 1998)

Table 3. Physical Oseanographic Parameter, Sediment Characteristic and Microorganism Assemblages of Madura Waters

ZONE	SEDIMENT			MICROORGANISM ASSEMBLAGES					
				NANNOPLANKTON			FORAMINIFERA		
	TYPE	TEXTURE	COMPOSITION	MARKER SPECIES	ABUNDANCE		MARKER SPECIES	ABUNDANCE	
Inner shelf in Madura Strait (Zone I) Bathymetry = 0 -3 m Sea surface temperature = 29,3 ° C Salinity < 30 ‰ pH = 6,0 - 7,3	Clay, silt, sandy silt, silty sand, sand.	(i) Sphericity and roundness index alter significant during transport (0,1 to 0,5) (ii) precentage of fine grain proportional with distance (0 to 78%);	(i) Dominated by lithic (ii) Volcanic material > carbonate	Made up of the only species ***Gephyrocapsa oceanica***.	(i)	No to very rare (≤ 14 individu), being less than 1% sediment	***Ammonia* spp.,** Arenaceous benthic (***Ammobaculites* spp.**, ***Textularia agglutinans, Haplopragmoides* spp.**) & Miliolidae (***Quinqueloculina* spp**)	(i) (ii)	No planktic foram No to rare benthic foram (≤ 14 individu, ≤ 10 species)
Inner shelf in open marine north of Madura (Zone II) Bathymetry = 0 - 3 m Sea surface temperature = 29,4 ° C Salinity = 31 - 34 ‰ pH = 6,2 - 7,6	Silty clay	(i) (ii) % fine grain material < 55 % precentage of fine grain proportional with distance	(i) Carbonate > 70%	***Gephyrocapsa oceanica*** dominant. ***Emiliania huxleyi*** common ***Helicosphaera carteri, H. pavimentum, H. wallichii, Pontosphaera discopora, P. multipora,*** and ***Syracosphaera* spp.** rare.	(i) (ii)	≥ 87 individu ≥ 12 species	***Elphidium* spp.,** ***Ammonia* spp.,** ***Pseudorotalia* spp.** and ***Asterorotalia* spp.**	(i) (ii)	planktic foram ≥ 2 individu, ≥ 2 species total ≥ 34 individu, ≥ 16 spesies
Outer shelf in Madura Strait (Zone III) Bathymetry = 30 - 200 m Sea surface temperature = 29,6 ° C Salinity = 31 - 33 ‰ pH = 6,2 - 7,8	Clay, silty clay, silty sand	(i) precentage of fine grain proportional with distance (74 to 87%)	(i) Carbonate content decreasing northward (68 to 1%) (ii) Volcanic material content increasing southward (3 to 23%)	***Gephyrocapsa oceanica*** and ***Emiliania huxleyi*** dominant. ***Helicosphaera carteri, H. pavimentum, H. wallichii, Pontosphaera discopora, P. multipora,*** and ***Syracosphaera* spp.** rare. ***Calcidiscus leptoporus, Umbellosphaera irregularis*** and ***Umbilicosphaera*** spp. rare founded.	(i) (ii) (iii)	≥ 45 individu ≥ 8 species at same depth, abundance in this zone is less than Zone IV	***Elphidium* spp.,** ***Ammonia* spp.,** ***Cibicides* spp.,** ***Pseudorotalia* spp.** and ***Asterorotalia* spp**	(i) (ii) (iii)	planktic foram ≥ 4 individu, ≥ 2 species total ≥ 30 individu, ≥ 17 species at same depth, abundance in this zone is less than Zone IV
Outer shelf in open marine north of Madura (Zone IV) Bathymetry = 30 - 200 m Sea surface temperature = 30,3 ° C Salinity = 31 - 34 ‰ pH = 7,4 - 8,2	Clay, silty clay	(i) fine material dominant (78 to 85%) (ii) precentage of fine grain proportional with distance	(i) Carbonate content decreasing northward (42 to 10%)	***Gephyrocapsa oceanica*** and ***Emiliania huxleyi*** abundant. ***Helicosphaera carteri, H. pavimentum, H. wallichii, Pontosphaera discopora, P. multipora,*** and ***Syracosphaera* spp.** common.	(i) (ii) (iii)	≥ 150 individu ≥ 14 species amount- & number- of spesies increases with increasing depth	***Bolivina* spp.,** ***Cibicides* spp.,** ***Pseudorotalia* spp.,** ***Asterorotalia* spp.** & ***Uvigerina* spp.**	(i) (ii) (ii)	planktic foram ≥ 9 individu, ≥ 4 species total ≥ 40 individu, ≥ 16 species amount- & number of planktic species increases with increasing depth

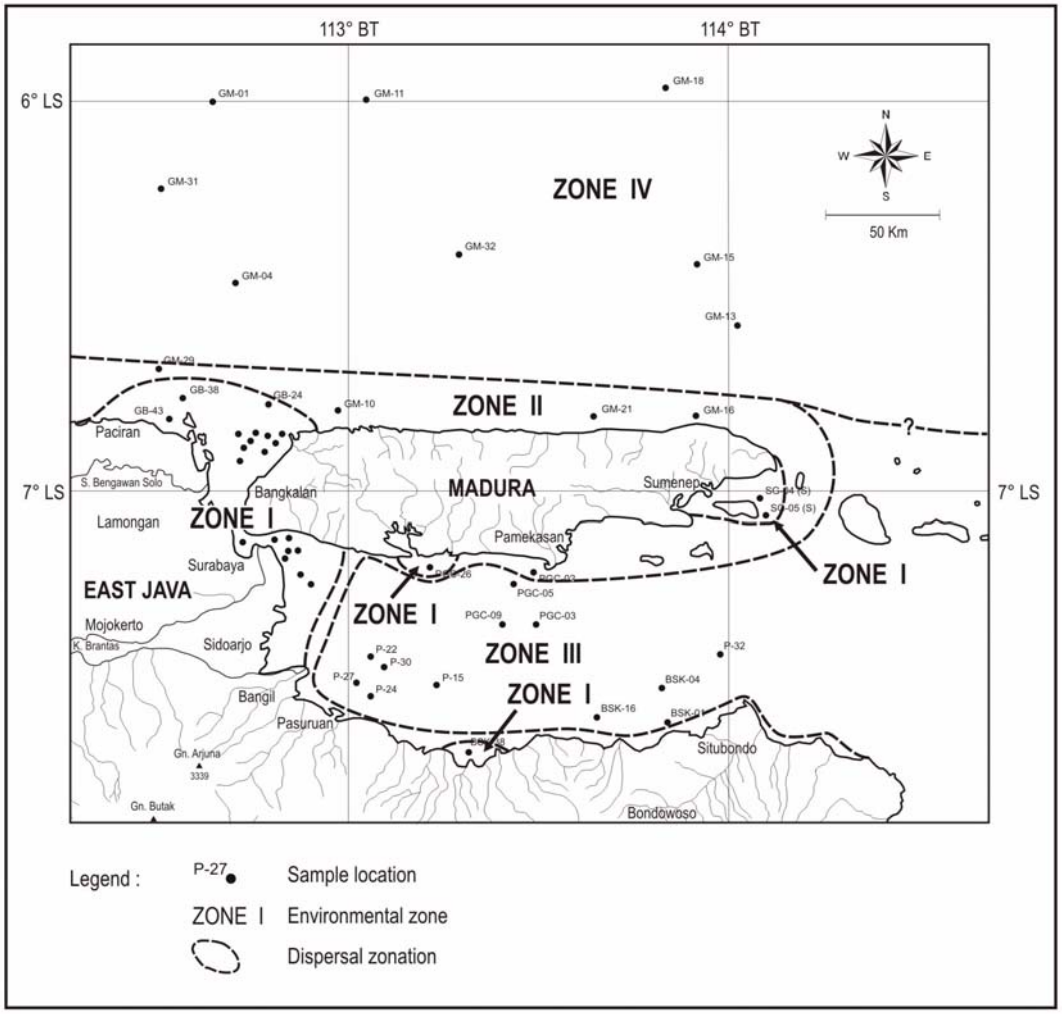

Figure 2. Environment Zone of Madura Waters (taken from 50 samples analyses)

Ammonia* spp.,** arenaceous carbonate test taxa (Ammobaculites* spp., *Textularia agglutinans, Haplophragmoides* spp.**), milliolidae (***Quinqueloculina* spp.**); none of the planktic foraminifera observed.

In inner shelf open marine north of Madura (Zone II), very fine-grained sediments, low temperature (29,4° C), normal salinity and pH 6,2 to 7,6 yielded the zone; the nannoplankton assemblages are dominated by ***Gephyrocapsa oceanica*** together with a few ***Emiliania huxleyi, Helicosphaera carteri, H. pavimentum, H. wallichii, Pontosphaera* spp**; the foraminifera assemblages includes ***Globigerinoides ruber, G. trilobus sacculiferus, G. conglobatus, Elphidium* spp, *Ammonia* spp., *Pseudorotalia* spp.** and ***Asterorotalia* spp.**

In Madura Strait, the outer shelf zone (Zone III) is indicated by the accumulation of the relative fine-grained sediment, sea surface temperature = 29,6° C, normal salinity, and pH 6,2 to 7,8; the nannoplankton assemblages are dominated by ***Gephyrocapsa oceanica*** and ***Emiliania huxleyi*** which are closely associated with ***Helicosphaera carteri, H. pavimentum, H. wallichii, Pontosphaera* spp.,** and a few ***Calcidiscus leptoporus, Umbellosphaera irregularis, Umbilicosphaera* spp.**; the foraminifera assemblages includes ***Globigerinoides ruber, G. trilobus sacculiferus, G. conglobatus, Elphidium* spp, *Ammonia* spp., *Cibicides* spp., *Pseudorotalia* spp.,** and ***Asterorotalia* spp.** are common.

In the outer shelf open marine north of Madura (Zone IV), which is indicated by clay, high temperature (30,3° C), normal salinity, normal pH (7,4 to 8,2); the nannoplankton species such as ***Gephyrocapsa oceanica, Emiliania huxleyi, Helicosphaera carteri, H. pavimentum, H. wallichii, Pontosphaera* spp., *Discoaster* spp., *Calcidiscus leptoporus, Umbellosphaera irregularis, Umbilicosphaera* spp.** are abundant; the foraminifera assemblages of ***Globigerina calida, Pulleniatina obliquiloculata, Orbulina universa, Hastigerina aequilateralis, Bolivina* spp., *Bulimina* spp., *Cibicides* spp., *Pseudorotalia* spp., *Asterorotalia* spp., *Lenticulina* spp., *Cassidulina* spp., *Siphonina* spp.,** and ***Uvigerina* spp.** are common. In open marine, both amount- and number- of species of nannoplankton as well as foraminifera increases with increasing water depth.

Nannoplankton and foraminifera assemblages displayed optimal abundancy in the very fine grain sediment (clay and silty clay); whilst few nannoplankton species (such as *Gephyrocapsa oceanica*) and foraminifera (*Ammobaculites* spp. and *Haplophragmoides* spp.) are observed in coarser grain.

CONCLUSION

The distribution and abundance of both nannoplankton and foraminifera assemblages in both Madura Strait and water north of Madura are closely related to environment.

The most significant physical environment parameter controlling appearance of marker species, amount- and number- of spesies in microorganism assemblages are bathymetry, salinity, temperature, pH and sediment due to fluvial supply.

This study displayed a good correlation between nannoplankton as well as foraminifera assemblages in the sense of environment interpretation. In open marine region, the abundancy of shallow marine taxa reduces with increasing water depth, on the other hand the abundancy and diversity index (number of species) of deeper marine taxa are present in proportional with depth. In strait region, the asemblages is most controlled by the physical and chemical environment parameters.

ACKNOWLEDGEMENTS

The author thank to the head of the Marine Geological Institute of Indonesia for using samples to study. Thank also to Prof. Dr. Emmy Suparka, Dr. Rubiyanto Kapid and Hamzah Latief, PhD for supporting to publish this paper; Prof.Ris. Mimin Karmini for editing the script; the head of Faculty of Geology and the head of PURISKA (Centre of Research and Collaboration) FMIPA University of Padjadjaran for facilities support.

REFERENCES

Arifin, L., Darlan, Y., Kusnida, D., Kamiludin, U., and Silitonga, F., 1992, Laporan Penyelidikan Geologi dan Geofisika Kelautan di Perairan Utara Pulau Madura, Lembar Peta 1609 Jawa Timur, *Pusat Penelitian dan Pengembangan Geologi Kelautan*, 10-12

Astjario, P., Budiono, K., Masduki, A. and Hermasyah, G.M., 1998, Peta Sebaran Sedimen Laut Perairan Lembar 1608 (Surabaya), skala 1:250.000, *Pusat Penelitian dan Pengembangan Geologi Kelautan*

Baumann, K., Young, J.R., Cachao, M., and Ziveri, P., 2001, Biometric Study of Coccolithus Pelagicus and Its Palaeoenvironmental Utility, 18 Agustus 2005, http://www-user.uni-bremen.de/~micropal

Bolli, H.M., and Saunders, J.B, Oligocene to Holocene Low Latitude Planktic Foraminifera, *in* Plankton Stratigraphy, Bolli, H. M., Saunders, J .B., and Perch – Nielsen, K., Editor, Cambridge University Press, 155-262

Dwiyanto, B., and Sutardy, 1992, Marine Geologycal Institute (MGI) Sediment Cores Data Base Volume I, *Directorate General of Geology and Mineral Resources, Ministry of Mines and Energy*, 24-25, 32-33, 60-62, 93-95,110-113, 139-144.

Faturachman, A., and Saefudin, A., 1992, Marine Geologycal Institute (MGI) Sediment Cores Data Base Volume II, *Directorate General of Geology and Mineral Resources, Ministry of Mines and Energy*, 21-26, 32-33, 43-45, 49-52, 62-64, 73-75.

Gibbs, S., 2001, Pliocene to Early Pleistocene Evolution of Nannofossil Assemblages in Response to Palaeoceanographic Changes, 18 Agustus 2005, http://www-user.uni-bremen.de/~micropal,

Ingle, James C. Jr, 1980, Cenozoic Paleobathymetry and Depositional History of Selected Sequences within the Southern California Continental Borderland, Chusman Foundation Special Publication No. 19, Memorial to Orville L. Bandy, 163 - 195

Masria, M., 1991, Peta Sedimen Permukaan Dasar Laut Wilayah Laut Indonesia, skala 1 : 5.000.000, *Pusat Penelitian dan Pengembangan Geologi Kelautan*

McIntyre, A., Be, A., and Roche, 1970, Modern Pasific Coccolithophorida : A Paleontological Thermometer, *Lamont Doherty Geological Observatory Contribution No. 1574, New York*, 27-41

Okada, H., 1984, Modern Nannofossil Assemblages in Sediment of Coastal and Marginal Seas along the Western Pasific Ocean and in the Red Sea, *Uttrecht Micropaleontology Bulletin*, *Volume 30,* 71-187

Okada, H., 1992, Biogeographic Control of Modern Nannofossil Assemblages in Surface Sediments of Ise Bay, Mikawa Bay and Kumano-Nada, Off Coast of Central Japan, *Memorie Di Scienze Geologiche, Allegato al, Volume XLIII* , 431-449

Perch-Nielsen, K., 1986, Cenozoic Calcareous Nannofossils, *in* Plankton Stratigraphy, Bolli, H. M., Saunders, J .B., and Perch – Nielsen,

K., Editor, Cambridge University Press, 427-544

van Marle, L.J., 1991, Eastern Indonesian, Late Cenozoic Smaller Benthic Foraminifera, North Holland, Amsterdam/Oxford/New York/ Tokyo

Wang, P., and Samtleben, C., 1983, Calcareous Nannoplankton in Surface Sediments of the East China Sea, *Marine Micropaleontology, Volume 8*, 249-259

Winter, A., Reiss, Z., and Luz, B., 1979, Distribution of Living Coccolithosphore Assemblages in Gulf of Elat (Aqaba), *Marine Micropaleontology, Volume 4*, 197-223