Oral Paper : JCJ2003-025

THE BENTHIC FORAMINIFERA *AMMONIA BECCARII* AS INDICATOR OF ESTUARINE ENVIRONMENTS IN INDONESIA (SEGARA ANAKAN LAGOON AND SOUTHERN GOMBONG, JAVA)

Luli Gustiantini[1], Kresna Tri Dewi[2], Anne Müller[3], and Praptisih[4]

1. The University of Padjadjaran, Bandung, Indonesia (luli.gustiantini@mgi.esdm.go.id)
2. Marine Geological Institute, Bandung, Indonesia (kresnatd@mgi.esdm.go.id)
3. UFZ Centre for Environmental Research, Magdeburg, Germany (amueller@gm.ufz.de)
4. Center for Geotechnology-LIPI, Bandung, Indonesia (praptisih@geotek.lipi.go.id)

Abstract

In order to test the potential of the benthic foraminifera *Ammonia beccarii* to function as an indicator of estuarine environments, we compared the occurrence of this species in two estuarine environments representing two different spatial and temporal environments. Firstly, we investigated 20 surface samples from the modern Segara Anakan Lagoon in southern Java. In addition, we also investigated 13 samples from a borehole from southern Gombong in Central Java, representing an ancient estuarine environment from the Quaternary.

The study shows that the abundances of *Ammonia beccarii* at the two different sites are completely different. The abundance in the ancient estuarine environment is very high, with mean percentages reaching up to 78.6% of all benthic foraminifera in horizons between 6.7m and 19.5 m depth below the surface. The high abundance indicates that estuarine environments offer suitable conditions for *Ammonia beccarii* and that these foraminifera can indeed function as an environmental indicator of estuarine environments. In contrast, the abundance of *Ammonia beccarii* in Segara Anakan Lagoon is very low where it was found in five surface sediments.

Comparing the two sites and taking into consideration previous studies of the occurrence and morphology of *Ammonia beccarii* and links to environmental stress (Gustiantini *et al.,* 2003), we infer that the abundance of this foraminifera in the Segara Anakan Lagoon reflects the low environmental quality of the lagoon due to high sediment supply to the lagoon, the current system and other environmental factors, such as pollution. However, we also infer from our results that *Ammonia beccarii* shows the ability to adapt and tolerate various environmental changes in estuarine environments in Indonesia.

Sari

Untuk mengetahui potensi foraminifera bentik *Ammonia beccarii* sebagai indikator lingkungan estuari, kami membandingkan keberadaan spesies ini pada dua estuari yang berbeda dalam ruang dan waktu. Pertama, diselidiki 20 contoh sedimen permukaan dari perairan modern Laguna Segara Anakan, Jawa bagian selatan. Kemudian, dibandingkan dengan 13 contoh dari sebuah lubang bor di Gombong Selatan, Jawa Tengah yang mewakili perairan lingkungan estuari purba berumur Kuarter.

Hasil penelitian menunjukkan bahwa kedua daerah penelitian mempunyai kelimpahan foraminifera yang sangat berbeda. Kelimpahan *Ammonia beccarii* dari estuari purba sangat tinggi, dengan rata-rata persentase mencapai 78,6% yang ditemukan pada kedalaman antara 6,7dan 15,5 m di bawah permukaan. Hal ini dapat mengindikasikan bahwa estuari tersebut mempunyai kualitas lingkungan yang ideal bagi kehidupan *Ammonia beccarii,* serta membuktikan bahwa spesies ini merupakan penciri lingkungan estuari. Sebaliknya, kelimpahan *Ammonia beccarii* di Laguna Segara Anakan sangat rendah yaitu hanya ditemukan di lima contoh sedimen permukaan.

Dengan membandingkan dari dua lokasi serta berdasarkan penelitian sebelumnya tentang kelimpahan dan morfologi *Ammonia beccarii* yang dikorelasikan dengan tekanan lingkungan (Gustiantini, *et al.,* 2003), dapat disimpulkan bahwa kelimpahan foraminifera ini di Laguna Segara Anakan menunjukkan rendahnya kualitas lingkungan laguna akibat proses sedimentasi dan pola arus, serta faktor lain yaitu pencemaran yang berkembang di laguna. Selain itu dari hasil penelitian tersebut akan menambah keyakinan bahwa *Ammonia beccarii* memiliki kemampuan untuk beradaptasi serta sangat toleran terhadap berbagai perubahan lingkungan.

INTRODUCTION

Benthic foraminifera are very sensitive to environmental changes because they live attached to the sediments, rocks, and plants at the bottom of the water, where environmental changes are noticeable (Boltovskoy and Wright, 1976). In addition, benthic foraminifera are sensitive because of their simple body structure (Rositasari, 1996). The potential of benthic foraminifera to function as bioindicators has been described in previous studies (e.g. Yanko *et al.,* 1994, Alve, 1995, Schafer, 2000). These studies showed that benthic foraminifera are sensitive bioindicators because (1) They can occur in nearly all types of marine environments; (2) They are usually found in large numbers. Consequently, only small samples are needed to provide statistically significant data; (3) They have a

short life cycle, which makes them sensitive to environmental changes; (4) Their tests can be well preserved; (5) They have relatively high species diversity; (6) In polluted areas foraminifera are usually the organisms which are terminated last.

Estuaries have been considered as unstable environments because environmental parameters undergo a wide range of changes. These changes of environmental parameters (e.g. salinity, temperature, oxygen, nutrient levels) cause considerable environmental stress to the foraminifera and influence the diversity and the abundance of organisms (Murray, 1991). This environmental stress occurrs naturally and is commonly reflected in ancient estuarine environments. However, nowadays, human activities have increased the degree of environmental stress, causing considerable pressures to organisms. Most modern estuaries have been polluted by noticeable input of heavy metals and organic matter (Alve, 1995).

Typical foraminifera which characterize estuarine environments are *Ammonia, Elphidium, Trochammina, Cyclomina, Rheophax,* and *Haynesina* (Rositasari, 2000). In estuaries, environmental stress gives an advantages to the more opportunistic species because species capable of very high levels of adaptation will benefit. In general, environmental stress decreases the abundance of most species. Some species may respond to stress by moving to more suitable sites within the estuary, but if the stress is above their viability, they will be terminated. Some species, however, are abundant in contaminated areas, because they can adapt to environmental stress and then get more nutrition as predation and competition decrease (Alve, 1995). One of these species which adapts very well to environmental stress is *Ammonia beccarii* (Sharifi *et al.,* 1991, Goldstein and Moodley, 1993, Rositasari, 1997).

Ammonia beccarii is a shallow water cosmopolitan species which has occurred widely at great abundance since the Miocene (Debenay *et al.,* 1998). Due to its ability to adapt to various environmental factors it is found across the whole world in shallow water, estuarine and brackish marsh environments (Goldstein and Moodley, 1993). The species can live in contaminated areas (Sharifi, 1991), low oxygen environments (Alve, 1995), and environments with great variability of salinity and temperature (Murray, 1991), even when other species disappear.

Ammonia beccarii adapts to environmental stress by showing great morphologic variability and even abnormalities in the morphology. The morphologic variability has made it very difficult to identify *Ammonia* species to the degree that DNA tests had to be used to allow identification (Holzmann and Pawlowsky, 1997). Furthermore, several authors have also investigated the deformations shown by *Ammonia* sp. Firstly, they concluded that deformation may be related to heavy metal pollution (Nagy and Alve, 1987, Alve, 1991; Sharifi, 1991, and Yanko *et al.,* 1994). However, there are indications that deformation can also have natural causes as it has been found frequently to occur in pre-industrial domains (Freitas *et al.,* 1999). Geslin *et al.* (1998) concluded that deformation may also be related to changes in physical and chemical parameters and to shortage of nutrients.

The purpose of this study is to compare the composition and abundance of benthic foraminifera, and of *Ammonia beccarii* in particular, in different estuarine environments in Indonesia. The results of this comparison are needed as a data base toward the interpretation of paleoenvironmental changes based on the abundance of benthic foraminifera and *Ammonia* beccarii in particular in the study area. Here, we compare the modern lagoonal estuary of the Segara Anakan Lagoon and an ancient estuarine environment in the Gombong region.

Study area

The Segara Anakan Lagoon (Fig. 1) is a lagoonal estuarine environment. It is blocked from the ocean by a barrier island called Nusakambangan Island. Geographically, the Segara Anakan Lagoon lies between 108°47'16" E, 07°38'21" S and 108°52'16" E, 07°42'43" S. The Segara Anakan lagoon represents a modern lagoon which experiences considerable environmental stress. Strong tidal currents, high input of lithogenic matter and heavy metal pollution strongly influence environmental conditions in the Segara Anakan Lagoon (Sarmili *et al.,* 2000). In the lagoon, *Ammonia beccarii* is the dominant benthic foraminifera (Gustiantini et al., 2003).

In contrast, the Gombong area (109°33' E, 07°42' S) in Central Java (Fig. 1) represents an ancient estuarine environment which has never experienced any anthropogenic influence. The sediments contain fossil ostracods which reflect shallow water conditions. The abundance of *Ammonia beccarii* in the sediments is high suggesting that deposition occurred in an estuarine environment (Soebowo *et al.,* 2002).

METHODS

Surface sediments were taken using a grab sampler from 20 sites in the Segara Anakan Lagoon, southern Java (Fig. 1). Furthermore, a twenty meter borehole was collected from the southern Gombong region (Fig. 1). From the borehole, 13 subsamples were collected at 1m intervals, starting at five meters depth below the surface.

From both study areas, foraminifera were picked from the washed residue larger than 63μm. Foraminifera were identified and interpreted until species level under a binocular microscope, with reference to Barker (1960), Phleger (1960), Albani and Yassini (1993), and Yassini and Jones (1995).

Up to 300 specimens were picked from each sample. The numbers of each species were divided by 300 to calculate their percentages, except for the locations where the samples contained less than 300 foraminifera where the absolute number lower than 300 was used as the divident.

RESULT

In the Segara Anakan Lagoon, only one species of benthic foraminifera, *Ammonia beccarii* is found. The species is found at only 5 of the 20 sites investigated. Overall, the abundance of *Ammonia beccarii* in the Segara Anakan lagoon is low. With the exception of one site, less than five specimen are found at all sites. At site SGA 15 in the western part of the lagoon, *Ammonia beccarii* is common and 28 specimens are found (Fig.2).

In contrast, benthic foraminifera are abundant and show moderate diversity in the sediments of the Gombong borehole, except at the top (5.4 – 5.5m), where the sediment contained only *Ammonia beccarii* accounting to only two specimens (Table 1).

In the Gombong estuary, nine species of benthic foraminifera are found. The dominant species is *Ammonia beccarii. Ammonia beccarii* is highly abundant below 5.4m depth, but is even more so in the interval 6.7m to 11.4m, with mean percentages reaching up to 78.6% (Fig.3). Maximum abundance is at 6.7m and 7.55m depths, where 295 specimens, equal to 98.3% of percentage, are found. From 12.5m to 18.8m the abundances of *Ammonia beccarii* are lower than in the overlying sediments, with a mean percentage of 59.4%.

The second most abundant species is *Quinqueloculina poeyana.* It is found down from 7.55m. The highest abundance is at 16.7m where 122 specimens are found representing 40.7% of benthic foraminifera. The mean percentage of *Quinqueloculina poeyana* is 14.61%. Unlike *Ammonia beccarii, Quinqueloculina poeyana* is also found to be abundant in the interval 12.5m to 18.8m, with average percentage accounted for 31.73% of all benthic foraminifera. From 7.55m to 11.3m, the number of *Quinqueloculina poeyana* found in the samples is only between two to ten (less than 10%).

Miliolinella lakemacquariensis is also found to be widely distributed in the Gombong Estuary. It is found from 6.7m down to 18.8m, except at the depth of 7.55m. The mean abundance is 2.97%. The highest percentage is found at 15.4m (6.67%). The abundance of *Miliolinella lakemacquariensis* is relatively higher at 18.7m to 12.5m. The other species showing a distribution equal to *Miliolinella lakemacquariensis* is *Miliolinella subrotunda.* Furthermore, *Cibrononion simplex*, like *Ammonia beccarii*, shows a decrease in abundance at the interval 12.5m to 18.8m.

DISCUSSION

In the Segara Anakan Lagoon *Ammonia beccarii* is only found at very low abundance. This low abundance reflects the high degree of environmental stress in the lagoon. As mentioned above, three mayor factors are considered to have significant impact on the Segara Anakan Lagoon. These factors are strong tidal currents, high input of lithogenic matter and heavy metal pollution (Sarmili *et al.,* 2000).

As the Segara Anakan Lagoon is blocked by the Nusakambangan Island from the open ocean, the influence of the ocean in the lagoon is reduced. The high sediment supply to the lagoon reflects that fluvial influence may be more dominant than the ocean influence. As a consequence, salinity is noticeably lower in the lagoon than in the open ocean, resulting in low abundances of foraminifera.

Ammonia beccarii is concentrated in the western part and at one location in the eastern part of the Segara Anakan Lagoon. At SGA 15 in the western part the abundance of *Ammonia beccarii* is high. This high abundance is due to the vicinity of the ocean. This location offers ideal environmental conditions for *Ammonia beccarii.* The site is influenced by both the river and the ocean, and the location is rather protected. This also suggests for the other sites that the high lithogenic input by the

river appears to destroy the foraminiferal community in the lagoon, possibly because the lagoon has become shallower and smaller (Datun, 1981).

At present, only *Ammonia beccarii* is found in the Segara Anakan Lagoon. This suggests that events of environmental stress occurred and terminated the foraminifera, and *Ammonia beccarii* appears to be the only survivor. Even today, however, the degree of environmental stress in the Segara Anakan Lagoon can be considered to be very high, because *Ammonia beccarii* is found at very low abundance.

The Gombong site, which is expected not to have experienced any significant events of environmental stress, is characterized by nine species of benthic foraminifera, and clearly dominated by *Ammonia beccarii.* Beside *Ammonia beccarii,* the other species found in the sediments are also typical of coastal lagoons, open estuaries and sheltered ocean embayments (Yassini and Jones, 1995). This confirms that Gombong used to be an estuary. Generally, Gombong used to be an open estuary, where the influence of the ocean was bigger than that by fluvial systems. By looking at the changes of the abundance of *Ammonia beccarii* (Fig.3), we have derived 3 periods of environmental changes at the Gombong site.

1. Below the depth layer 19.5-19.6m *Ammonia beccarii* is dominant while the abundance of *Quinqueloculina poeyana* is low. There is no *Miliolinella lakemacquariensis* and *Miliolinella subrotunda.* This diversity and abundance of benthic foraminifera suggests that the influence of the ocean is small, possibly because the estuary is blocked from the ocean. This small influence caused low salinity and a change in the water circulation, accompanied by a change of some environmental parameters (e.g. temperature, oxygen, pH) in the study area. As *Ammonia beccarii* is the opportunistic species among the benthic foraminifera, it is able to adapt to these conditions. As in the modern Segara Anakan lagoon, *Ammonia beccarii* becomes dominant, while the other species, especially those dependent on high salinity such as *Quinqueloculina* and *Miliolinella,* are terminated. In this interval there are also reworked fossils of *Ammonia beccarii* and *Quinqueloculina poeyana*. The occurrence of these reworked fossils shows that at the time period before the period represented by the interval discussed here there was also an estuary characterized by the same condition as the estuary of the interval discussed here.
2. In the interval 12.5m to 19.5m, the benthic foraminifera shows higher diversity than in the interval above. The percentages of some benthic foraminifera, particularly *Quinqueloculina poeyana, Miliolinella lakemacquariensis* and *Miliolinella subrotunda* increase. This suggests that in this interval the environmental conditions are more suitable for benthic foraminifera. The influence of the ocean must have been more noticeable, which resulted in higher salinity, changes in water circulation, temperature, and oxygen supply. Nevertheless, in this interval the percentages of *Ammonia beccarii* decrease, which is contradictory to site SGA 15 in the Segara Anakan Lagoon. As mentioned before, site SGA 15 in Segara Anakan Lagoon offers ideal environmental conditions because it is influenced by both the river and the ocean.Consequently, the number of *Ammonia beccarii* increases. Such an increase, however, is not observed in the interval discussed here. Possibly, the presence of other species in the interval has created competition. Several species have to share nutrients and oxygen, which causes *Ammonia beccarii* to be less dominant in this interval.
3. Above 12.5m the sediments indicate that the environment of the estuary is changed once more. *Ammonia beccarii* is clearly dominating while *Quinqueloculina poeyana* and *Miliolinella lakemacquariensis* show lower abundances than in the interval below. In the interval discussed here, the influence from the ocean is less significant than that from land, which resulted in a decrease in salinity. From 12.5m upwards, the environmental conditions become gradually less favourable for the foraminifera in the estuary, possibly because of the ongoing change of the environment from an estuary to land. This is inferred from the decrease in the abundance of benthic foraminifera, with the exception of *Ammonia beccarii.* This change in foraminiferal abundance and diversity strongly resembles that observed in relation to the recent development of the Segara Anakan Lagoon towards a shallower lagoon. Finally, when the estuary changes into land, *Ammonia beccarii* is also terminated. This is shown by the very low abundance *Ammonia beccarii* (only two species) and the absence of any other microfauna at 5.4-5.5m. This very low abundance of *Ammonia beccarii* and the fact that it is the only species found in the sediments have previously been observed for the modern Segara Anakan lagoon at sites which are strongly influenced by high sediment supply from land.

CONCLUSIONS

Generally, in the Gombong Estuary the diversity and abundance of benthic foraminifera is higher than in the Segara Anakan Lagoon. This may indicate that environmental conditions in the Gombong Estuary are more suitable for the foraminifera. It is likely that these more suitable conditions reflect an environment that had not yet been influenced by anthropogenic activities and that had not experienced any pollution. The assemblages and abundances of benthic foraminifera and of *Ammonia beccarii* in particular indicate, however, that considerable natural environmental changes occurred in the Gombong estuary. The results of this study clearly show that *Ammonia beccarii* is an indicator of changing environmental conditions. Both in the Gombong Estuary and the Segara Anakan Lagoon *Ammonia beccarii* is found to tolerate environmental stress.

Overall, because of its ability to adapt to changing conditions, *Ammonia beccarii* will be the last species to disapear in polluted estuaries. Consequently, *Ammonia beccarii* is a very good bioindicator for identifiying environmental stress. Overall, environmental stress decreases the abundance and diversity of benthic foraminifera, but the opportunistic species such as *Ammonia beccarii* will benefit from this decrease by the availability of higher nutrient levels and the decrease in predation. However, although *Ammonia beccarii* is a species with high tolerance, it will still be terminated when the stress exceeds the limits of the viability of the species.

AKNOWLEDGEMENTS

The first author wishes to thank Mr. Lubis for his invitation to perform this study at the Marine Geological Institute (MGI) of Indonesia in Bandung. The authors would like to thank the staff of the MGI for taking samples in the Segara Anakan Lagoon, and the staff of the Institute of Geotechnology (LIPI) in Bandung for taking samples from Gombong. We are grateful to Mr. Sarmili for providing samples and helpful discussions. The authors would also like to thank Mr. Purwanto, Miss. Auliaherliaty, Mr. Masduki, Mr. Fauzi, and Mr. Eixler for stimulating discussions and support, and also to anonymous reviewers provided constructive comments. This study was funded within the frame of the Indonesian-German collaboration program in Marine Science by the International Office of the German Ministry of Education and Research (IDN 01/010, granted to Dr. Anne Müller and Mrs Kresna Tri Dewi).

REFERENCES

Alve E., 1991. Benthic Foraminifera in Sediment Cores Reflecting Heavy Metal Pollution in Sorfjord, Western Norway. *Journal of Foraminiferal Research,* v. 21, no. 1, p. 1-19.

Alve, E., 1995. Benthic Foraminiferal Responses to Estuarine Pollution: A Review. *Journal of Foraminiferal Research,* v.25, no.3, p.190-203.

Barker, W. R., 1960. *Taxonomic Notes, Soxy of Economic Paleontologists and Mineralogists*. Shelf Development Company, Houston, Texas, 238p.

Boltovskoy, E., and Wright, R., 1976. *Recent Foraminifera.* Dr. W. Junk Publishers, The Netherlands, 414p.

Datun, M., 1981. Pengaruh Arus Terhadap Arah Sedimentasi di Segara Anakan, Jawa Tengah. *Proceedings PIT X Ikatan Ahli Geologi Indonesia.* Ikatan Ahli Geologi Indonesia, Bandung, p. 137 - 143.

Debenay, J. P., Beneteau, E., Zhang, J., Stouff, V., Geslin, E., Redois, F., and Fernandez-Gonzalez, M., 1998. *Ammonia beccarii* and *Ammonia tepida* (Foraminifera): Morphofunctional Arguments for Their Distinction. *Marine Micropaleontology*, v. 34, p. 235 – 244.

Freitas, M.C., Andrade, C., Moreno, J. C., Munhá, J. M., and Cachão, M., 1999. The Sedimentary Record of Recent (Last 500 Years) Environmental Changes in the Seixal Bay Marsh, Tagus Estuary, Portugal. *Geologie en Mijnbouw,* 77:283-293.

Geslin, E., Debenay, J. P., and Lesourd, M., 1998. Abnormal Wall Textures and Test Deformation in *Ammonia* (Hyaline Foraminifer). *Journal of Foraminiferal Research*, v.28, no.2, p. 148 – 156.

Goldstein, S. T., and Moodley, L., 1993. Gametogenesis and The life Cycle of The Foraminifer *Ammonia beccarii* (Linne) *Forma tepida* (Chusman). *Journal of Foraminiferal Research*, v. 23 (4) : 213 – 220.

Gustiantini, L., Dewi, K. T., & Müller, A., 2003. Distribution of Foraminifera in Surface Sediments of Segara Anakan Lagoon, Central Java: Its Relation to Heavy Metal Pollution and Environmental Stress. *MGI Bulletin,* vol. 1: 36-47.

Holmann, M., and Pawlowski, J., 1997. Molecular, Morphological, and Ecological Evidence for Species Recognito in *Ammonia* (Foraminifera). *Journal of Foraminiferal Research,* v.27, no.4, p. 311-318.

Murray, J. W., 1991. Ecology and Distribution of Benthic Foraminifera. In J. J. Lee and O. R. Anderson (Editors). *Biology of Foraminifera.* Academic Press, United Kingdom, p.221-253.

Nagy, J. and Alve, E., 1987. Temporal Changes in Foraminiferal Faunas and Impact of Pollution in Sandebukta, Oslfjφrd. *Marine Micropaleontology*, v. 12, p. 109 - 128.

Phleger, F. B., 1960. *Ecology and Distribution of Recent Foraminifera*. The Johns Hofkins press. Baltimore, 297p.

Rositasari, R., 1996. Keterkaitan Populasi Foraminifera Resen dengan Beberapa Faktor Lingkungan di Perairan Muara Sungai Dadap, Tangerang. In D. P. Praseno, W. W. Atmaja, I. Supangat, Ruyitno, and Bambang S. Soedibjo (Editors): *Inventarisasi dan Evaluasi Lingkungan Pesisir Oseanografi, Geologi, Biologi dan Ekologi*. Pusat Penelitian dan Pengembangan Oseanologi, Lembaga Ilmu Pengetahuan Indonesia, p. 25 – 30.

Rositasari, R., 1997. Variasi Morfologi pada Marga *Ammonia. Oseana.* Majalah Ilmiah Semi Populer. Badan Penelitian dan Pengembangan Oseanografi, Pusat Penelitian dan Pengembangan Oseanologi Lembaga Ilmu Pengetahuan Indonesia, Jakarta, v. 22, no.3, p. 1 - 15.

Rositasari, R., 2000. Foraminifera Bentik sebagai Bioindikator Lingkungan Estuarin. In D. P. Praseno, R. Rositasari, and S. H. Riyono (Editors.): *Foraminifera sebagai Bioindikator Pencemaran, Hasil Studi di Perairan Estuarin, Sungai Dadap, Tangerang.* Pusat Penelitian dan Pengembangan Oseanologi, Lembaga Ilmu Pengetahuan Indonesia, Jakarta, p. 78-91.

Sarmili, L., Arifin, L., Karmini, M., Wahib, A., and Suprijadi, 2000. *Penelitian Proses Sedimentasi Perairan Segara Anakan, Jawa Tengah*. Departemen Pertambangan dan Energi Direktorat Jenderal Geologi Kelautan, Bandung. Unpublished. 84p.

Soebowo, E., Praptisih, Rachmat, A., and Irianto, B., 2002. Geologi Kuarter di Daerah Gombong Selatan dan Sekitarnya: Kaitannya dengan Daya Dukung Keteknikan Lahan dan Hidrogeologinya. *Laporan Penelitian.* Pusat Penelitian Geoteknologi Lembaga Ilmu Pengetahuan Indonesia, Bandung. Unpublished.

Schafer, C. T., 2000. Monitoring Nearshore Marine Environments Using Benthic Foraminifera: Some Protocols and Pitfalls. *Micropaleontology,* v.46, supplement no. 1, p.161-169.

Sharifi, A. R., Croudace, I. W., and Austin, R. L., 1991. Benthic Foraminiferids as Pollution Indicators in Southampton Water, Southern England, U.K. *Journal of Micropaleontology*, v. 10, no. 1, p. 109 - 113.

Yanko, V., Kronfeld, J., and Flexer, A., 1994. Response of Benthic Foraminifera to Various Pollution Sources: Implications for Pollution Monitoring. *Journal of Foraminiferal Research*, v. 24, no. 1. p. 1 – 17.

Yassini, I., and Jones, B. G., 1995. *Foraminiferida and Ostracoda from Estuarine and Shelf Environments on The South Eastern Coast of Australia,* University press., Wollonggong, 270p.

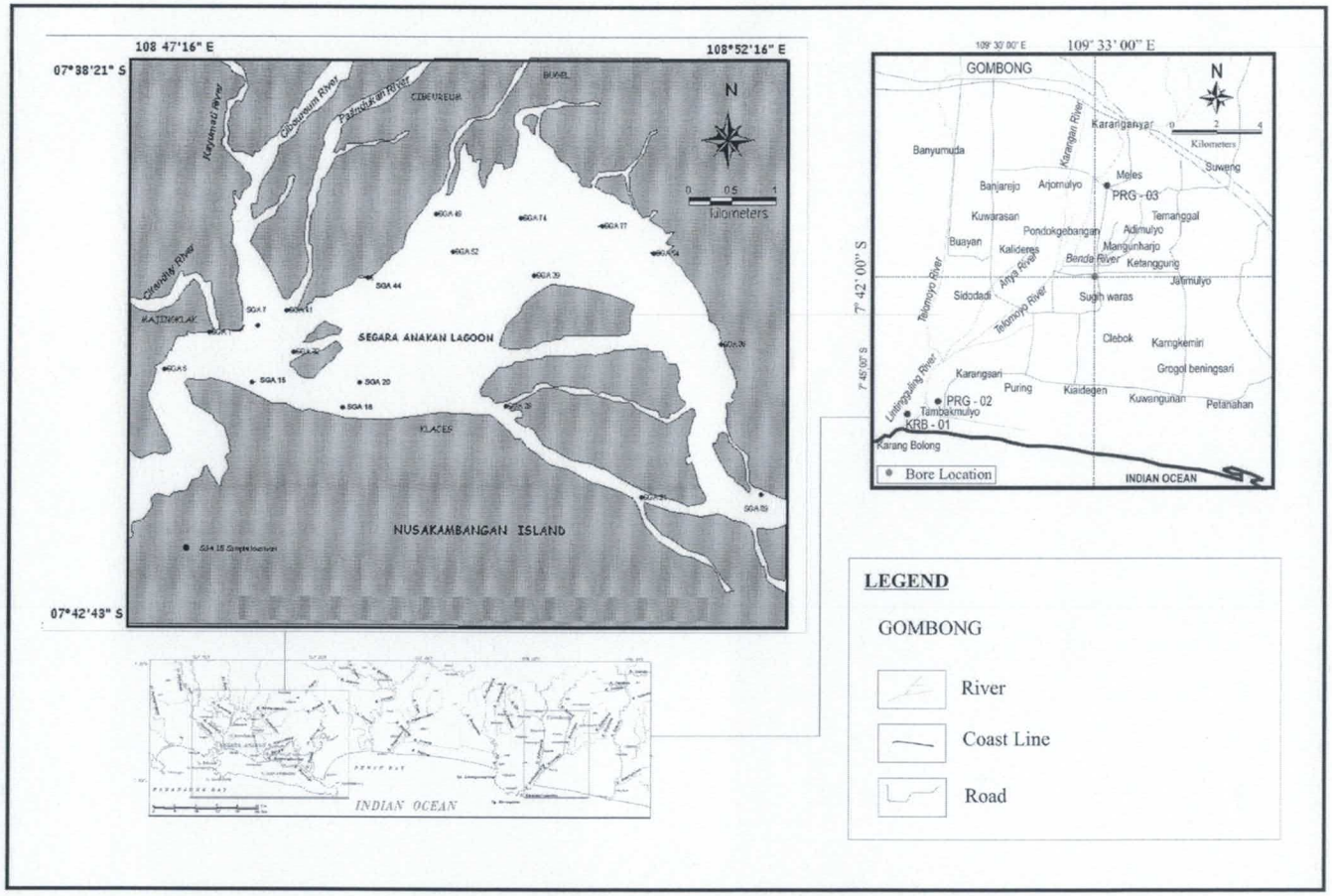

Figure 1. Study Area

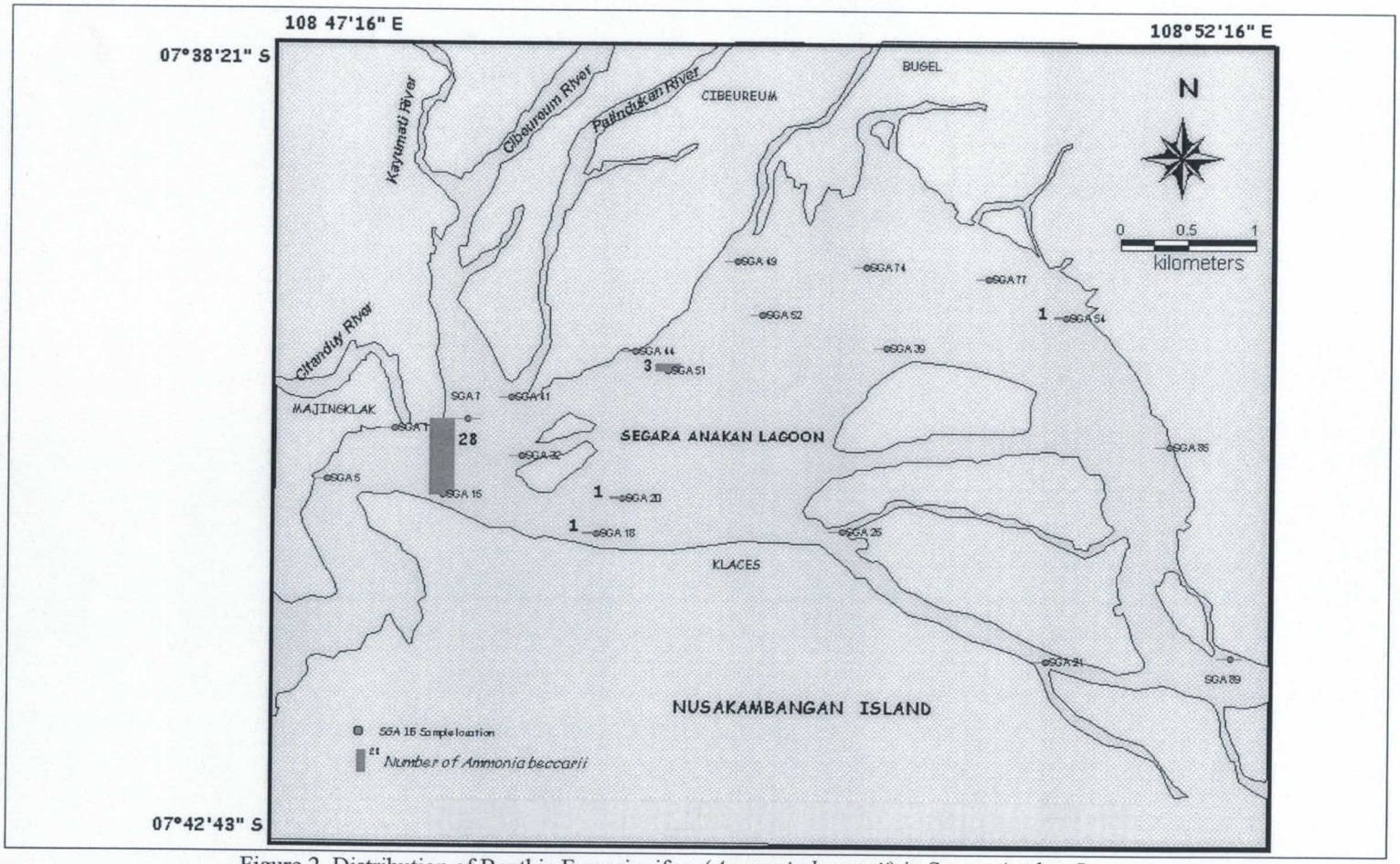

Figure 2. Distribution of Benthic Foramionifera (*Ammonia beccarii*) in Segara Anakan Lagoon

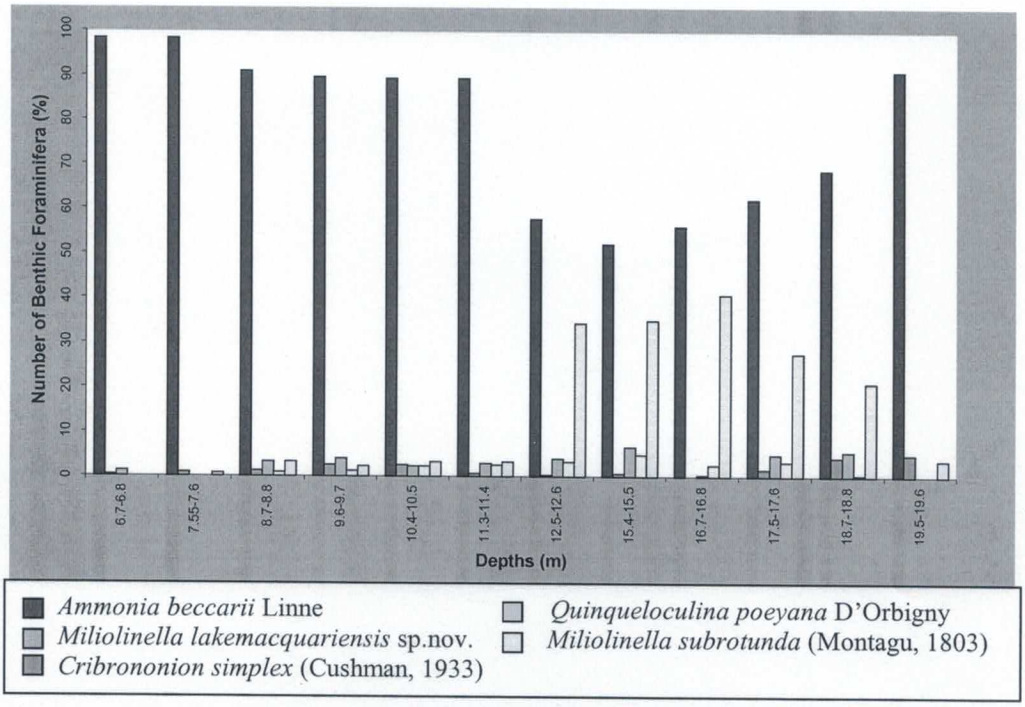

Figure 3. Percentage of Benthic Foraminifera in the Gombong Estuary

Table 1 The Composition of Benthic Foraminifera in Gombong Estuary

Location	Gombong												
no.samples / Species	5.4-5.5m	6.7-6.8m	7.55-7.6m	8.7-8.8m	9.6-9.7m	10.4-10.5m	11.3-11.4m	12.5-12.6m	15.4-15.5m	16.7-16.8m	17.5-17.6m	18.7-18.8m	19.5-19.6m
Ammonia beccarii Linne	2	295	295	273	269	268	268	173	156	168	186	206	273
Cribrononion simplex (Cushman, 1933)	0	1	3	4	8	8	2	1	2	0	5	13	15
Elphidium depressulum Cushman	0	0	0	0	0	0	2	0	2	1	1	0	0
Elphidium striatopunctatum (Fichtel & Moll)	0	0	0	0	0	0	1	0	0	0	0	0	0
Miliolinella lakemacquariensis sp.nov.	0	4	0	10	12	7	9	12	20	1	15	17	0
Miliolinella subrotunda (Montagu, 1803)	0	0	0	3	4	7	8	10	15	8	10	1	0
Quinqueloculina poeyana d'Orbigny	0	0	2	10	7	10	10	103	105	122	83	63	11
Textularia sp.1	0	0	0	0	0	0	0	0	0	0	0	0	1
Textularia sp.2	0	0	0	0	0	0	0	1	0	0	0	0	0
Total	2	300	300	300	300	300	300	300	300	300	300	300	300

Table 2. Percentages of Benthic Foraminifera in Gombong Estuary

Location	Gombong											
no.samples / Species	6.7-6.8m	7.55-7.6m	8.7-8.8m	9.6-9.7m	10.4-10.5m	11.3-11.4m	12.5-12.6m	15.4-15.5m	16.7-16.8m	17.5-17.6m	18.7-18.8m	19.5-19.6m
Ammonia beccarii Linne	98.33	98.33	91.00	89.67	89.33	89.33	57.67	52.00	56.00	62.00	68.67	91.00
Cribrononion simplex (Cushman, 1933)	0.33	1.00	1.33	2.67	2.67	0.67	0.33	0.67	0.00	1.67	4.33	5.00
Elphidium depressulum Cushman	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.67	0.33	0.33	0.00	0.00
Elphidium striatopunctatum (Fichtel & Moll)	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00
Miliolinella lakemacquariensis sp.nov.	1.33	0.00	3.33	4.00	2.33	3.00	4.00	6.67	0.33	5.00	5.67	0.00
Miliolinella subrotunda (Montagu, 1803)	0.00	0.00	1.00	1.33	2.33	2.67	3.33	5.00	2.67	3.33	0.33	0.00
Quinqueloculina poeyana d'Orbigny	0.00	0.67	3.33	2.33	3.33	3.33	34.33	35.00	40.67	27.67	21.00	3.67
Textularia sp.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
Textularia sp.2	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00
Total	100	100	100	100	100	100	100	100	100	100	100	100