

**Effects of enrichment on nutrient dynamics, phytoplankton  
dynamics and productivity in Indonesian tropical waters :  
a comparison between Jakarta Bay, Lampung Bay  
and Semangka Bay**

Dissertation  
zur Erlangung des Doktorgrades  
der Mathematisch-Naturwissenschaftlichen Fakultät  
der Christian-Albrechts-Universität  
zu Kiel

vorgelegt von

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**Kiel, 2003**

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**Tag der mündlichen Prüfung** : 11.02.03  
**Zum Druck genehmigt** : Kiel, den 05.03.03

**Der Dekan**

## Zusammenfassung

Die vorliegende Untersuchung wurde in Indonesien in der Bucht von Jakarta-, der Lampung- und der Semangkabucht mit dem Ziel durchgeführt die Besonderheiten der Ökologie des küstennahen tropischen Phytoplanktons zu beschreiben. Dabei wurden insbesondere die unterschiedlichen Nährstoffeinträge in diese Küstenökosysteme und die sich daraus ergebenden Unterschiede in der Nährstoff- und Phytoplanktodynamik sowie der Primärproduktion untersucht. Die drei Buchten wurden vor allem wegen ihres unterschiedlichen Grades der Nährstoffanreicherung ausgewählt. In die Bucht von Jakarta werden sehr große Nährstoffmengen durch organisch belastetes Wasser eingeleitet, während die Einträge in die Lampung- und Semangkabucht viel geringer sind.

Die Bucht von Jakarta liegt an der Nordküste der Insel Java und öffnet sich weit zur angrenzenden Javasee. Die Bucht ist mit einer mittleren Tiefe von 8,4 m flach, und umfasst einen Bereich von ca. 285 km<sup>2</sup>. Das Gewässer wird stark durch die rund 8,5 Millionen Einwohner zählenden Landeshauptstadt Jakarta beeinflusst. Die Lampungbucht befindet sich an der Südküste der Insel Sumatra und hat eine mittlere Tiefe von 17,3 m, ihre Fläche beträgt ca. 847 km<sup>2</sup>. Die mittelgroße Stadt Bandar Lampung mit ihren rund 900.000 Einwohnern befindet sich an der Nordseite dieser Bucht. Die westlich der Lampungbucht, ebenfalls an der Südseite der Insel Sumatra liegende Semangkabucht hat eine mittlere Tiefe von 140 m und erstreckt sich über ca. 924 km<sup>2</sup>. Im Gegensatz zu den Buchten von Lampung und insbesondere Jakarta ist ihr Wasser kaum verschmutzt; die nächstgelegene Stadt Kota Agung zählt lediglich 50.000 Einwohner.

Die Probennahmen-Kampagnen wurden über einen Zeitraum von einem Jahr, von Dezember 2000 bis Dezember 2001 durchgeführt und umfassten sowohl die Trocken- als auch die Regenzeit. Der Hauptunterschied zwischen diesen beiden tropischen Jahreszeiten ist die Niederschlagsmenge. Änderungen in der Temperatur und der Sonneneinstrahlung sind in tropischen Regionen, im Gegensatz zur temperierten Klimazone, weniger stark ausgeprägt. Während der Messfahrten wurden Wasserproben zur Ermittlung des gelösten anorganischen Nährstoffgehaltes, der Chlorophyll-*a*-Konzentration, der Phytoplankton-Zusammensetzung sowie für <sup>14</sup>C-Primärproduktionsmessungen genommen. Ungefähr alle zwei Monate wurden diese Daten für die Stationen in den untersuchten Buchten ermittelt.

Mit der Klusteranalyse und der PCA (principal component analysis) konnten deutliche räumliche Regionen innerhalb der Buchten abgegrenzt werden. Es ergaben sich aus den Buchten heraus führende, steil abfallende Gradienten der Lichtverfügbarkeit, des Nährstoffgehaltes und der Biomasse und Produktion des Phytoplanktons, die mit einem Ansteigen des Salzgehaltes einhergingen. Abweichende Verläufe wurden an der Mündung des Semangka Flusses gefunden, wo trotz hoher Nährstoffgehalte die Biomasse und Produktion des Phytoplanktons gering war. Dies ist auf die starke Trübung in diesem Bereich und die daraus resultierende Lichtlimitation zurückzuführen.

Die steil abfallenden Gradienten des Nährstoffgehaltes sowie der Biomasse und Produktion des Phytoplanktons zeigen die natürliche Fähigkeit der Meeresumwelt Nährstoffeinträge von Land zu absorbieren. Eine Kombination hydrologischer und biologischer Faktoren, wie Wasseraufenthaltszeit, Lichtverfügbarkeit und „Grazer-Häufigkeit“ ist entscheidend für den Grad der Nährstoffanreicherung innerhalb der Buchten.

Saisonale Schwankungen des Nährstoffgehaltes, der Biomasse und der Produktion des Phytoplanktons wurden untersucht und zeigten insbesondere in der Bucht von Jakarta während der Regenzeit höhere Werte - als in der Trockenzeit. Unterdessen war das Wasser der Lampung- und der Semangkabucht auch während der Trockenzeit durch verhältnismäßig hohe Nährstoff- und Chlorophyll-a-Werte charakterisiert. Diese sind auf Wasser aus der Java See zurückzuführen, das während dieser Jahreszeit aus der Javasee in die Buchten einfließt und relativ reich an Nährstoffen ist. Umgekehrt werden in der Regenzeit diese Buchten durch das nährstoffarme Wasser des Indischen Ozeans beeinflusst.

Der Vergleich der drei untersuchten Buchten zeigt:

- Die Bucht von Jakarta Bucht war die Trübste der untersuchten Buchten. Dies wurde aus den Jahresmitteln der Seccitiefe und den Trübungsmessungen ersichtlich, die sich signifikant von den Werten der anderen Buchten abhoben. Dennoch war die Lichtverfügbarkeit für das Phytoplankton, ausgedrückt durch das Verhältnis  $Z_{\text{mix}}:Z_{\text{eu}}$ , in der Bucht von Jakarta günstiger als in der Lampung- und der Semangkabucht. Dies ist in erster Linie auf die geringe Wassertiefe dieser Bucht zurückzuführen, die zu einem niedrigen Wert für  $Z_{\text{mix}}$  und letztendlich zu einem niedrigen Verhältnis von  $Z_{\text{mix}}:Z_{\text{eu}}$  führt. Umgekehrt wiesen die tiefere Lampung- und Semangkabucht eine mächtigere durchmischte Schicht auf, so dass sich jeweils ein höheres Verhältnis von  $Z_{\text{mix}}:Z_{\text{eu}}$  ergab.
- Die Nährstoffeinträge in die Bucht von Jakarta sind weitaus höher als die in die anderen beiden Buchten. Die jährlichen Nährstofffrachten aus einmündenden Flüssen in diese Bucht betragen 6.741 t Phosphat, 21.260 t gelösten anorganischen Stickstoff (DIN) und 52.417 t Silikat. Der Eintrag in die Lampung Bucht beträgt 1.096 t Phosphat, 5.003 t DIN und 14.731 t Silikat. In die Semangka Bucht werden 419 t Phosphat, 1.378 t DIN und 16.449 t Silikat jährlich eingetragen.
- Die Konzentrationen an gelösten anorganischen Nährstoffen waren in der Jakartabucht höher als in den anderen beiden Buchten. Die jährlichen Durchschnittskonzentrationen des gelösten anorganischen Phosphats ( $\text{PO}_4\text{-P}$ ) betragen in der Jakarta-, Lampung- und Semangkabucht 5,1  $\mu\text{M}$ , 2,3  $\mu\text{M}$  bzw. 0,4  $\mu\text{M}$ . Die Werte für gelösten anorganischen Stickstoff (DIN) betragen im Jahresdurchschnitt für die Buchten jeweils 20,1  $\mu\text{M}$ , 14,3  $\mu\text{M}$  und 3,5  $\mu\text{M}$ . Als Silikatwerte ( $\text{SiO}_4$ ) wurden für die Jakartabucht 44,8  $\mu\text{M}$ , für die Lampungbucht 39,3  $\mu\text{M}$  und für die Semangkabucht 28,5  $\mu\text{M}$  im Jahresdurchschnitt ermittelt.
- Entsprechend der Unterschiede der gelösten anorganischen Nährstoffe verhielten sich die Durchschnittswerte für die Chlorophyll *a* Konzentration und die Primärproduktion. Die Konzentrationen für Chlorophyll *a* (Chl *a*) lagen im Jahresdurchschnitt in der Bucht von Jakarta bei 13,2  $\mu\text{g l}^{-1}$ , während die Lampung- und die Semangkabucht lediglich Konzentrationen von 4,1  $\mu\text{g l}^{-1}$  bzw. 0,85  $\mu\text{g l}^{-1}$  aufwiesen. Die Primärproduktion war mit 223  $\text{g C m}^{-2}\text{y}^{-1}$  als Durchschnittswert der Jahresproduktion in der Bucht von Jakarta ebenfalls deutlich höher als in der Lampung- und der Semangkabucht (89  $\text{g C m}^{-2}\text{y}^{-1}$  bzw. 25  $\text{g C m}^{-2}\text{y}^{-1}$ ).
- In der gesamten Bucht von Jakarta waren Diatomeen die dominierende Gruppe des Phytoplanktons, wobei kleine kettenbildende Arten wie *Skeletonema costatum* und *Chaetoceros* spp., besonders im landfernen Bereich den größten Anteil bildeten. Im Küstenbereich mit ruhigerem Wasser kamen zudem Cyanobakterien (*Trichodesmium* spp.) und Dinoflagellaten (*Ceratium* spp. und *Dinophysis caudata*) vor. In der Lampung- und der Semangkabucht war die Dominanz der Diatomeen (*Chaetoceros* spp.) noch ausgeprägter als in der Jakartabucht. Lediglich in den

weniger turbulenten und mehr geschichteten Flussmündungsbereichen kamen im Vergleich zum küstenfernen Bereich vermehrt Dinoflagellaten und Blaualgen vor.

- Die Abschätzung einer möglichen Nährstofflimitation wurde für die Bucht von Jakarta mittels eines „Bioassays“ sowie für allen drei untersuchten Buchten durch Auswertung der molaren Nährstoffverhältnisse und deren Vergleich mit den jeweiligen Schwellenwerten durchgeführt. In der Bucht von Jakarta deutete sich mit Ausnahme des Flussmündungsbereiches eine Phosphatlimitation hinsichtlich des Phytoplanktonwachstums an. In der Lampung- und Semangkabucht war das Wachstum möglicherweise sowohl stickstoff- als auch phosphatlimitiert. Diese doppelte Limitation deutete sich insbesondere in den küstenfernen Bereichen an. Eine Silikatlimitation konnte in keiner der untersuchten Buchten festgestellt werden.
- Die Berechnung des „Tropical Marine Index“ (TRIX) ergab unterschiedliche Regionen innerhalb der Buchten denen bestimmte Trophiestadien zugeordnet waren. Die Jakarta- und die Lampungbucht konnten wie folgt in Regionen dreier Trophiestadien eingeteilt werden: (1) Hyper-eutrophe Region in der Flussmündung und dem küstennahem Wasser, (2) eutrophe Region im mittleren Bereich der Bucht und (3) mesotrophe Region im äußeren Bereich der Bucht. Die Semangkabucht konnte ebenfalls in drei Trophiestadien gegliedert werden: (1) Eutrophe Region im Bereich des Hafens, (2) mesotrophe Region im küstennahen und mittleren Bereich und (3) oligotrophe Region im äußeren Bereich der Bucht.

Einhergehend mit dem drastischen Bevölkerungswachstum wird Küsteneutrophierung in naher Zukunft, insbesondere in den Buchten von Jakarta und Lampung, zu einem ernsthaften Problem werden, das dringend gelöst werden muss. Ähnlich wie in vielen anderen indonesischen Städten stellt die unzulängliche Klärung der Abwässer das Hauptproblem dar. Die Stickstoff- und Phosphateinleitungen in die Buchten sollten reduziert werden um die Verhältnisse von Stickstoff bzw. Phosphat zu Silikat niedrig zu halten. Einrichtungen zu Abwasserklärung müssen dringend verbessert und ausgebaut werden. Schließlich ist allgemeines Bewusstsein für eine saubere Umwelt ein weiterer wesentlicher Faktor, der innerhalb der indonesischen Gesellschaft gestärkt werden sollte.

## Summary

The present study, which was performed in Jakarta, Lampung and Semangka bays, Indonesia, aimed to describe the characteristics of tropical coastal phytoplankton ecology, and especially to compare between different nutrient loadings on coastal and marine ecosystems, as represented by nutrient and phytoplankton dynamics and primary production. The main reason of selecting these three bays was to obtain a representation of different nutrient enrichment levels. Jakarta Bay receives large amounts of nutrient-enriched waters, Lampung has moderate level of nutrient inputs, while Semangka Bay has the smallest inputs of organic-polluted waters.

Jakarta Bay is an open embayment situated along the north coast of the island Java. The bay is shallow with a mean depth of 8.4 m and has an area of approximately 285 km<sup>2</sup>. The waters of the bay have been profoundly influenced by discharges from approximately 8.5 million inhabitants of the country's capital, the city of Jakarta. Lampung Bay is located at the southern coast of Sumatera Island, has an area of about 847 km<sup>2</sup> and a mean depth of 17.3 m (Wiryawan *et al.*, 1999). The moderate-sized city, Bandar Lampung, inhabited by around 900 000 people, is located at the northern side of the bay. Semangka Bay is located remotely at southernmost tip of Sumatera Island, and has a mean depth of 140 m and an area of about 924 km<sup>2</sup> (Wiryawan *et al.*, 1999). In contrast to Jakarta and Lampung bays, the latter is relatively less polluted since the nearest and largest town in the area, Kota Agung, is only inhabited by around 50 000 people.

The measurement campaigns were conducted over a one-year period, from December 2000 till December 2001, encompassing 2 different tropical seasons, namely dry and rainy. The main difference between seasons is the amount of rainfall, while variations in temperature and solar radiation (which mainly govern the temperate area) are not pronounced in tropical regions. During the surveys, water samples for dissolved inorganic nutrients, for chlorophyll *a*, for phytoplankton composition and for <sup>14</sup>C primary production measurements were taken. At each sampling station, measurements were performed approximately every 2 months.

Cluster analysis and PCA resulted in distinct spatial regions, showing steep gradients of light availability, nutrients, phytoplankton biomass and production, which decreased down the bay along with an increasing salinity. An exception was observed at the river mouth of Semangka River, which shows high nutrients but low phytoplankton biomass and production due to strong turbidity and therefore light limitation.

Steep gradients of nutrients and phytoplankton biomass and production show the natural capability of the marine environment to absorb the effect of nutrient enrichment from land. A combination of several hydrological and biological factors, such as water residence time, light availability and grazer abundance, plays an important role in controlling the response towards nutrient enrichment.

Seasonal variation was observed, showing that especially in Jakarta Bay, nutrient concentrations, phytoplankton biomass and production were higher during the rainy season. Meanwhile, in Lampung and Semangka bays, the dry season was also characterised by relatively high values of nutrients and chlorophyll *a*, which might be caused by the influence of incoming waters from the Java Sea, with relatively high nutrient concentrations. Inversely, during the rainy season, these waters were likely influenced by oceanic waters from the Indian Ocean, which were low in nutrients.

Comparison between bays resulted in :

- Jakarta Bay was the most turbid system among the three bays studied, clearly shown by the annual average values of Secchi depth and turbidity, which were significantly different from the 2 other bays. However, the light availability for phytoplankton, presented by  $Z_{\text{mix}}:Z_{\text{eu}}$  ratio, was better in Jakarta Bay than in Lampung and Semangka bays. This is mainly caused by the shallow depth of Jakarta Bay, causing a low  $Z_{\text{mix}}$ , and finally resulting in a low  $Z_{\text{mix}}:Z_{\text{eu}}$  ratio. Inversely, in Lampung and Semangka bays, the mixed layers depths are larger than in Jakarta Bay, resulting in a high  $Z_{\text{mix}}:Z_{\text{eu}}$  ratio.
- Jakarta Bay receives more nutrients than Lampung and Semangka bays. Loads of phosphate, DIN and silicate from the incoming rivers to Jakarta Bay were  $6741 \text{ t y}^{-1}$ ,  $21260 \text{ t y}^{-1}$ , and  $52417 \text{ t y}^{-1}$ , respectively. Lampung Bay receives  $1096 \text{ t y}^{-1}$ ,  $5003 \text{ t y}^{-1}$  and  $14731 \text{ t y}^{-1}$ , while Semangka Bay receives  $419 \text{ t y}^{-1}$ ,  $1378 \text{ t y}^{-1}$  and  $16449 \text{ t y}^{-1}$ , for phosphate, DIN and silicate, respectively.
- Jakarta Bay showed higher concentrations of dissolved inorganic nutrients than in Lampung and Semangka bays. The annual average of dissolved inorganic phosphate ( $\text{PO}_4\text{-P}$ ) concentrations in Jakarta, Lampung and Semangka Bays were  $5.1 \mu\text{M PO}_4\text{-P}$ ,  $2.3 \mu\text{M PO}_4\text{-P}$  and  $0.4 \mu\text{M PO}_4\text{-P}$ , respectively. The average of dissolved inorganic nitrogen (DIN) concentrations were  $20.1 \mu\text{M N}$ ,  $14.3 \mu\text{M N}$  and  $3.5 \mu\text{M N}$  for Jakarta, Lampung and Semangka Bays, respectively. Concentrations of silicate in Jakarta, Lampung and Semangka Bays were  $44.8 \mu\text{M Si}$ ,  $39.3 \mu\text{M Si}$  and  $28.5 \mu\text{M Si}$ , respectively.
- Commensurate with the differences in dissolved inorganic nutrient concentrations, are the average values of chlorophyll *a* and primary production. Annual average chlorophyll *a* concentration in Jakarta Bay was  $13.2 \mu\text{g Chl } a \text{ l}^{-1}$ , while Lampung and Semangka Bays were  $4.1 \mu\text{g Chl } a \text{ l}^{-1}$  and  $0.85 \mu\text{g Chl } a \text{ l}^{-1}$ , respectively. The mean annual primary production showed that Jakarta Bay had the highest ( $223 \text{ g C m}^{-2}\text{y}^{-1}$ ), while Lampung and Semangka bays accounted for  $89 \text{ g C m}^{-2}\text{y}^{-1}$  and  $25 \text{ g C m}^{-2}\text{y}^{-1}$  respectively.
- In Jakarta Bay, the dominant group of phytoplankton was diatoms, which was mainly composed of small chain-forming species: *Skeletonema costatum* and *Chaetoceros* spp. especially in the more offshore region. In the inshore waters, where the water is less turbulent, cyanophyceae (*Trichodesmium* spp.) and dinophyceae (*Ceratium* spp and *Dinophysis caudata*) also occurred but in limited numbers relative to diatoms. In Lampung and Semangka bays, phytoplankton communities were more dominated by diatoms (*Chaetoceros* spp.) than in Jakarta Bay. In the less turbulent and more stratified waters in the river mouths, the occurrence of dinoflagellates and cyanophyceae increases compared to their abundance in the offshore waters.
- Potential nutrient limitation was assessed through nutrient bioassays (only for Jakarta Bay), analysis of molar nutrient ratios and comparison with threshold values of each nutrient. The phytoplankton assemblage from Jakarta Bay showed a potential limitation by phosphate, except in the river mouth areas. Meanwhile, in Lampung and Semangka bays, phytoplankton assemblages were potentially limited by both N and P, especially in the offshore waters. There was no indication of silicate limitation in all bays studied.
- Calculation of Trophical Marine Index (TRIX) showed distinct trophic states within the bays. Jakarta and Lampung bays can be divided in 3 trophic states: (1) hyper-eutrophic in the river mouth and inshore waters ; (2) eutrophic in the middle part of the bay and (3) mesotrophic in the outer part of the bay. Semangka Bay can be

classified comparably: (1) eutrophic state in the harbour waters ; (2) mesotrophic in the inner and middle parts of the bay and (3) oligotrophic in the outer part of the bay.

Ultimately, especially in Jakarta and Lampung bays, with a rapid increase of inhabitants in the coming years, coastal eutrophication becomes a big problem needs to be solved urgently. As with many others cities in Indonesia, the inadequate sewage treatment is one of the main obstacle in the area. The loads of N and P to the bay should be reduced, to keep the N or P to Si ratios low. Improvement and extension of sewage treatment in the area is urgently required. Finally, public awareness towards a clean aquatic environment is another societal factor that should be enhanced within the Indonesian society.



## Acknowledgements

I wish to express my cordial gratitude to my supervisor, Prof. Dr. Franciscus Colijn for supporting, guidance, critical reading of the thesis and for inviting me to conduct my study and research at Forschungs und Technologiezentrum (FTZ), Westküste in Büsum, Germany. My special gratitude also to Dr. Karl-Jürgen Hesse for the very valuable discussions and significant improvement of the thesis. I would also like to express my sincere thanks to Prof. Dr. Michael Spindler for reviewing and improvement of this thesis.

This study would not be possible without the scholarship from the German Academic Exchange Service (DAAD) granted to me from October 1999 to March 2003, for which I am very grateful. Special thanks go to Dr. Joachim Schneider and Mr. Achim Apweiler as Indonesian referees (Ref. 424) for their kind and professional co-operation.

I would like to express my gratitude to Dr. Urban Tillmann and Ms. Cornelia Reineke who trained me how to conduct the  $^{14}\text{C}$  primary production measurements. I would like to thank Ms. Britta Egge at FTZ, who trained me how to analyse nutrients and chlorophyll and also for the pigment analysis. I would like to express my gratitude also to Ms. Marion Rademaker for her valuable advise in phytoplankton species identification.

I wish to express my special gratitude to Drs. Zainal Abidin, the head of Hydrology Department, P3TIR-National Nuclear Energy Agency (BATAN), Indonesia, who allowed me to use the scintillation counter for my  $^{14}\text{C}$  analyses. I would like to thank Mr. Heiner Fabian for the correction of the german version of the Summary chapter. I wish also to express my gratitude to Dr. Richardus Kaswadji and Dr. Enan M Adiwilaga at Bogor Agricultural University, Indonesia, for their support and technical advise during my field research period 2000-2001 in Indonesia. I would like to express my gratitude to Prof. Dr. Tridoyo Kusumastanto as the director of PKSPL in Bogor Indonesia for his full support of my field measurements in Indonesia. I would like also to thank Dr. Dietriech G. Bengen and Dr. Budy Wiryawan for the small but valuable financial supports during some of my field campaigns.

I am greatly indebted to Ms. Hendiarti Moeloek, Ms. Anna Mariana, Mr. Yayat Supriatna and Mr. Herry Suhery at FPIK-Bogor Agricultural University, Indonesia, for their kind co-operation during my laboratory analysis. My sincerest thanks go to Mr. Amran, Ms. Yuliana, Ms. Isti, Mr. Tonny Junaedi, Mr. Basuki, Mr. Rizal, Mr. Firmansyah, Mr. Sri Meigo and Ms. Mevita Banowati for their technical helps and co-operation during my field campaigns and laboratory analyses.

The warmest thanks go to the all colleagues of the coastal ecology working group at FTZ, for their kind and hospitality during my stay in Büsum. The last but not least, I am especially grateful to my wife (Ina), our parents in Indonesia and our family members in Indonesia, for their love, moral supports throughout my studies in Germany. I love you all.

## Abbreviations

A	Angke River
ANOVA	Analysis of variance
$\alpha^B$	the initial slope of PE curve ( $\text{mg C mg}^{-1} \text{ Chl h}^{-1} (\mu\text{mol photon m}^{-2}\text{s}^{-1})^{-1}$ )
BOD5	Biological Oxygen Demand
CA	Cluster Analysis
Chl <i>a</i>	Chlorophyll <i>a</i>
Chl <i>b</i>	Chlorophyll <i>b</i>
Chl <i>c</i>	Chlorophyll <i>c</i>
COD	Chemical Oxygen Demand
CTD	Conductivity Temperature Depth
DIN	Dissolved inorganic nitrogen
e.g.	<i>Exempli Gratia</i> : for example
$E_k$	the light saturation parameter, $\mu\text{mol photon m}^{-2}\text{s}^{-1}$
Fig.	Figure
LSD	Least Significant Difference
FTZ	Forschungs-und Technologiezentrum, Büsum
<i>I</i>	Light resource in Cloern's phytoplankton sensitivity map
i.e.	<i>Id Est</i> : that is
<i>K</i>	Light attenuation coefficient
<i>K<sub>I</sub></i>	Half saturation constant of light for algae growth
KK	Kota Karang River
<i>K<sub>N</sub></i>	Half saturation constant of nutrient for algae growth
M	Marunda River
<i>N'</i>	Nutrient resource in Cloern's phytoplankton sensitivity map
NH <sub>4</sub> -N	Ammonium-Nitrogen
NO <sub>2</sub> -N	Nitrite-Nitrogen
NO <sub>3</sub> -N	Nitrate-Nitrogen
NTU	Nephelometric Turbidity Unit
P	Priok River
PAR	Photosynthetically Active Radiation
$P^B$	Daily water column primary production
PCA	Principal Component Analysis
PO <sub>4</sub> -P	Phosphate
SiO <sub>4</sub>	Silicate
SS	Sum Squared
SD	Standard deviation
TRIX	Tropical Index
TSS	Total Suspended Solid
WL	Way Lunik River
$Z_{\text{mix}}$	Mixed layer depth
$Z_{\text{eu}}$	Euphotic layer depth
$\mu\text{M}$	$\mu\text{mol l}^{-1}$

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## 1. Introduction

### 1.1. Background

As many other developing countries in the world, Indonesia has faced an enormous aquatic environmental degradation since the last few decades. One of the main problems are those related to the load of organic waste from the land into coastal or estuarine areas through the rivers, and there is an urgent need for recuperative actions. The main obstacle related to reduce the amount of domestic waste is the fact that most of the cities in the country lack sewage treatment facilities, allowing untreated waste flowing directly into the river and finally to the nearby coastal waters (Anonymous, 1999). This environmental degradation is predicted to be apprehensively aggravated in the coming period due to the rapid increase in the number of people. In 1971, Indonesia's population was 119 millions and has increased almost 2-fold reaching 206 million people in the year 2000, and predicted to reach 250 million by 2020 (Anonymous, 2002; Dahuri, 1994). Tremendous expansion of coastal settlements, coastal aquaculture, organic waste producing industries and coastal agriculture are among the main sources of organic pollution in Indonesia's coastal waters (Dahuri, 1994).

Anthropogenic eutrophication has been associated with the increase of nutrient concentration, which in turn may lead to detrimental situations such as decrease of oxygen concentration, declining fish and shellfish stocks, increase of unusual novel and toxic algal blooms and other aquatic ecosystem alterations (Nixon, 1995). The most causative nutrients for algal growth, nitrogen and phosphorus, are closely related to human activities. Meanwhile, another important nutrient for some classes of phytoplankton, silicate, is believed not to be directly associated to the anthropogenic activities. This different mechanism resulted in a change of nutrient balances, especially in the ratios of Si:P and Si:N. The increase of nutrients and change in the ratios among them finally will create a fundamental change in phytoplankton ecology and group composition (Sommer, 1994).

The concept of eutrophication was firstly developed by limnologists starting in the 1960's by the study of lake eutrophication motivated by huge degradation of freshwater ecosystems due to excessive anthropogenic nutrient enrichment (Cloern, 2001; Nixon, 1995). Coastal eutrophication has been a societal and scientific focus only since the last two decades, resulting in a concept of coastal eutrophication strongly influenced by the conceptual model developed firstly by limnologists (Cloern, 2001). Cloern (2001) stated that the early work on coastal eutrophication was highly inspired by a simple causal-relationship concept involving a one to one ratio of signal and response. Later on, the study of coastal eutrophication has been significantly increased by the actual needs on this specific problem, which resulted in the understanding that coastal eutrophication is more complicated than that of freshwater systems. Evaluation of various coastal-eutrophication studies by Borum (1996) and Cloern (2001) showed a complexity in the relation of nutrient loads with the responses in phytoplankton biomass. Not all estuaries with high nutrient loads are characterized by a high phytoplankton biomass. As an example, the two nutrient-rich bays, Chesapeake and San Francisco bays, which are relatively similar in nutrient loads showed differences in phytoplankton biomass (Cloern, 2001). Other estuaries, the Ythan in Scotland and the Bay of Brest in France showed no trend of increasing phytoplankton biomass during decades of increasing nutrient concentrations (Le Pape *et*

*al.*, 1996 and Cloern, 2001). Finally, this indicates that there are some inter-system differences in the linkage between the signal of nutrient change and the response of changed phytoplankton biomass. The first linear response system in the conceptual model of eutrophication needs to be more broadened and extended by other factors, resulting in the complexity of the relationship between nutrients and phytoplankton biomass in a coastal environment.

The study on nutrient enrichment and its ecological consequences in tropical coastal waters is not as extensive as in temperate areas (Cloern, 2001 ; Berdalet *et al.*, 1996 ; Foy, 1993 ; Olli *et al.*, 1996 ; Hessen *et al.*, 1995 ; Muscatine *et al.*, 1989). In contrast, in temperate regions, studies on the effects of extreme nutrient enrichment on coastal ecosystems have been both intensively and extensively performed either in natural ecosystems or in experimental lab-based studies (Anderson, 1995 ; Humpage *et al.*, 1994 and Holmboe *et al.*, 1999).

In Indonesian waters, studies on nutrient enrichment and its relation to phytoplankton are very limited (Kaswadi *et al.*, 1993). In fact, there is a need for appropriate studies on nutrient enrichment and eutrophication and their relation with phytoplankton to understand eutrophication in a tropical environment and as a basis for future more intricate studies, and finally to develop coastal management strategies.

### **1.1. The hypotheses and aims of the study**

The hypotheses of this study are :

- The increase of nutrient loads and concentrations (mainly nitrogen, phosphorus and silicon) in a coastal water will increase phytoplankton biomass and production (e.g. Dring, 1982 ; Sommer, 1994). High-nutrient loaded coastal waters have higher phytoplankton biomass and production compared to low-nutrient loaded coastal waters (Margalef, 1978 ; Estrada, 1978).
- The susceptibility of a coastal ecosystem to nutrient enrichment varies from site to site, and depends on the local physical environmental attributes : light availability and attenuation properties, physical water movement and grazer interferences (Cloern, 2001).
- There will be a spatial gradient of nutrient concentration and phytoplankton biomass from the inshore to the more offshore sites, which is commensurate with the decrease of fresh water influence as nutrient source.
- In tropical waters, during high precipitation period (rainy season), input of nutrient into coastal waters increases, promoting higher phytoplankton biomass and production than during the dry season (Gin *et al.*, 2000).
- Differences in the ratio of N/P and N/Si promote the change of phytoplankton (group) compositions (Sommer, 1994).

Regarding to the hypotheses mentioned above, this study was conducted to observe the nutrients and phytoplankton characteristics and its relation in three different nutrient-polluted bays in Indonesian tropical regions (Jakarta, Lampung and Semangka bays). It is expected that the results will be beneficial for the improvement of the knowledge about the biological variability of coastal ecosystems, especially in the tropical environment and



might serve as a database for local coastal management strategies. The specific aims of this study are to test and verify the hypotheses mentioned above:

- To verify and evaluate the relationship between nutrient load and nutrient concentration to phytoplankton biomass and production in the three different organic-polluted coastal waters.
- To observe the influence of the site-specific physical and biological attributes on the phytoplankton community response to difference nutrient enrichment.
- To test and evaluate the occurrence of spatial and seasonal variability on the light properties, nutrients, phytoplankton biomass and production in each tropical bay studied.
- To observe and evaluate the influence of nutrient ratio (N:P and N:Si) on phytoplankton group composition.

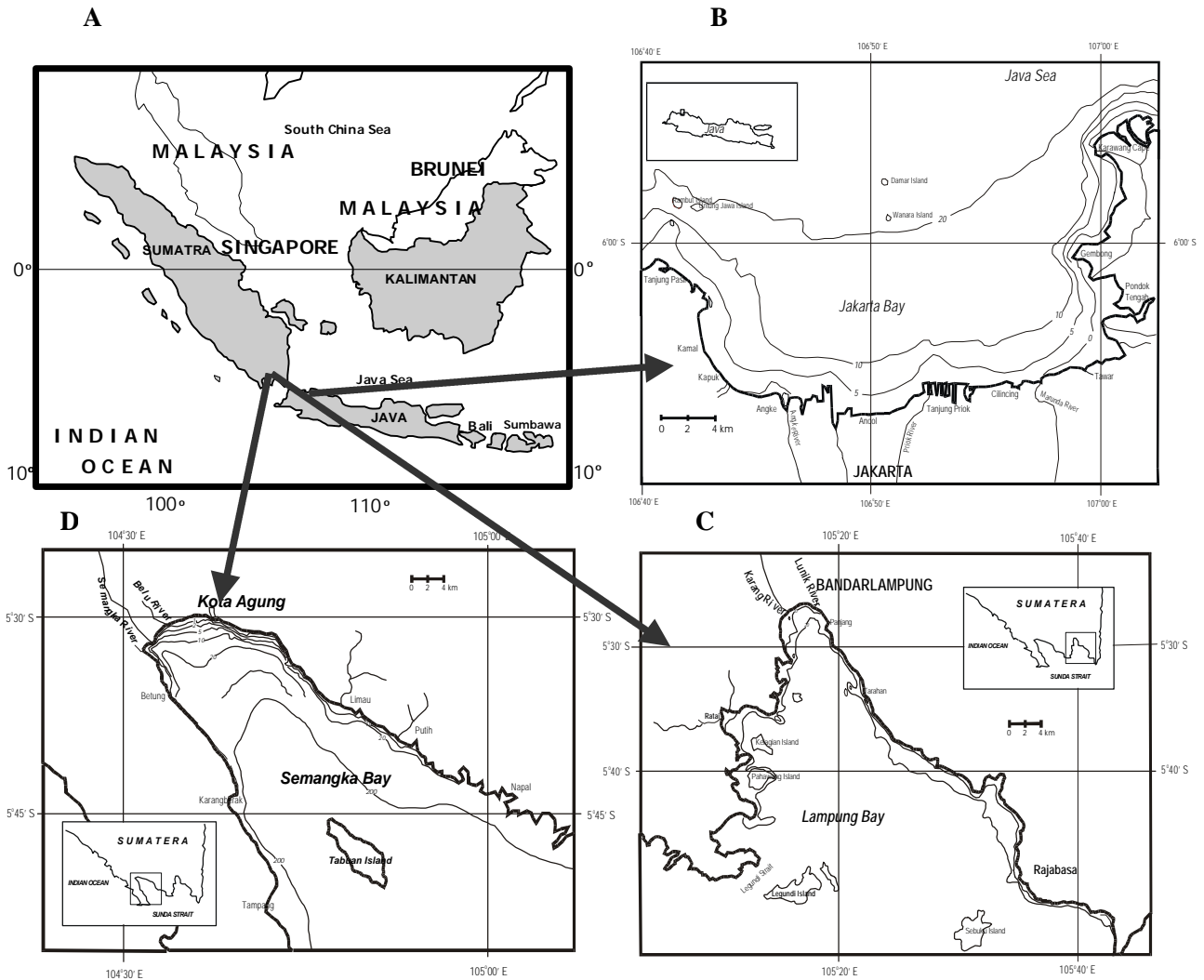
In order to achieve the aims described above, three different anthropogenic-pressure coastal waters were chosen as study areas, those are Jakarta, Lampung and Semangka bays. It is expected that a range of differently nutrient-loaded coastal ecosystems can be compared regarding their different ecological behaviour. Jakarta Bay is considered as a highly organic-polluted water (Anonymous, 1994), while Lampung and Semangka are less organic-polluted waters (Prartono *et al.*, 1999).

### **1.3. General description of study area**

Jakarta, Lampung and Semangka bays are three economic and ecological important bays in Indonesia. Jakarta Bay is located at the north coast of Java, while Lampung and Semangka bays are located at the southernmost part of Sumatra Island (Fig.1.1.).

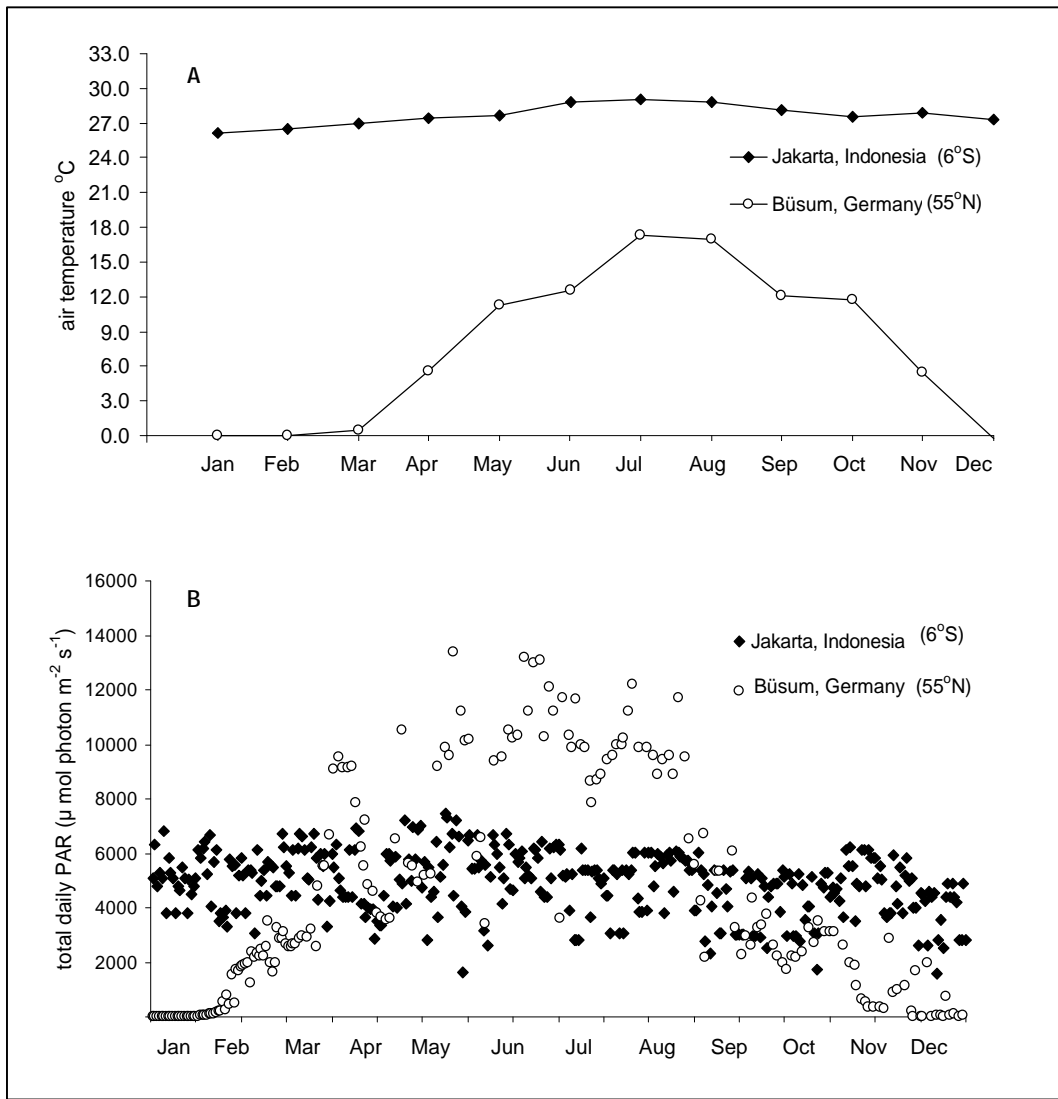
The main environmental variables which create the specific-character of tropical aquatic ecosystem as compared to temperate areas are light and temperature. Temperate zones have a strong seasonal variation (extremely low production in winter and high production in spring and summer), while tropical ecosystems are relatively stable throughout the year. The stability of light and temperature (Fig. 1.2) will support a continuous production in a coastal system and leave the nutrients as the most influential and changing elements for primary production processes (Nybakken, 1988 ; Brown *et al.*, 1989).

There are two dominant monsoonal seasons, which drive the climate cycles in the study areas (as in all other Indonesian areas) named dry and rainy seasons. Dry season is related to southeast (SE) monsoon, while rainy season is related to northwest (NW) monsoon.

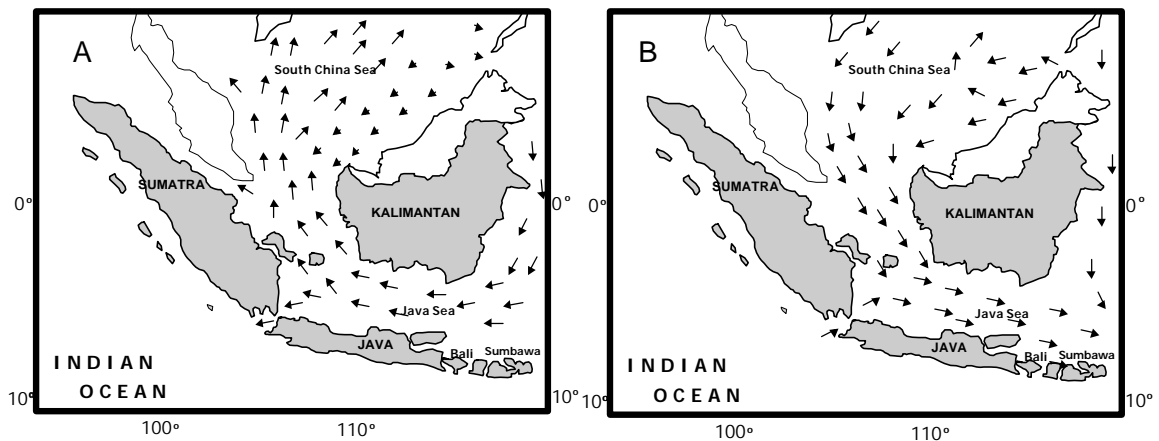


**Fig. 1.1.** Maps of west part of Indonesia (A), Jakarta Bay (B), Lampung Bay (C) and Semangka Bay (D).

The dry season occurs between February till August, driven by low air pressure over Asia and high air pressure over Australia. Consequently, the wind blows from southeast to northwest, carrying dry air from Australia, resulting the dry season in the country. Inversely, during September/October to January, high air pressure over Asia and low air pressure over Australia are observed, allowing wet air transport from the South China Sea and the Pacific Ocean across the archipelago, forming the rainy season (Bühring, 2001 ; Tomascik *et al.*, 1997). The monsoonal sea current pattern, during dry season, flows from the eastern part of the Java Sea to the west, entering the Indian Ocean (through the Sunda Strait) and the South China Sea (Fig.1.3). Consequently, during this period, Jakarta Bay is influenced by the water masses from the eastern part of Java Sea, while Lampung and Semangka bays are influenced by the nutrient-rich water masses from the Java Sea. Inversely, during rainy season, current flows from the South China Sea to the east (the Java Sea) and the water masses from Indian Ocean flows to Java Sea through Sunda Strait. During this period, Lampung and Semangka bays are influenced by the low nutrient water masses from the Indian Ocean (Bühring, 2001 ; Hendiarti *et al.*, 2002).



**Fig. 1.2.** Temperature (A) and Photosynthetically Active Radiation, PAR (B) values in a tropical area (Indonesia) compared to a temperate region (Büsum, Germany). Data on Indonesian temperature and PAR were obtained from Jakarta Meteorological Station (2001) and Büsum temperature and PAR were obtained from Forschungs und Technologie Zentrum's weather station in Büsum, Germany (2001).



**Fig.1.3.** Sea surface circulations during the dry (A) and the rainy (B) seasons in the region ; redrawn from Bühring (2001) and Wyrтки (1961).

### 1.3.1. Jakarta Bay

Jakarta Bay (Fig.2.1) is located on the northern coast of Jakarta City ( $5^{\circ}55'30''$  to  $6^{\circ}07'00''$  S and  $106^{\circ}42'30''$  to  $106^{\circ}59'30''$  E) bordered by two capes, Karawang Cape at the east and Pasir Cape at the west. The bay has an area of approximately  $285 \text{ km}^2$  with a coast-length of around 33 km and a mean depth of 8.4 m (Koropitan, pers.comm.; Anna, 1999). The tides in Jakarta Bay are diurnal, with one high tide and one low tide during the day. The average tidal range is 0.9 m. The whole water column is always thoroughly mixed due to its shallow water (Suyarso, 1995). Water residence time of Jakarta Bay was calculated as around 5 days (Koropitan, pers.comm.). The sediment in Jakarta Bay consists of sand (2 to 8 %), silt (46-66%) and clay (33 – 52%) (Anonymous, 1994).

There are 13 small rivers (total mean discharge of  $112.7 \text{ m}^3 \text{ s}^{-1}$ ), flowing into the bay after passing through Jakarta City (catchment area of about  $1421 \text{ km}^2$ ) carrying most of the untreated sewage. Around 38.5% of the people (total inhabitants was 8.5 million people in the year 2000) in Jakarta discharge their daily organic waste directly into the river (through small discharge canals) and most of this is directly transported into the bay. Calculation of the organic load in the bay in 1993 resulted in 120 ton of  $\text{BOD}_5$  per day (Anonymous, 1994). Analysis of time series (1984 – 1997) calculated by Anna (1999) showed that the concentration and loads of dissolved inorganic nitrate, ammonia and phosphate have increased during the last 10-year period. Increase and accumulation of nutrient concentrations were also reported by a monitoring project on water quality of Jakarta Bay in the period of 1991 - 1994 (Anonymous, 1991; Anonymous, 1994). This increase was especially related to the rapid economic development of the city during that period, but unfortunately, it was not accompanied by the development of environmental protection facilities (Anna, 1999). Recently, there is only one small domestic sewage treatment facility in operation and it is completely insufficient to clean the whole city's domestic waste water.

Ilahude (1995) stated that the distribution and fluctuation pattern of nutrients in the bay is mostly related to land-interaction processes (e.g. transported through the incoming rivers) and monsoonal influences. In general, distribution of nutrients in Jakarta Bay displayed a strong seasonal cycle throughout the year, is highly influenced by the monsoonal cycles. However, the spatial variations were more pronounced, showing high values in the near-shore waters and lower values in the more offshore area. There was no specific seasonal cycle of phosphate. Similar patterns also showed up for ammonium, which reached maximum concentration during the rainy season and concentrated in the river mouth areas.

Silicate concentration reached its maximum during rainy season at the west coast of the bay, ranging from  $5.0$  to  $27.0 \mu\text{g at Si l}^{-1}$ . As the monsoon shifted to the transitional period, the region of silicate maxima shifted to the east coast of the bay, but still ranged between  $5.0$  to  $20.0 \mu\text{g at Si l}^{-1}$ . During the dry season, silicate slightly reduced below  $5.0 \mu\text{g at Si l}^{-1}$ , but still concentrated in the east coast of the bay. Entering the transitional period, silicate increased again up to  $27.0 \mu\text{g at Si l}^{-1}$  and concentrated along the west and middle coast of the bay (Suyarso, 1995).

Ilahude (1995) stated that in general, a regional monsoonal cycle causes a regular pattern of salinity in the Java Sea. There are two times of minimum salinity during a year: in February and September ; also there are two times of maximum : in May and November. During the period of low salinity, it ranged from 25.0 to 32.5, while during the maximum, it ranged from 29.0 to 34.0.

In Jakarta Bay, during the rainy season, sea current flows from northwest to east (speed ranged from 0.8 till 1.4 m s<sup>-1</sup>), whereas during dry season, it flows from east to northwest (speed ranged from 0.8 till 1.2 m s<sup>-1</sup>) (Setiawan and Putri, 1998).

Arinardi (1995) summarized the phytoplankton and chlorophyll *a* distribution in Jakarta Bay obtained from the 1976-1979 data. During the rainy season, the overall chlorophyll *a* concentration reached maximum values, which concentrated along the coastline of the bay (around 7.5 µg Chl *a* l<sup>-1</sup>). There was no significant difference in distribution of chlorophyll *a* as the rainy season shifted to the dry season. During the dry season, the concentration of chlorophyll *a* slightly reduced down to 5 µg Chl *a* l<sup>-1</sup>, but the general distribution pattern remained similar to that of the rainy season, which showed higher concentration along the coastline. He also revealed that the distribution and abundance of phytoplankton was slightly influenced by monsoonal behaviour. During the rainy season, as the nutrient slightly increased due to higher inputs from the land, the abundance of phytoplankton increases, dominated by diatoms. In general, the predominant genera of phytoplankton in the bay over the year were *Chaetoceros* spp, *Rhizosolenia* spp and *Skeletonema costatum*. Diatoms increased during the rainy season, reaching 25.26 x 10<sup>6</sup> cell l<sup>-1</sup>. During the rainy-dry transitional period, diatoms numbers remained high with 27.99 x 10<sup>6</sup> cells l<sup>-1</sup>, but reduced as the monsoon shifted to the dry-rainy transitional period to 12.52 x 10<sup>6</sup> cells l<sup>-1</sup>. He also found that there was no regular pattern in the distribution of dinoflagellates, and the predominant species were *Noctiluca scintillans* and *Ceratium* spp. No strong correlation was observed with the monsoonal cycles. Algal bloom is an annual regular phenomenon in Jakarta Bay, and consists of *Noctiluca scintillans* and *Skeletonema costatum* blooms (Dahril, 1981; Praseno, 1981 ; Adnan, 1994).

The Office of Cities and Environment of the local government of Jakarta City which conducts monitoring of Jakarta Bay water quality reported that the water quality of these waters ranged from 'bad' to 'moderate' water quality classes. These classes were set by the criteria of the national aquatic environmental board (Anonymous, 1994).

### 1.3.2. Lampung Bay

Geographically, Lampung Bay is located at 5 ° 26' S to 5 ° 50' S and 105 ° 10' E to 105 ° 35' E, has an area of about 847 km<sup>2</sup>, a mean depth of 17.3 m and coast-length of around 160 km (Wirawan *et al.*, 1999). Slightly different to Jakarta Bay, the tidal pattern in Lampung Bay is influenced by the Indian Ocean, resulting in a semi-diurnal tide. The average tidal range is 1.46 m. The whole water column is always thoroughly mixed due to its relatively shallow water depth (Wirawan *et al.*, 1999). Water residence time of Lampung Bay was calculated to be around 15 days (Koropitan, pers.comm.). The sediment in Lampung Bay consists of sand (2 to 16 %), silt (57-71%) and clay (27 – 41%) (Wirawan *et al.*, 1999).

Compared to Jakarta Bay, Lampung Bay receives less freshwater due to the smaller rivers in the area. There are 6 small rivers, flowing into the bay (total mean discharge around  $22.2 \text{ m}^3 \text{ s}^{-1}$ ), from a small catchment area (around  $278 \text{ km}^2$ ) due to its high and steep land-slope. The source of anthropogenic nutrient enrichment in the bay is predominantly from domestic waste water of the Bandar Lampung City through small rivers and a set of canals and direct sources from fisheries activities along the east coast of the bay. It is estimated that organic waste water of around 900,000 people in the area directly flow into the bay (Anonymous, 2001). Right at the north coast of the bay, there is a small industrial area, which also discharges some waste water into the bay.

Wiryanan *et al.* (1999) revealed that during rainy season, current speed ranged from  $0.27$  to  $0.45 \text{ m s}^{-1}$ , with the maximum occurring in December. The direction of currents during this period is constant to the south east. Meanwhile, during the dry season, current weakens and ranges from  $0.01$  to  $0.36 \text{ m s}^{-1}$  directed to the northwest, with minimum occurring in July, ranging from  $0.01$  to  $0.05 \text{ m s}^{-1}$ . At the outer mouth of the bay, the monthly average current speed ranges from  $0.01$  to  $0.45 \text{ m s}^{-1}$ , where the maximum value prevailed during January and February and the minimum occurred during March and April. On a regional scale, during the dry season, Lampung Bay waters are highly influenced by water masses from the Java Sea, characterised by high nutrient and chlorophyll *a*. Meanwhile, during the rainy season, Lampung Bay waters are influenced by water masses from the Indian Ocean, which are relatively low in nutrients and chlorophyll *a* (Hendiarti *et al.*, 2002).

Monthly average sea surface temperature in the bay was relatively constant throughout the year ( $28^\circ\text{C}$ - $29^\circ\text{C}$ ), with the maximum in May, and minimum in October (Wyrski, 1961). Salinity in the area ranged from  $32.50$  to  $33.6$  characterised by a minimum value in January, and a maximum in August. Lower salinity usually prevails during the rainy season, due to a high precipitation and river discharge.

The reports on water quality for this area are limited, and based on the research done by the Coastal Project (Wiryanan *et al.*, 1999); it was reported that temperature, salinity, pH, turbidity, oil content, Cu and Coliforms in the Lampung Bay waters were still in the range of acceptable values if compared to the Indonesian standards of water quality for tourism, as well as for fisheries culture and marine biota.

In general, the quality of coastal habitat of Lampung bay has degraded especially due to human expansion. The former mangrove area has been almost completely converted into shrimp ponds. Coral reefs, seagrasses and seaweeds are mostly found along the small reef flat, surrounding the small islands in the bay (Wiryanan *et al.*, 1999).

### 1.3.3. Semangka Bay

Scientific information on Semangka Bay is extremely limited. Studies in the area are really rare due to its unattractive and remote location. The bay is located at  $5^\circ 28'$  to  $5^\circ 56'$  S and  $104^\circ 30'$  to  $105^\circ 05'$  E. The area of this bay is around  $924 \text{ km}^2$ , a coast-length of around  $200 \text{ km}$  and a mean depth of  $140 \text{ m}$ , which is much deeper than that of Jakarta and Lampung bays (Koropitan, pers. comm.). Hydrodynamically, this bay is highly influenced by the Sunda Strait and the Indian Ocean and has a larger tidal range (around  $1.6 \text{ m}$ ). Based on CTD profiles done by Hendiarti (pers.comm.), the upper mixed layer of the water column reaches to  $60 \text{ m}$  depth. Water residence time of Semangka

Bay was calculated to be around 100 days (Koropitan, pers.comm.). The sediment in Semangka Bay consists of sand (11 to 63 %), silt (29-78%) and clay (8 – 19%) (Wiryawan *et al.*,1999).

The dominant and relatively big river, flowing into the bay, is Semangka river. This river has an annual average discharge of  $52.2 \text{ m}^3 \text{ s}^{-1}$ . In contrast to the rivers in Jakarta and Lampung bays, which flow through dense-human settlements, this river flows through natural landscapes, with a catchment area of around  $1413 \text{ km}^2$ . There is no dominant source of organic waste along this river. The most influential settlement in the area, named Kota Agung has only around 50,000 people. However, as many others towns in Indonesia, it does not have a domestic sewage treatment facility. The raw sewage flows directly through a series of canals into the bay. The discharge point of these sewage canals are at Kota Agung harbour.

During the dry season, Semangka Bay waters are influenced by the water masses coming from the northern Sunda Strait, while inversely during the rainy season, it is influenced by the water masses from the Indian Ocean, which is low in nutrient and chlorophyll *a* (Hendiarti *et al.*, 2002).

The coastline of the bay has a steep topographic slope, because it is surrounded by a chain of mountains. The only relatively flat and low land area is concentrated around the Semangka river mouth.

The general physical and hydrodynamic characteristics of the three bays studied are summarized in Table 1.1.

**Table 1.1.** Summaries of the main physical and hydrodynamic properties of the three bays studied.

Parameters	Units	Jakarta Bay	Lampung Bay	Semangka Bay	Reference*)
area	$\text{km}^2$	285	847	924	a,b,c
coast-length	km	33	160	200	a,b
mean water depth	m	8.4	17.3	139.4	a,b,c
water column mixed layer	m	whole depth	whole depth	60	b,f,g
tidal type	-	Diurnal	semi-diurnal	semi-diurnal	a,b
tidal amplitude	m	0.9	1.46	1.60	a,b
water residence time	days	ca. 5	ca. 15	ca. 100	c
current	$\text{m s}^{-1}$	0.80-1.4 (rainy season : to east) 0.80-1.2 (dry season : to northwest)	0.27-0.45 (rainy season : to southeast) 0.01-0.36 (dry season : to northwest)	no information	b,d

Table 1.1. Continuation.

sediment texture	-	sand : 2-8 % silt : 46-66% clay : 33-52%	sand : 2-16 % silt : 57-71% clay : 27-41%	sand :11-63 % silt : 29-78% clay : 8-19%	b,d
mean river discharge	m <sup>3</sup> s <sup>-1</sup>	112.7	22.2	52.2	h,i
catchment area	km <sup>2</sup>	1421	278	1413	a,h,i
population in the catchment area (year 2000)	million people	around 8.5	around 0.9	around 0.05	a,b,e
main land-use	-	urban, coastal aquaculture and industry	urban, coastal agriculture, industry and forest	forest and urban	b,e,d

\*) a = Anna (1999) e = Anonymous (2001) i = Anonymous (2002 B)  
b = Wiryawan *et al.* (1999) f = Hendiarti (pers.comm)  
c = Koropitan (pers.comm) g = Suyarso (1995)  
d = Anonymous (1994) h = Anonymous (2002 A)



## 2. Materials and methods

### 2.1. Study area and sampling stations

Measurement campaigns were conducted in all bays over a one-year period, from December 2000 till December 2001, encompassing the 2 different tropical monsoonal seasons, namely dry and rainy seasons. Water samples were taken at each sampling station in each bay (Fig. 2.1, 2.2 and 2.3), with a frequency of approximately every 2 months. In each bay, sampling stations were defined in order to have sufficient spatial coverage of the area as well as representation of spatial gradients.

In Jakarta Bay, water samples were collected approximately bimonthly, from 11 December 2000 to 20 November 2001. There were 15 sampling stations, of which 3 were river mouth stations and 12 were marine stations. The selected rivers were Angke, Priok and Marunda. Angke River represents the west part of the bay, Priok River represents the middle part of the bay and Marunda River represents the east part of the bay. Apart from those 3 river mouth stations, sampling was also performed at 12 other marine sampling stations (Fig. 2.1). The geographical position of sampling stations are listed in Table 2.1.

**Table 2.1.** Geographical position of sampling stations in Jakarta Bay.

Stations	East	South
1	106°44' 23"	5° 58'43"
2	106°45' 37"	6° 03' 13"
3	106° 46' 20"	6° 05' 15"
4	106° 51' 40"	5° 59' 43"
5	106° 52' 0"	6° 01' 40"
6	106° 52' 33"	6° 04' 23"
7	106° 56' 37"	5° 57' 20"
8	106° 57' 33"	6° 01' 0"
9	106° 58' 7"	6° 03' 33"
10	106° 58' 1.4"	6° 04' 33.1"
11	106° 46' 56.4"	6° 05' 53.6"
12	106° 54' 22"	6° 05' 30"
Angke River	106° 46' 38"	06° 06' 15"
Priok River	106° 54' 18"	06° 06' 29"
Marunda River	106° 56' 23.9"	06° 06' 2.7"

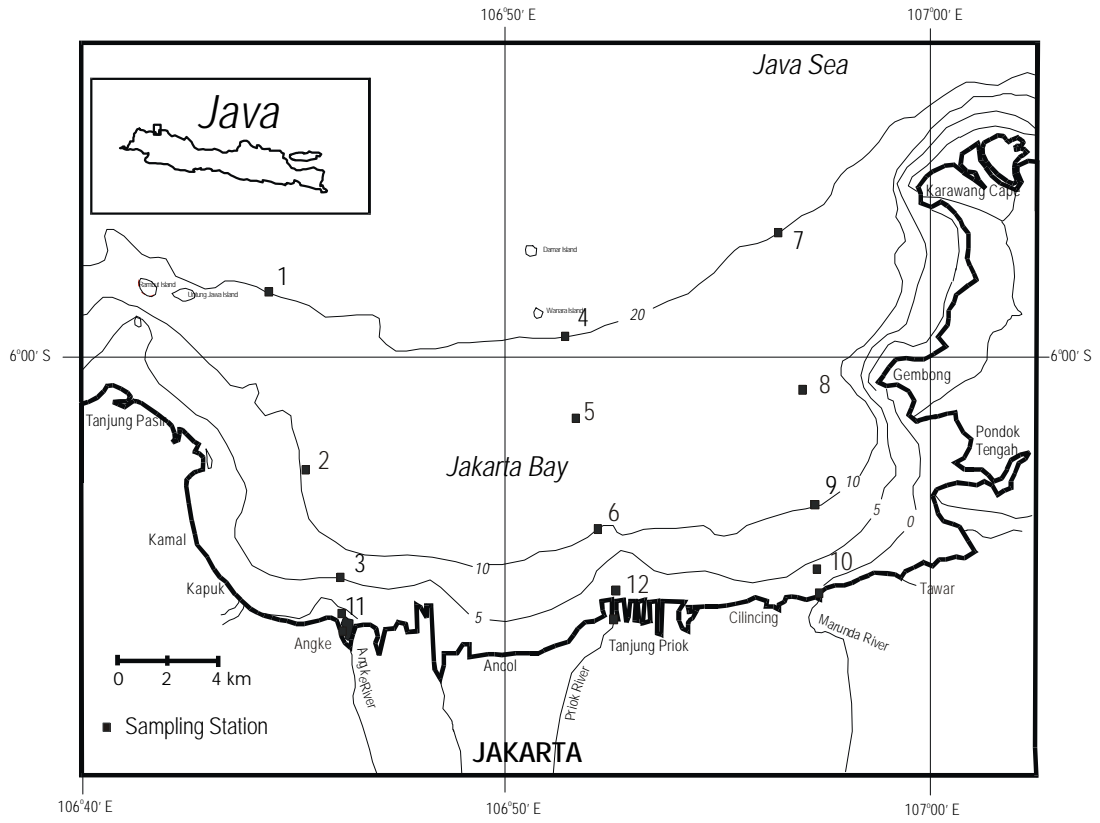


Fig. 2.1. Location of sampling stations in Jakarta Bay.

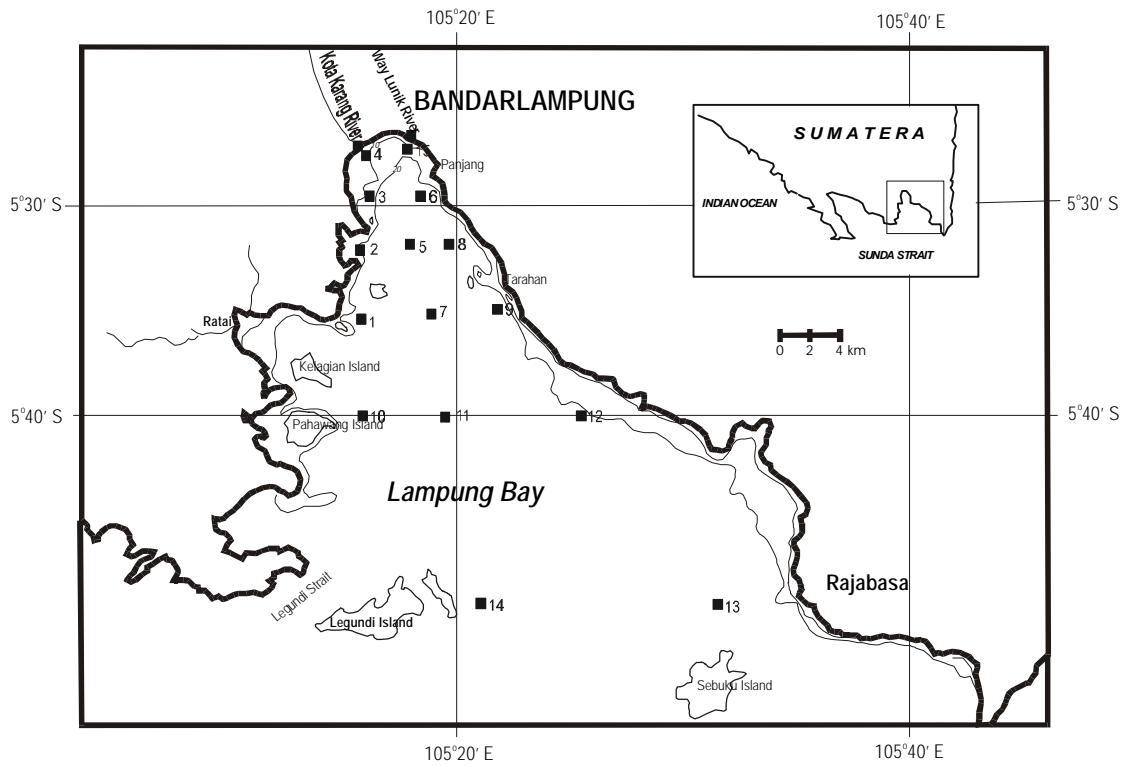


Fig. 2.2. Location of sampling stations in Lampung Bay.

In Lampung Bay, sampling was conducted at 17 stations, of which 2 were river mouth stations, while the rest were marine stations. The river-mouth's sampling sites were in Kota Karang River and Way Lunik River (Fig. 2.2). Samples were taken approximately every 2 months, starting from 9 January 2001 till 24 November 2001. Table 2.2 shows the geographical position of sampling stations.

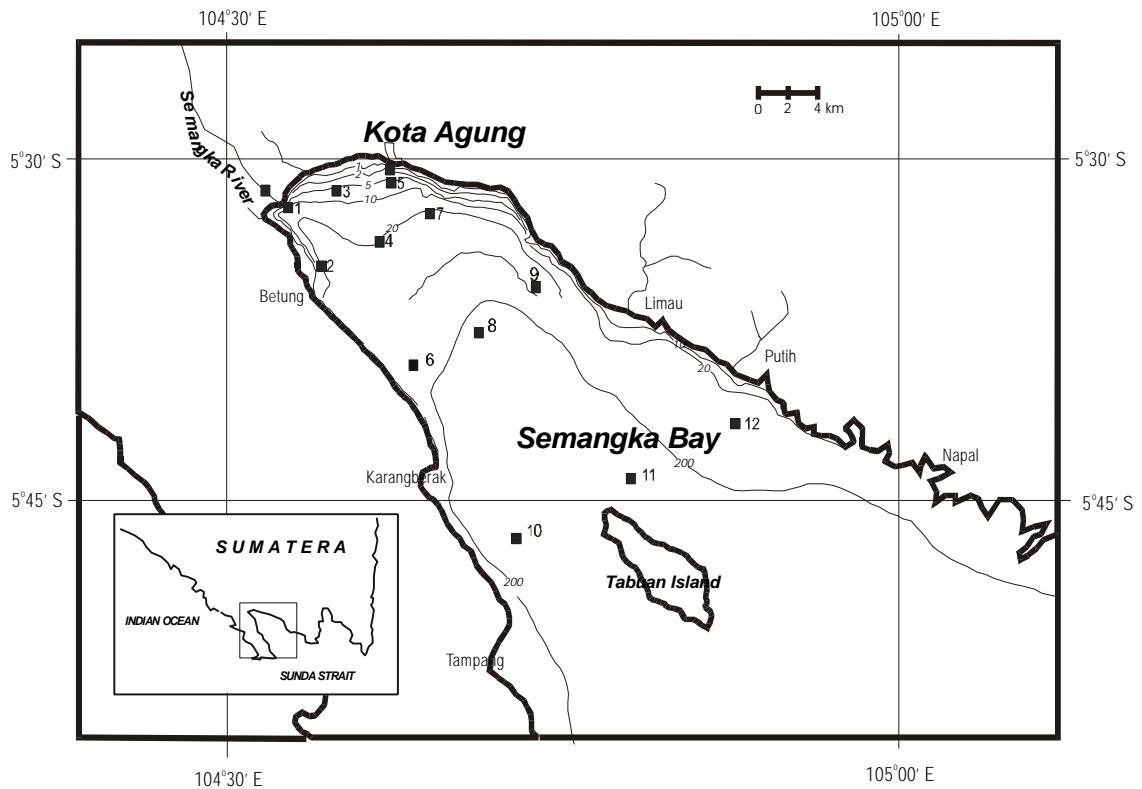
**Table 2.2.** Geographical positions of sampling stations in Lampung Bay.

Stations	East	South
1	105 °15' 50"	05 ° 36' 07"
2	105 ° 16' 10"	05 ° 32' 17"
3	105 ° 16'24"	05 ° 30' 00"
4	105 ° 16' 02"	05 ° 27' 44"
5	105 ° 18' 10"	05 ° 32' 04"
6	105 ° 18' 40"	05 ° 30' 20"
7	105 ° 18' 57"	05 ° 34' 57"
8	105 ° 19' 40"	05 ° 31' 47"
9	105 ° 21' 20"	05 ° 34' 27"
10	105 ° 15' 50"	05 ° 40' 00"
11	105 ° 20' 00"	05 ° 40' 00"
12	105 ° 24' 00"	05 ° 40' 00"
13	105 ° 32' 00"	05 ° 48' 00"
14	105 ° 25' 00"	05 ° 48' 00"
15	105 ° 18' 18"	05 ° 27' 30"
Kota Karang River	105 ° 15' 15"	05 ° 27' 34"
Way Lunik River	105 ° 18' 20"	05 ° 27' 12"

In Semangka Bay, sampling was conducted at 14 stations, consisting of 1 river-mouth station, 1 harbour station and 12 marine stations. (Fig. 2.3). Samples were collected approximately every 2 months, starting from 18 January 2001 till 1 December 2001. The geographical positions of sampling stations are listed in Table 2.3.

**Table 2.3.** Geographical positions of sampling stations at Semangka Bay.

Stations	East	South
1	104° 33' 10"	05° 32' 20"
2	104° 34' 37"	05° 35' 34"
3	104° 34' 57"	05° 31' 24"
4	104° 37' 04"	05° 33' 27"
5	104° 37' 47"	05° 30' 54"
6	104° 37' 37"	05° 38' 44"
7	104° 39' 20"	05° 32' 14"
8	104° 39' 50"	05° 36' 10"
9	104° 42' 37"	05° 34' 20"
10	104° 39' 54"	05° 42' 14"
11	104° 42' 24"	05° 40' 10"
12	104° 45' 57"	05° 38' 27"
13 (Kota Agung Harbour)	104° 37' 32"	05° 30' 25"
Semangka River	104° 32' 43"	05° 32' 09"

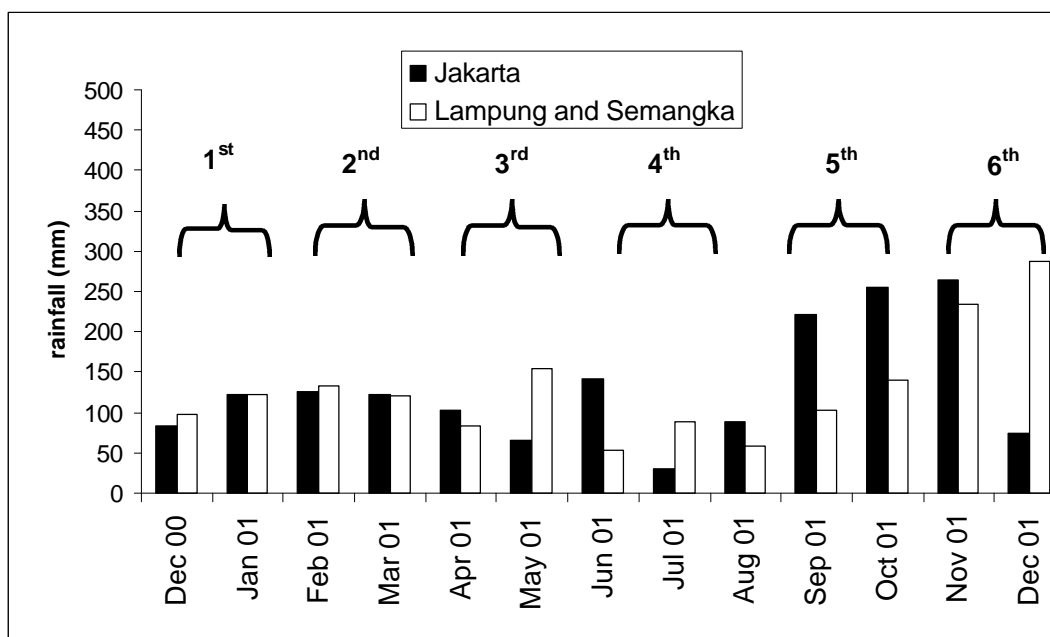


**Fig. 2.3.** Location of sampling stations in Semangka Bay.

Sampling dates are presented in Table 2.4 and Fig.2.4. It is shown that sampling times represent the variability of the season in one year period, which was mainly governed by the variability of rainfall.

**Table 2.4.** Date of temporal sampling and measurement surveys in each bay.

The surveys	Date			remarks
	Jakarta Bay	Lampung Bay	Semangka Bay	
1. 1 <sup>st</sup>	11 Dec. 2000	9 Jan. 2001	18 Jan. 2001	rainy season
2. 2 <sup>nd</sup>	23 Feb. 2001	28 Feb. 2001	8 March 2001	dry season
3. 3 <sup>rd</sup>	24 Apr. 2001	2 May 2001	19 May 2001	dry season
4. 4 <sup>th</sup>	9 Jul. 2001	19 Jul. 2001	31 Jul. 2001	dry season
5. 5 <sup>th</sup>	20 Sept. 2001	28 Sept. 2001	6 Oct. 2001	rainy season
6. 6 <sup>th</sup>	20 Nov. 2001	24 Nov. 2001	1 Dec. 2001	rainy season



**Fig. 2.4.** Monthly rainfall in the study areas and temporal surveys during research period of 2000-2001. Sources: Anonymous (2002C) and Anonymous (2002D).

## 2.2. Methods

### 2.2.1. Water sampling and *in situ* measurements

Surface water samples (depth of 0 to 1.5 m) were collected by means of 2-liter PVC Van Dorn bottle. At each sampling station, 5 liter of water was collected and distributed into several sub-samples : dissolved inorganic nutrients (0.25 l), chlorophyll *a* (1 to 2 l), total algae pigments (1 to 2 l), phytoplankton (0.25 l), turbidity (100 ml) and primary production measurement (1 l). The net plankton samples were collected by using a 40- $\mu$ m net, to enable phytoplankton species identification. Samples were placed temporarily in a cool box until being analyzed at the main laboratory in Bogor. Besides taking a water sample, *in situ* measurements were also conducted for dissolved oxygen, water temperature, pH, and Secchi depth. Dissolved oxygen was measured according to the Winkler method as recommended by Strickland and Parsons (1972). Light availability was measured by means of a 30-cm diameter Secchi disk. Temperature and salinity were measured *in situ* by using STD meter (YSI-30), while pH was measured with a pH meter (Orion), calibrated by pH 4.00 and 9.00 standard solution before each temporal survey.

Turbidity was measured at the laboratory, based on the nephelometric method recommended by Strickland and Parsons (1972). This method is based on the measurement of light reflected by turbidity agent in a water sample.

### 2.2.2. Dissolved inorganic nutrients

Dissolved inorganic nutrient analysis was started by filtering 250 ml of water sample through MFS nucleopore filter (diameter 47 mm and pore size of 0.2  $\mu$ m). Filtration was conducted on land approximately 6 hours after sampling. The filtered water was then stored into a 250-ml PVC flask and transported in a cool-box to the main laboratory in Bogor. All dissolved inorganic nutrients : nitrate,

nitrite, ammonium, phosphate and silicate, were determined spectrophotometrically according to Grasshoff *et al.* (1983).

### 2.2.3. Chlorophyll *a* and other algae pigments

For chlorophyll *a* analysis, 1 – 2 liters of water was filtered through a glass microfibre filter (Whatman GF/C, 47 mm diameter and 1.2 µm porosity) by using a vacuum pump (200 mm Hg pressure) and stored deep frozen (-20°C) until being analyzed in the laboratory by using the spectrophotometrical method of Lorenzen (1967). The filter was extracted by 10 ml of 90% acetone and grinded until it was thoroughly macerated, and then centrifuged at 3600 rpm for 5 minutes. The supernatant is measured in spectrophotometer at 665 nm and 750 nm, then acidified with 1 N HCl and re-measured at the same wave lengths. The equation for the calculation of chlorophyll *a* content is :

$$\text{Chl } a \text{ (}\mu\text{g/l)} = \frac{A * K * (665_o - 665_a) * v}{V * l}, \text{ where}$$

- A = absorption coefficient of chlorophyll *a* = 11.0  
 K = factor to equate the reduction in absorbancy to initial chlorophyll concentration, 2.43  
 665<sub>o</sub> = abs. at 665 nm – abs. at 750 nm, both before acidification  
 665<sub>a</sub> = abs. at 665 nm – abs. at 750 nm, both after acidification  
 v = volume of acetone used for extraction (ml)  
 V = volume of water filtered (l)  
 l = path length of cuvette (cm)

Total pigment analysis was started by filtering another 1 to 2 liters of water through a Whatman GF/F filter (47 mm diameter and 0.7 µm porosity), and deep frozen stored (-20°C). All pigment analysis were performed according to Mantoura and Llewellyn (1983) method at FTZ's laboratory in Germany by means of HPLC (High Performance Liquid Chromatographer). The filters were thoroughly grinded in acetone 90%, and then placed in a 100 µl brown-glass vials before chromatographically separation by HPLC and further measured spectrophotometrically at the wavelength of 432 nm. The spectrophotometer detector used was a Spectrafocus TSP. The calibration was performed by using the standard pigments supplied by the DHI Denmark and Sigma companies for all algae pigments.

### 2.2.4. Phytoplankton

Phytoplankton cell counts were performed according to the settling method developed by Utermöhl (1958). Prior to be counted, 100 ml sub samples were preserved by lugol's solution and concentrated to 10 ml by settling and siphoning the supernatant. A subsample of 1 ml (counts were performed in 3 replications) was transferred to a 1 ml Sedwig-rafter glass chamber for cell counting in a light microscope (Zeiss AXIOVERT 35). Identification of phytoplankton was performed by using several identification standard books, such as : Tomas (1996), Hustedt (1930), Hustedt (1959), Hustedt (1966), and several other phytoplankton papers including internet website identification guides.

### 2.2.5. Zooplankton

Zooplankton was sampled by means of a 45 µm net, through filtration of 75 l of sea water, resulting in 50 ml of concentrated water sample which was then

preserved by 4% formaldehyde solution and placed in a brown-glass bottle transported to the main lab. for group identification.

### 2.2.6. Planktonic primary production

Planktonic primary production rates were determined at 3 stations in each bay, according to P-E curve's method by using the radiocarbon method as developed by Steeman Nielsen (1952) and recommended by Colijn and Edler (1999). Selection of these 3 stations was based on the representation of nutrient regimes in each bay. The samples (each flask contains 55 ml) were spiked with 1  $\mu\text{Ci}$  of  $\text{NaH}^{14}\text{CO}_3$  (supplied by DHI Denmark Company) and incubated in a rotating incubator at in situ temperature. A set of flasks (ZEMOKO, Middelburg, The Netherlands) were used providing 8 different light levels, ranging from 0% to 100%. The light source was TL - lamps installed on each side of the incubator (total irradiance  $606 \mu\text{mol photons m}^{-2} \text{s}^{-1}$ ). After addition of  $^{14}\text{C}$ , samples were incubated for 4 hours. After filtration through MFS cellulose nitrate filter (diameter 2.5 cm and  $0.45 \mu\text{m}$  porosity), the filters were dried at room temperature for 24 hours. After that, all filters were placed in a 5-ml flask containing 4 ml CytoScint (ICN-Biomed) as scintillation cocktail. The amount of radioactive  $^{14}\text{C}$  incorporated in the cells was determined by means of a liquid scintillation counter (Packard type TRI-CARB 1900 TR). From this, a total carbon uptake value was calculated (Colijn and Edler, 1999):

$$\text{dp/dt } (\mu\text{g Chl}^{-1} \text{ hr}^{-1}) = \frac{\text{dpm (a)} * \text{total } ^{12}\text{CO}_2 \text{ (c)} * 12 \text{ (d)} * 1.05 \text{ (e)} * \text{k1} * \text{k2}}{\text{dpm (b)}}$$

where :

- (a) = sample activity (minus back ground), dpm
- (b) = total activity added to the sample (minus back ground), dpm
- (c) = total concentration of  $^{12}\text{CO}_2$  in the water sample, ( $\mu\text{M}$ )
- (d) = the atomic weight of carbon
- (e) = a correction for the effect of  $^{14}\text{C}$  discrimination
- k1 = subsampling factor (e.g. sample 50 ml, subsample 10 ml:  $k1 = \text{subsamplefactor } 50/10=5$ )
- k2 = time factor (e.g. incubation time 125 minutes :  $k2=60/125=0.48$ )

Dissolved inorganic carbon was measured and calculated according to Strickland and Parsons (1972). The production rate in each light bottle (after normalisation by chlorophyll *a* content) was plotted into a P-E Curve according to Platt *et al.* (1980) :

$$P^B = a (1 - e^{-bE}) e^{-cE} \dots\dots\dots(1)$$

where ,

- $P^B$  = production rate ( $\text{mg C mg}^{-1} \text{ Chl h}^{-1}$ )
- E = the incubation irradiance ( $\mu\text{mol photon m}^{-2} \text{ s}^{-1}$ )
- a,b,c = fit parameters

From that equation, the maximal rate of photosynthesis ( $P^B_{\text{max}}$ ), the initial slope ( $\alpha^B$ ) and the light saturation parameter ( $E_k$ ) could be estimated from the following equations:

$$P^B_{\text{max}} = \left( \frac{a(b/(b+c))}{c/(b+c)^{c/b}} \right) \text{ (mg C mg}^{-1} \text{ Chl h}^{-1} \text{)} ; \text{ the maximal rate of photosynthesis (mg C mg}^{-1} \text{ Chl h}^{-1} \text{)} ; \text{ a, b and c are fit parameters derived from equation (1)}$$

$$\alpha^B = a \times b ; \text{ the initial slope (mg C mg}^{-1} \text{ Chl h}^{-1} \text{ (}\mu\text{mol photons m}^{-2}\text{s}^{-1}\text{)}^{-1}\text{)}$$

$$E_k = P^B_{\text{max}} / \alpha^B ; \text{ the light saturation parameter (}\mu\text{mol photons m}^{-2} \text{ s}^{-1}\text{)}$$

Daily water column production was estimated, by combining values of irradiance and chlorophyll *a* concentrations with P and E curve characteristics, as modelled by Platt *et al.* (1980). Surface irradiance were taken from the nearest

meteorological stations (Bandar Lampung and Jakarta meteorological stations), assuming a conversion factor of  $1 \text{ W m}^{-2} = 4.17 \text{ } \mu\text{mol photons m}^{-2} \text{ s}^{-1}$  (Lalli and Parsons, 1995) and 45 % photosynthetically active radiation (Kirk, 1994). Correction for light reflection at the water surface is also performed (10%) according to Kirk (1994). The light attenuation coefficient was calculated from Secchi disk readings ( $S_d$  (m)), by using the empirical relationship  $k = 0.191 + 1.242/S_d$  ( $r^2 = 0.853$ ) (Tillmann *et al.*, 2000).

### 2.2.7. Nutrient addition experiments

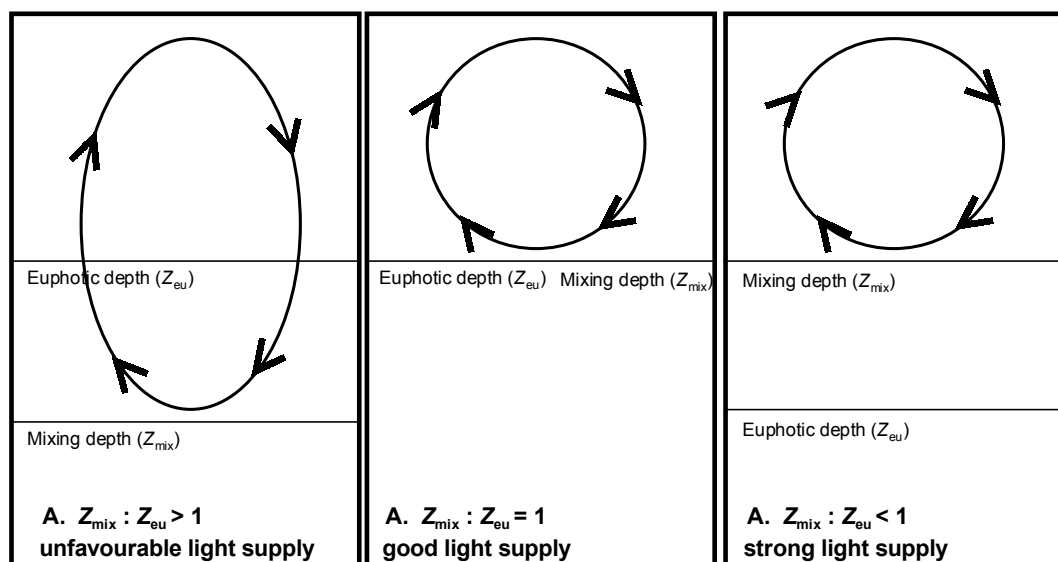
In order to observe the effects of different nutrient concentrations on natural phytoplankton growth and the occurrence of nutrient limitation, a laboratory scale experiment was conducted. The experiment was based on batch cultures (Kohl and Nicklisch, 1988), using several 3-l PVC-transparent containers, with different initial nutrient content (N and P), aimed to study the effects on the growth of natural phytoplankton (expressed as chlorophyll *a*) inspired by experiments performed by Holmboe *et al.* (1999); Kaswadji *et al.* (1993), and Sanders *et al.* (1987). Prior to the execution of the main experiment, a preliminary experiment was performed aimed to find the range of nutrient concentrations.

Natural phytoplankton from three stations in Jakarta Bay (the three-selected stations were representing each nutrient regime of low, medium and high nutrient concentration) were cultured in 3 liter bottles. After screening through 90- $\mu\text{m}$  mesh size net to remove zooplankton, the natural phytoplankton was treated differently. After filling, each bottle was sampled and the initial chlorophyll *a* and nutrient concentration were determined. Concentrated solutions of  $\text{NH}_4\text{-N}$  (as  $(\text{NH}_4)_2\text{SO}_4$  : ammonium sulphate),  $\text{NO}_3\text{-N}$  (as  $\text{KNO}_3$  : Kalium Nitrate) and  $\text{PO}_4\text{-P}$  (as  $\text{KH}_2\text{PO}_4$  : kalium dihydrogenphosphate) were then added to each bottle to reach a final concentration of 10  $\mu\text{M}$ , 20  $\mu\text{M}$ , 50  $\mu\text{M}$  and 70  $\mu\text{M}$  (for  $\text{NO}_3\text{-N}$  and  $\text{PO}_4\text{-P}$ ) and 5  $\mu\text{M}$ , 10  $\mu\text{M}$ , 20  $\mu\text{M}$  and 30  $\mu\text{M}$  (for  $\text{NH}_4\text{-N}$ ). Each bottle was continuously monitored for 30 hours (every 30 minutes each bottle was gently shaken to avoid settling of plankton) and on a 6-hour basis, a water sample from each bottle was taken to measure the chlorophyll *a* concentration. For each nutrient concentration, a growth rate based on chlorophyll *a* was calculated. The growth rate at each nutrient concentration was plotted, resulting in the specific growth rate ( $\mu$ ) of the phytoplankton community for each treatment (Holmboe *et al.*, 1999; Kaswadji *et al.*, 1993 ; Sanders *et al.*, 1987). The chlorophyll *a* contents were then exponentially regressed against time. The exponential growth rates were estimated by using  $\mu = (\ln N_t - \ln N_o)/t$  equation.  $N_o$  and  $N_t$  are the initial and final chlorophyll *a* content,  $t$  is the incubation time, and  $\mu$  is the rate of population growth ( $\text{day}^{-1}$ ).

### 2.2.8. Determination of $Z_{\text{mix}}:Z_{\text{eu}}$ ratios

Based on the CTD measurements, except in Semangka Bay, the depth of Jakarta and Lampung bays was determined as  $Z_{\text{mix}}$  (mixed zone). In Semangka Bay, the mixed zone was determined as of 60 m (Hendiarti, pers.comm.). The depth of the euphotic zone ( $Z_{\text{eu}}$ ) was calculated as the depth at which underwater irradiance was 1 % of the surface value, calculated from the attenuation coefficients. Fig 2.5. shows schematic diagrams of different scenarios of the  $Z_{\text{mix}}:Z_{\text{eu}}$  ratios in the water column and its consequences on phytoplankton light availability and growth.





**Fig.2.5.** Schematic diagrams of  $Z_{mix}:Z_{eu}$  ratio in the water column. (A)  $Z_{mix}:Z_{eu} > 1$  shows that phytoplankton are always transported to the depth where water column irradiance is below the minimum limit for net photosynthesis, resulting in a weak growth. (B)  $Z_{mix}:Z_{eu} = 1$  shows that phytoplankton are maintained in the illuminated layer, resulting in good growth. (C)  $Z_{mix}:Z_{eu} < 1$ , shows that phytoplankton always in the high irradiance water column, resulting in a strong growth.

### 2.2.9. Nutrient loads from rivers

The monthly nutrient load ( $\text{ton month}^{-1}$ ) was used as the unit of nutrient load. The monthly nutrient load of each nutrient species throughout the year 2001 were calculated by multiplying the respective monthly mean river discharge ( $\text{m}^3\text{s}^{-1}$ ) by each nutrient concentration of the river ( $\mu\text{M}$ ). Data of nutrient river was taken from the station river mouth of this study. The nutrient concentration values of river from temporal surveys were used for the calculation of the respective monthly nutrient loads. The 'missing month' nutrient concentration values were estimated by using the nutrient concentration values of the nearest survey's months. The annual load ( $\text{ton y}^{-1}$ ) of nutrient was calculated by summing up the monthly nutrient load. To obtain the monthly load of a nutrient, the following equation was used (e.g. Anna, 1999) :

$$L = ( 2\ 592\ 000 / 1\ 000\ 000 ) * MW * Q * C, \text{ where ,}$$

- L = the monthly nutrient loads ( $\text{ton month}^{-1}$ )  
 2 592 000 = conversion factor (month to second)  
 1 000 000 = conversion factor (ton to gram)  
 Q = mean river discharge of the respective month ( $\text{m}^3\text{s}^{-1}$ )  
 C = nutrient concentration of the respective month ( $\mu\text{M}$ )  
 MW = molecular weight of each nutrient species

### 2.3. Data and statistical analyses

The data obtained were analysed according to the following methods :

- **Analysis of variance (ANOVA).** This analysis was used for statistical significant differences test (by means of *Statistica V.5.* software). Prior to be analysed, all data were tested for their normal distribution through Shapiro-Wilk's W Test. The 2-way Anova test was performed based on both spatial and temporal bases and further Post-Hoc analyses were performed if a significant difference on a variable tested was observed.

- **Pearson's correlation.** Pearson's correlation among all environmental variables and linear regression between salinity and other environmental variables (dissolved inorganic nutrients, turbidity and chlorophyll *a*) were used as well. Pearson's correlation (Pearson's *r*) measures the correlation between two environmental variables and reflects the degree of linear relationship between those two variables.
- **Linear and exponential regression.** Linear regression between salinity as independent variable and other environmental variables (dissolved inorganic nutrients, and turbidity) as dependent variable was performed aimed to observe the influence of river outflow on the distribution of each environmental variable in the bay. Linear regression between each nutrient load and its nutrient concentration in the recipient waters (in shore waters nutrient concentration) as well as with bay's mean nutrient concentration were also performed aimed to observe the role of seasonal variability of nutrient loads in the variability of nutrient concentration in the bay. Linear regressions between nutrient loads and nutrient concentrations both in the inshore and offshore waters were performed to observe the relationship among them. The exponential regressions were performed to correlate between salinity and chlorophyll *a*.
- **Hyperbolic relationship.** Nutrient concentrations and chlorophyll *a* concentrations were plotted in a Monod hyperbolic curve to observe a saturation correlation between nutrient concentrations and chlorophyll *a* concentrations. Chlorophyll *a* concentrations increase in direct proportion to the nutrient concentrations at lower concentrations and gradually levels off and becomes saturated at higher concentrations (e.g. Dring, 1982). The equation is as follows :
 
$$Y = \frac{(a \cdot X)}{(b + X)}$$

Y = chlorophyll *a* ( $\mu\text{g Chl } a \text{ l}^{-1}$ )  
 X = nutrient concentration ( $\mu\text{M}$ )  
 a, b = curve constants
- **Cluster analysis.** Cluster analysis was calculated both on temporal and spatial basis (by means of *Minitab 11* Software). The cluster analysis was performed based on similarity between stations (ranged from 0 to 100%) calculated from all environmental variables observed. The environmental variables tested were: dissolved inorganic nutrients (phosphate, nitrite, nitrate, ammonium and silicate), salinity, turbidity, water temperature, secchi depth, pH, dissolved oxygen, chlorophyll *a* and other photosynthetic pigments, phytoplankton abundance,  $Z_{\text{mix}}$ ,  $Z_{\text{eu}}$ , ratio of  $Z_{\text{mix}}:Z_{\text{eu}}$ , water column light average and attenuation coefficient. The cluster analysis used in this analysis was an agglomerative clustering technique (Aldenderfer and Blashenfield, 1984). The clustering of observations starts with all separate observations, each forming its own cluster. In the first step, the two observations closest together are joined. In the next step, either a third observation joins the first two, or two other observations join together into a different cluster. Similarities between objects were calculated based on the similarities index between the variables compared.
- **Principal Component Analysis.** Principal component analysis were performed by means of the software of Biplot (Lipkovich and Smith, 2002). In principle, the biplot PCA is a 2 dimensional graphic describing a summary table, containing stations as objects and environmental parameters as variables. The information in the diagram includes the objects (in this case stations) and

variables (dissolved inorganic nutrients, salinity, turbidity, water temperature, secchi depth, pH, dissolved oxygen, chlorophyll *a* and others photosynthetic pigments, phytoplankton abundance,  $Z_{\text{mix}}$ ,  $Z_{\text{eu}}$ , ratio of  $Z_{\text{mix}}:Z_{\text{eu}}$ , average water column irradiance and attenuation coefficient). This tool is useful to observe the linear correlation and similarity among the observed objects and variables (Wiryawan, 1997). This analysis is also useful to observe the variation of each variable. A small variation of a variable will result in a plot close to the center of the diagram.

- **Phytoplankton growth rate sensitivity to light and nutrient** (Cloern, 1999). The potential limitation of light or nutrient was assessed by comparing the water column irradiance (PAR) and nutrient concentration (Dissolved Inorganic Nitrogen-DIN) in a diagram called phytoplankton resource-limitation map as developed by Cloern (1999). This procedure was used by Colijn and Cadée (2003) for observing the light and nutrient limitation of the Wadden Sea phytoplankton. The surface PAR and light attenuation data were used to calculate water column irradiance, while DIN concentration data from each measurement at each station were used for DIN data in this calculation. The procedure for the calculation of limiting resources was according to Cloern (Cloern, 1999 ; Colijn and Cadée, 2003):

$$I' = I/K_I \text{ and } N' = N/K_N$$

$I'$  = light resource index ;

$N'$  = nutrient resource index

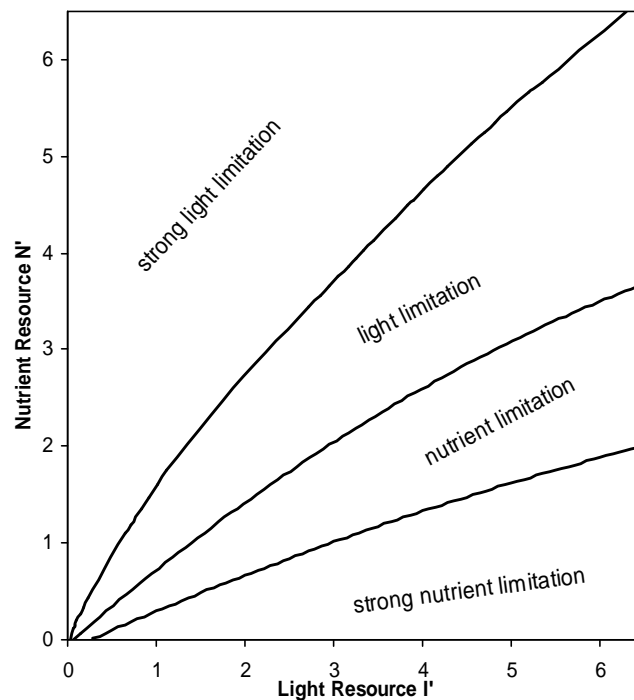
$I$  = daily water column irradiance ( $\text{mol quanta m}^{-2} \text{d}^{-1}$ )

$N$  = nutrient concentration ( $\mu\text{M DIN}$ )

$K_I$  = half-saturation constant for light,  $2.4 \text{ mol quanta m}^{-2} \text{d}^{-1}$  (Cloern, 1999)

$K_N$  = half-saturation constant for nutrient,  $1.5 \mu\text{M DIN}$  (Cloern, 1999)

$I'$  and  $N'$  were then plotted in a diagram called phytoplankton resource-limitation map (Fig.2.6).



**Fig.2.6.** Phytoplankton resource-limitation map. Redrawn from Cloern (1999).

- **Tropical index for marine systems (TRIX).** This index was basically developed by Vollenweider *et al.* (1998) aimed to characterize the trophic state of coastal marine waters, involving the eutrophication-related parameters : chlorophyll *a*, oxygen saturation, dissolved inorganic nitrogen and phosphate. The trophic state depends on the availability of nitrogen and phosphorus for primary production, which in turn determines the phytoplankton biomass (chlorophyll *a*) and oxygen saturation. In the calculation of TRIX, nutrients are represented by dissolved inorganic nitrogen (DIN) and phosphate concentrations, phytoplankton biomass represented by chlorophyll *a* and deviation of oxygen saturation from 100% as an indicator of the production intensity of the system. This index has been used by the Italian authorities on a routine basis to monitor the trophic state of the Adriatic Sea (Ærtebjerg *et al.*, 2001). The calculation of TRIX is as follows :

$$\text{TRIX} = k/n \sum_{i=1}^n ((\log M - \log L) / (\log U - \log L))$$

where,

k	= 10 (scaling factor)
n	= number of the variables (4)
U	= upper limit
L	= lower limit
M	= value of a variable

The trophic index is scaled in TRIX units from 0 to 10, in order to represent with a fine resolution a variety of trophic situations related to a coastal environment, from oligotrophic to eutrophic conditions. Values approaching 10 indicate strong eutrophication; characterised by high DIN, phosphate and chlorophyll *a* and low in oxygen content, while approaching 0 indicates oligotrophic waters. Caiaffa (1999) used values of > 6 as a threshold for an indication of strong eutrophication.

Basically, these analyses were performed to support the interpretation of the relationship between different nutrient regimes and seasonal (temporal) variation on the distribution of chlorophyll *a*, phytoplankton and primary production within and between the bays.

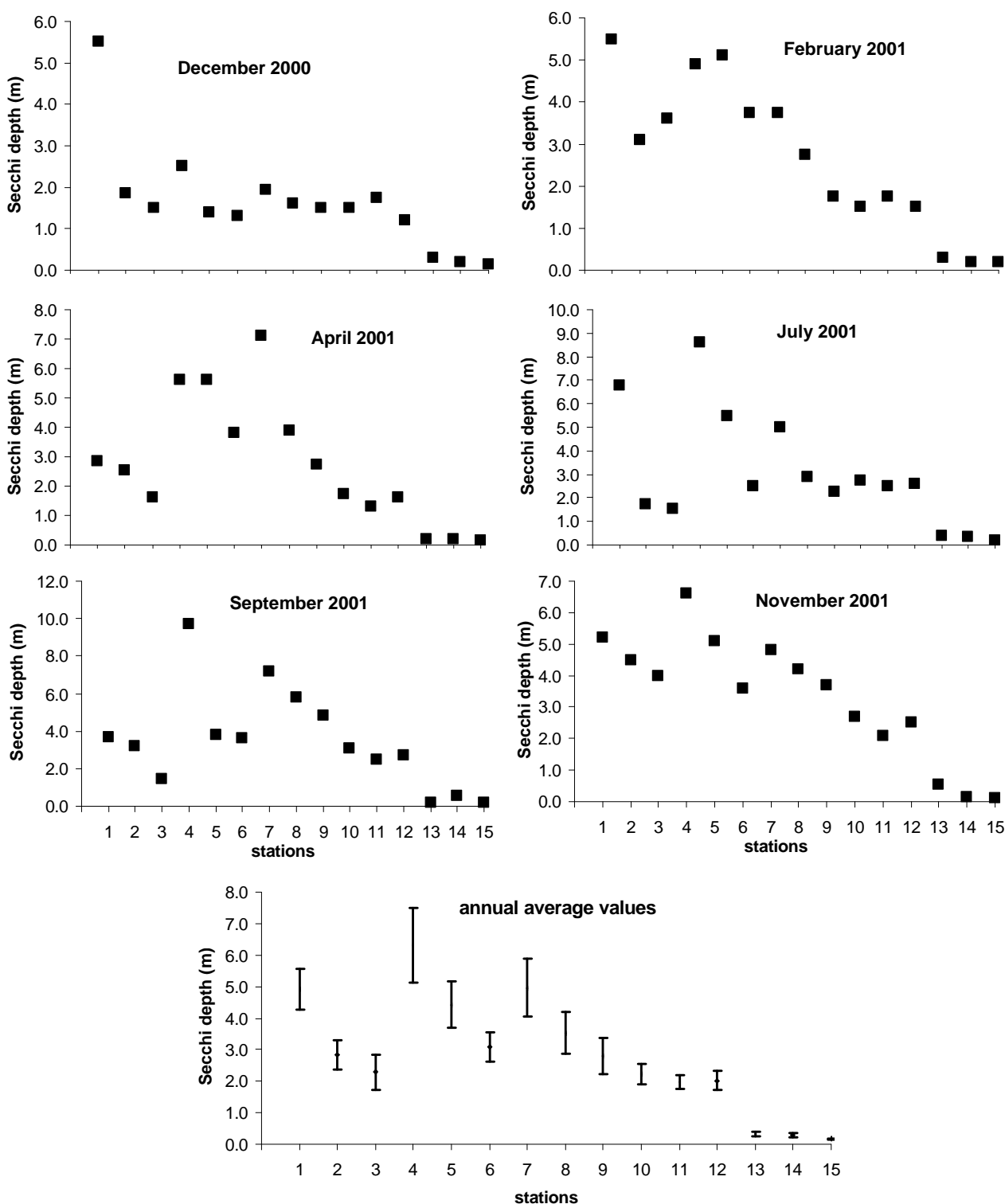
### 3. Results and discussion : Jakarta Bay

#### 3.1. Results

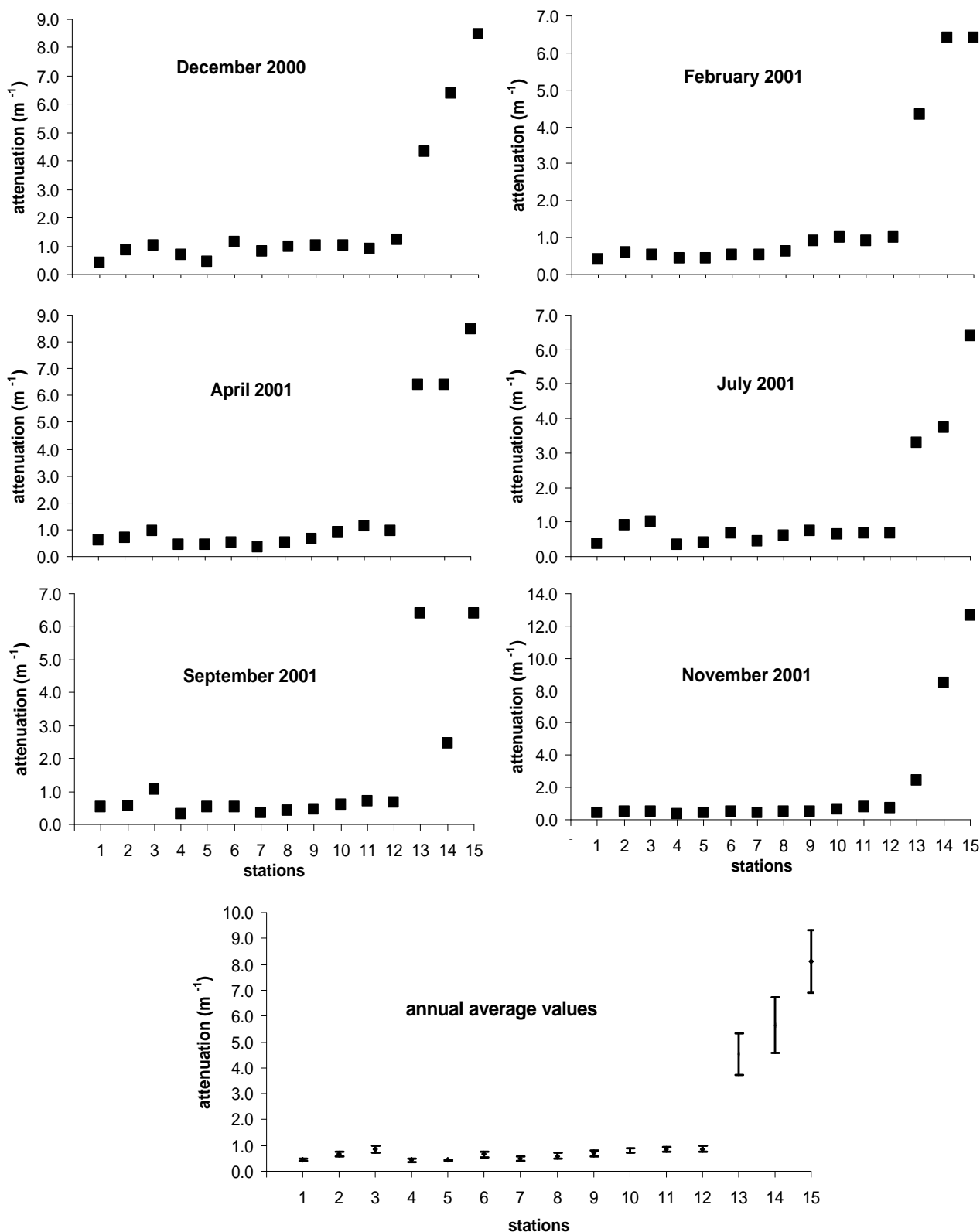
##### 3.1.1. Secchi depth, light-attenuation, $Z_{\text{mix}}:Z_{\text{eu}}$ ratio and water temperature

Fig. 3.1. shows the secchi depth values at Jakarta Bay's stations, for each of the temporal surveys and the annual average values per station. The lowest values always prevailed at Priok river mouth (ranging from 0.10 to 0.2 m), indicating a low water transparency on this site, while the highest was measured at station 4 (ranging from 2.5 to 9.7 m). Secchi depth values were significantly different between sites and seasons ( $p < 0.01$ ). The lowest annual average prevailed at Priok river mouth (0.17 m), while the highest was at station 4 (6.32 m). Accordingly, annual average of vertical light-attenuation coefficients ( $\text{m}^{-1}$ ) varied between  $0.43 \text{ m}^{-1}$  at station 4 (ranging from  $0.32$  to  $0.69 \text{ m}^{-1}$ ) to  $8.13 \text{ m}^{-1}$  at Priok river mouth (ranging from  $6.40$  to  $12.61 \text{ m}^{-1}$ ) (Fig.3.2). There were significant differences in the value of light attenuation coefficient between sites and seasons (ANOVA,  $p < 0.001$ ). Stations at river mouths, 10, 11, and 12 exhibited high light attenuation. Secchi disk readings were significantly inversely correlated with turbidity, but positively correlated with salinity ( $p < 0.001$ ; Pearson's  $r = -0.61$  and  $0.55$ , respectively), indicating a prominent role of river inflow for this parameter. The attenuation coefficient was significantly related to turbidity and salinity ( $p < 0.001$ ; Pearson's  $r = 0.95$  and  $-0.79$ , respectively).

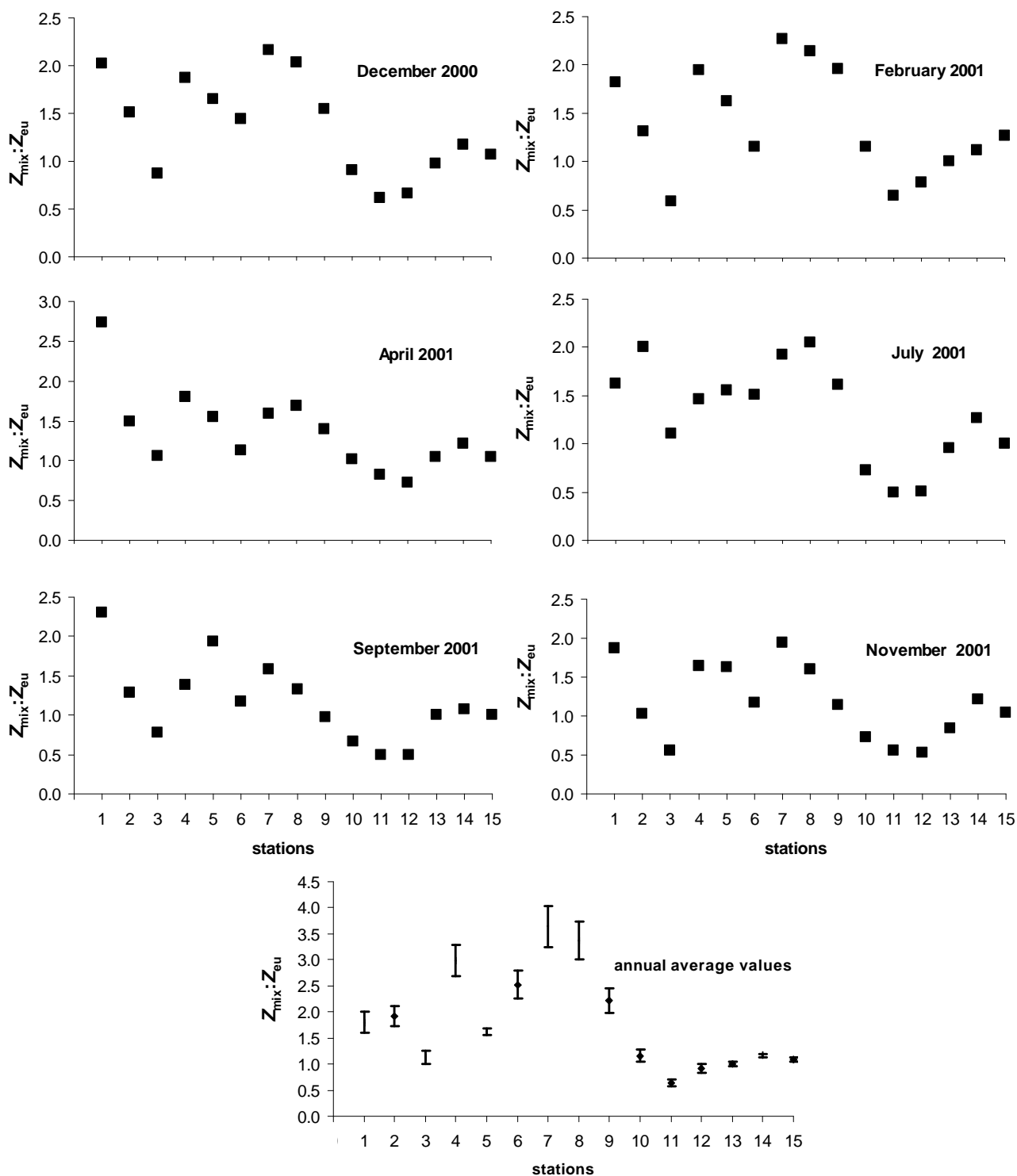
CTD profiles and previous studies done in the area (Suyarso, 1995), showed that the water column is always mixed down to the bottom, except in a limited area close to the river mouth due to differences in salinity. Thus, the depth of the mixed layer ( $Z_{\text{mix}}$ ) is defined as the water depth. In coastal sea areas, the ratio of  $Z_{\text{mix}}$  to  $Z_{\text{eu}}$  (the latter defined as the depth with 1% surface light) was successfully used (e.g. Tillmann *et al.*, 2000; Kocum *et al.*, 2002) as a factor for triggering phytoplankton bloom development. In Jakarta Bay, this ratio never exceeded 5, which might represent a critical limit for net primary production and bloom initiation in turbid coastal waters (Tillmann *et al.*, 2000). In general, all near-shore stations exhibited low  $Z_{\text{mix}}:Z_{\text{eu}}$  ratios, while the more offshore stations were characterised by high values (Fig.3.3). As for light attenuation, there was a significant seasonal difference in this ratio. The lowest value recorded was 0.49 at stations 11 and 12 in September 2001, while the highest ratio was 3.64 at station 7 in December 2000.  $Z_{\text{mix}}:Z_{\text{eu}}$  ratios were significantly correlated with  $K$  ( $p < 0.05$ ; Pearson's  $r = -0.21$ ), indicating the high importance of turbidity on the variation of this variable.



**Fig. 3.1.** Secchi depth value (m) at each sampling station and seasonal survey in Jakarta Bay. 13 = Marunda river mouth ; 14 = Angke river mouth and 15 = Priok river mouth. Bars are standard deviations calculated from 6 data.

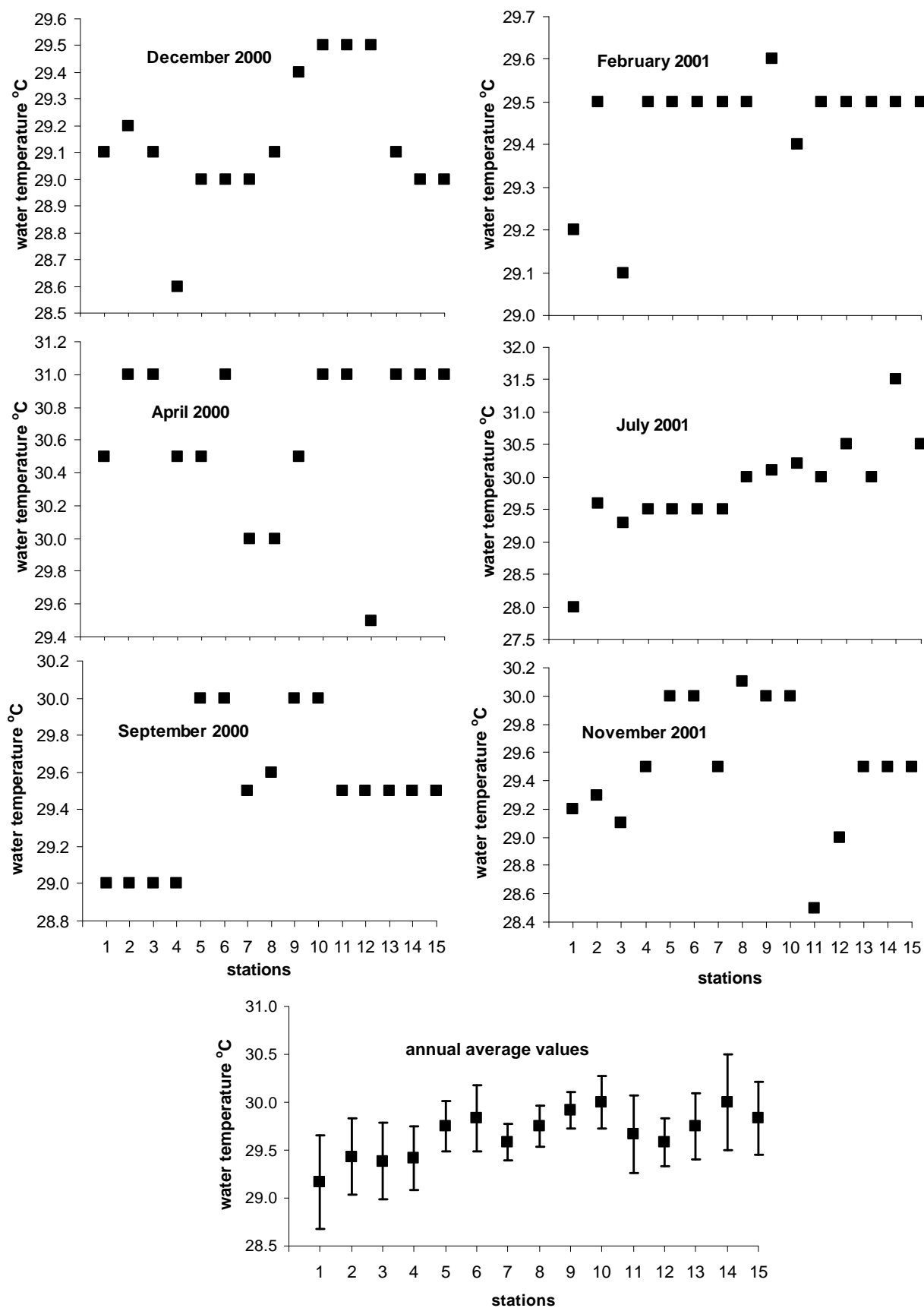


**Fig. 3.2.** Light attenuation coefficients ( $m^{-1}$ ) at each sampling station and seasonal survey in Jakarta Bay, 13 = Marunda river mouth ; 14 = Angke river mouth and 15 = Priok river mouth. Bars are standard deviations calculated from 6 data.



**Fig. 3.3.**  $Z_{mix}:Z_{eu}$  ratios at each sampling station and seasonal survey and its annual average values in Jakarta Bay, 13 = Marunda river mouth ; 14 = Angke river mouth and 15 = Priok river mouth. Bars are standard deviations calculated from 6 data.





**Fig. 3.4.** Water temperature (°C) at each sampling station and seasonal survey and its annual average in Jakarta Bay, 13 = Marunda river mouth ; 14 = Angke river mouth and 15 = Priok river mouth. Bars are standard deviations calculated from 6 data.

There was significant difference in water temperature on the spatial scale (ANOVA,  $p < 0.01$ ) but no significant difference on the temporal scale, indicating relatively constant tropical temperature conditions throughout the year. Minor variation of water temperature in tropical waters shows daily variation (day and night), instead of seasonal fluctuation. Annual average water temperature ranged from 29.1 to 30.0 °C (Fig. 3.4.). There was no significant correlation with salinity, indicating a minor role of freshwater discharge on water temperature in the study area.

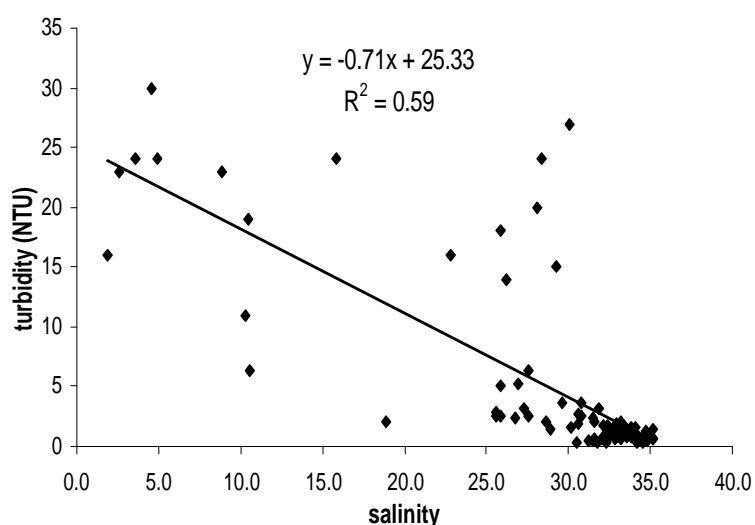
It is common to all of the 4 physical variables examined above, except water temperature, that strong spatial and seasonal variations occurred in the study area. Spatial difference is mostly due to the gradual decrease of riverine influence in the bay, while seasonal difference is due to the increase of riverine inputs during the rainy season.

### 3.1.2. Salinity and turbidity

Fig. 3.7 and 3.8 show the distribution of salinity and turbidity, respectively. Distinct spatial gradients in both parameters were found at each seasonal survey, reflecting the importance of fresh water inflow. In keeping with this, there was no significant difference in salinity between seasons, but there was a significant difference between sites (ANOVA,  $p < 0.05$ ). The lowest annual average of salinity was observed at Priok river mouth (4.65), whereas the highest was observed at station 5 (33.38). A LSD-Test (Least Significant Difference) showed that the spatial differences were due to stations at all river mouths, and inshore stations (10, 11 and 12). At stations 3, 6 and 9, salinity values exceeded 30, thus approaching those of the other offshore stations.

The lowest seasonal average in turbidity was observed in July 2001 (1.11 NTU), while the highest was observed in April 2001 (1.92 NTU), without showing any significant difference (ANOVA,  $p > 0.05$ ). As for salinity, a significant difference was observed on the spatial scale (ANOVA,  $p < 0.01$ ), ranging from 0.62 NTU (station 4) to 21.33 NTU (Priok's river mouth station). The LSD-test showed that the stations at river mouths and inshore waters (10, 11 and 12) always exhibited higher turbidity levels than the other stations. A steep gradient prevailed in the turbidity pattern along the riverine-marine transitional zone (Fig.3.8).

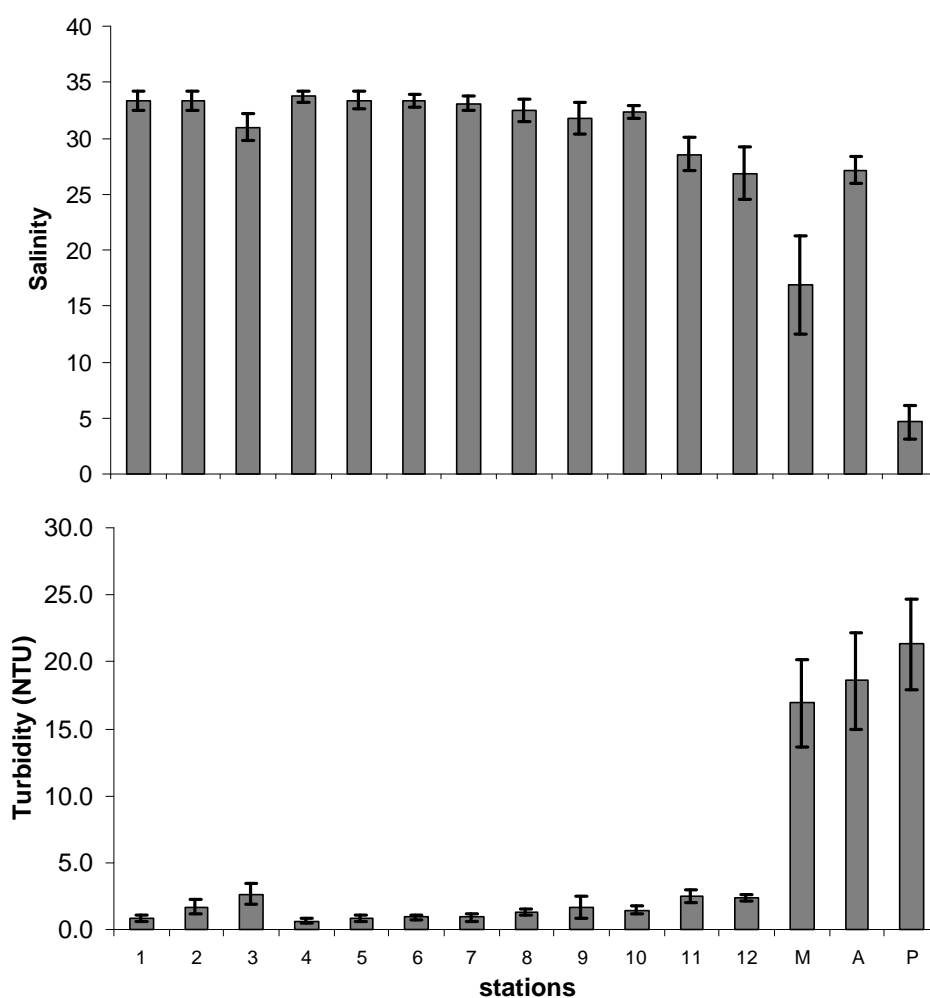
Salinity and turbidity patterns were very similar and showed a strong inverse correlation. Pearson's correlation and linear regression analysis (Fig. 3.5.) between these 2 variables showed a significant inverse relationship ( $p < 0.001$ ; Pearson's  $r = -0.77$ , and linear regression,  $R^2 = 0.58$ ),



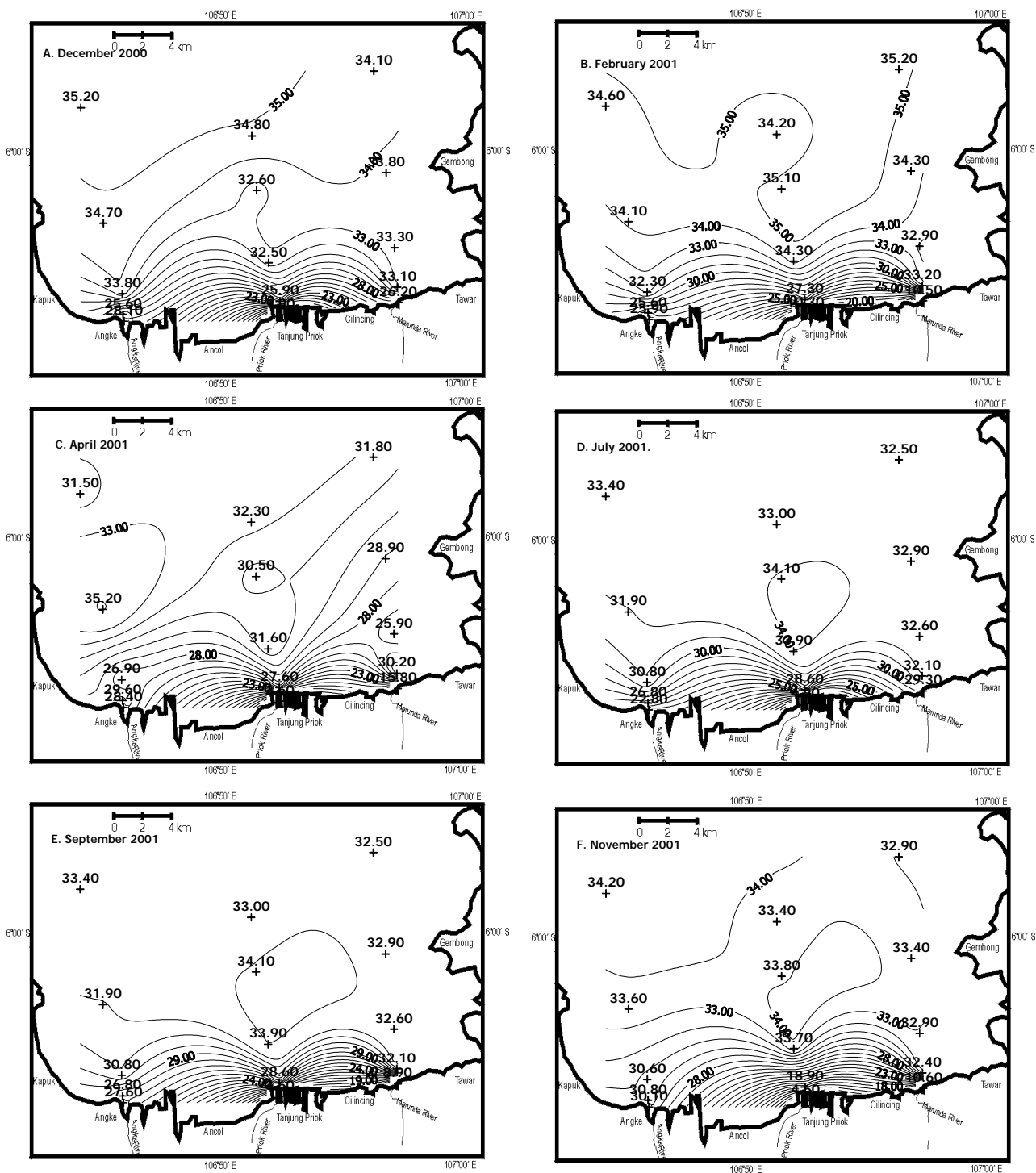
**Fig. 3.5.** Linear regression between salinity and turbidity (NTU) in Jakarta Bay.

indicating the prominent role of river discharge for the turbidity regime in the bay's waters. Fig.3.6 also shows a strong pattern in the relationship between annual average of salinity and turbidity. From that figure is also seen that Angke river mouth is relatively higher in salinity than the 2 other rivers due to the relatively lower river runoff.

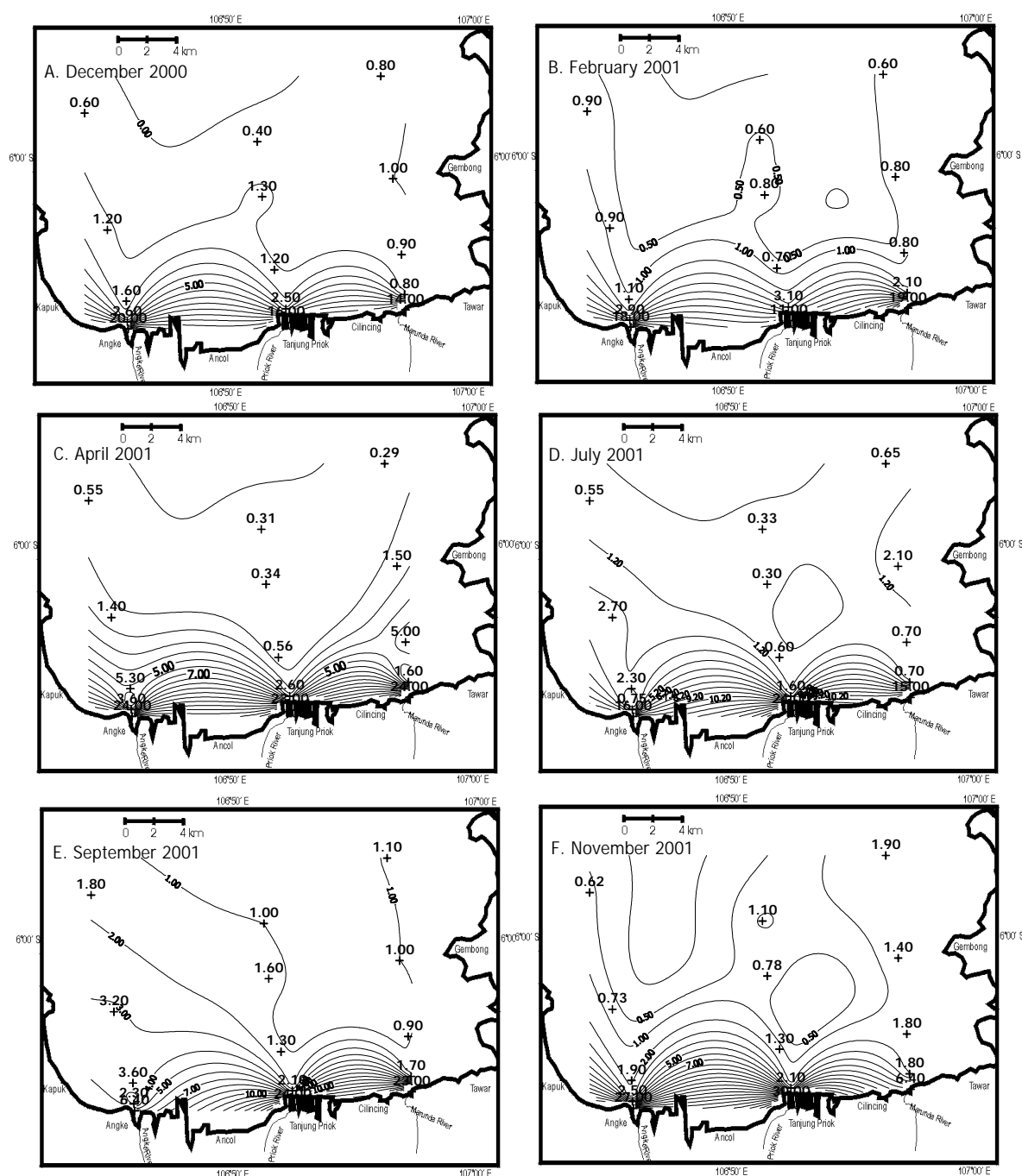
The three rivers observed : Angke, Priok and Marunda are the main sources of freshwater and turbidity. Measurement in each river showed turbidity levels which were 10-fold higher than in the offshore part of the area. However, there are still other sources of freshwater inflow in the eastern part of the bay, which were not observed in detail in this study.



**Fig. 3.6.** Annual average salinity (upper graph) and turbidity (lower graph) in Jakarta Bay. M = Marunda river mouth; A : Angke river mouth and P : Priok river mouth. Bars are standard deviations calculated from 6 data.



**Fig. 3.7.** Salinity contours in Jakarta Bay. A: December 2000. B: February 2001. C: April 2001. D : July 2001. E : September 2001 and F: November 2001.



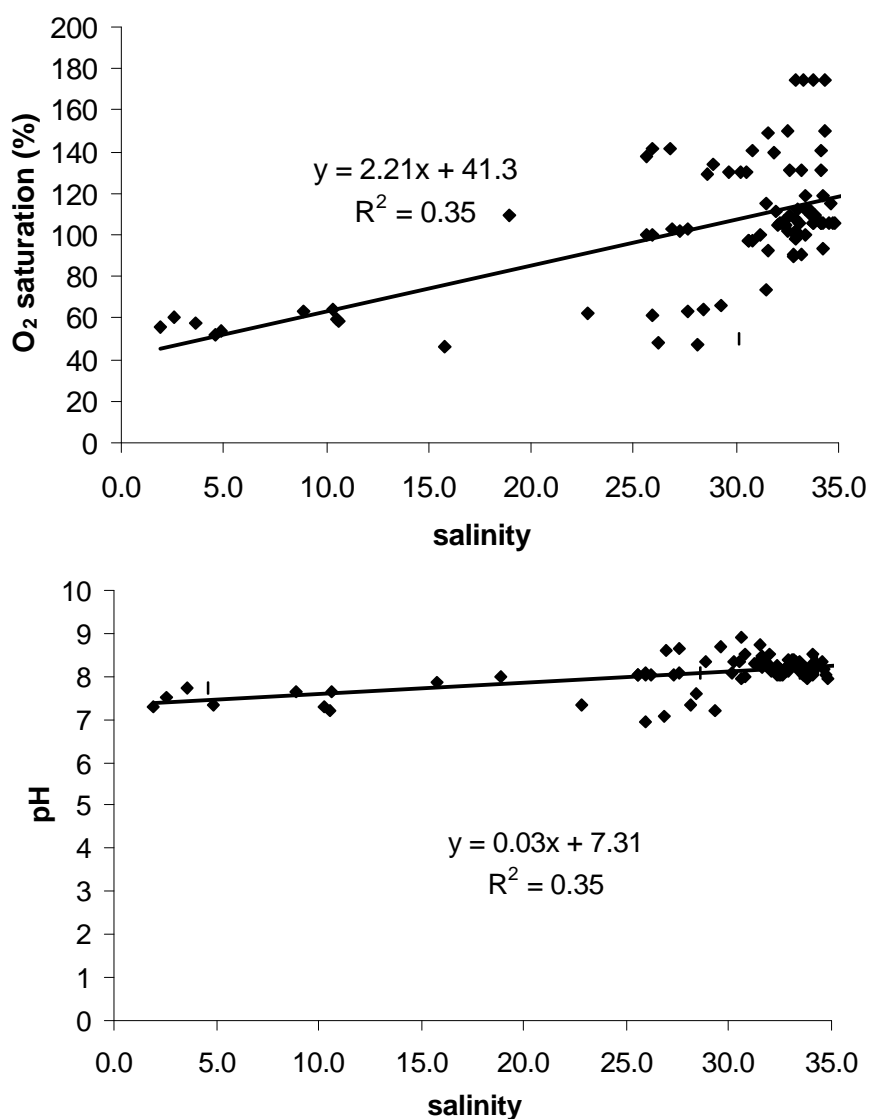
**Fig. 3.8.** Turbidity (NTU) contours in Jakarta Bay. A: December 2000. B: February 2001. C: April 2001. D : July 2001. E : September 2001 and F: November 2001.

### 3.1.3. Dissolved oxygen and pH

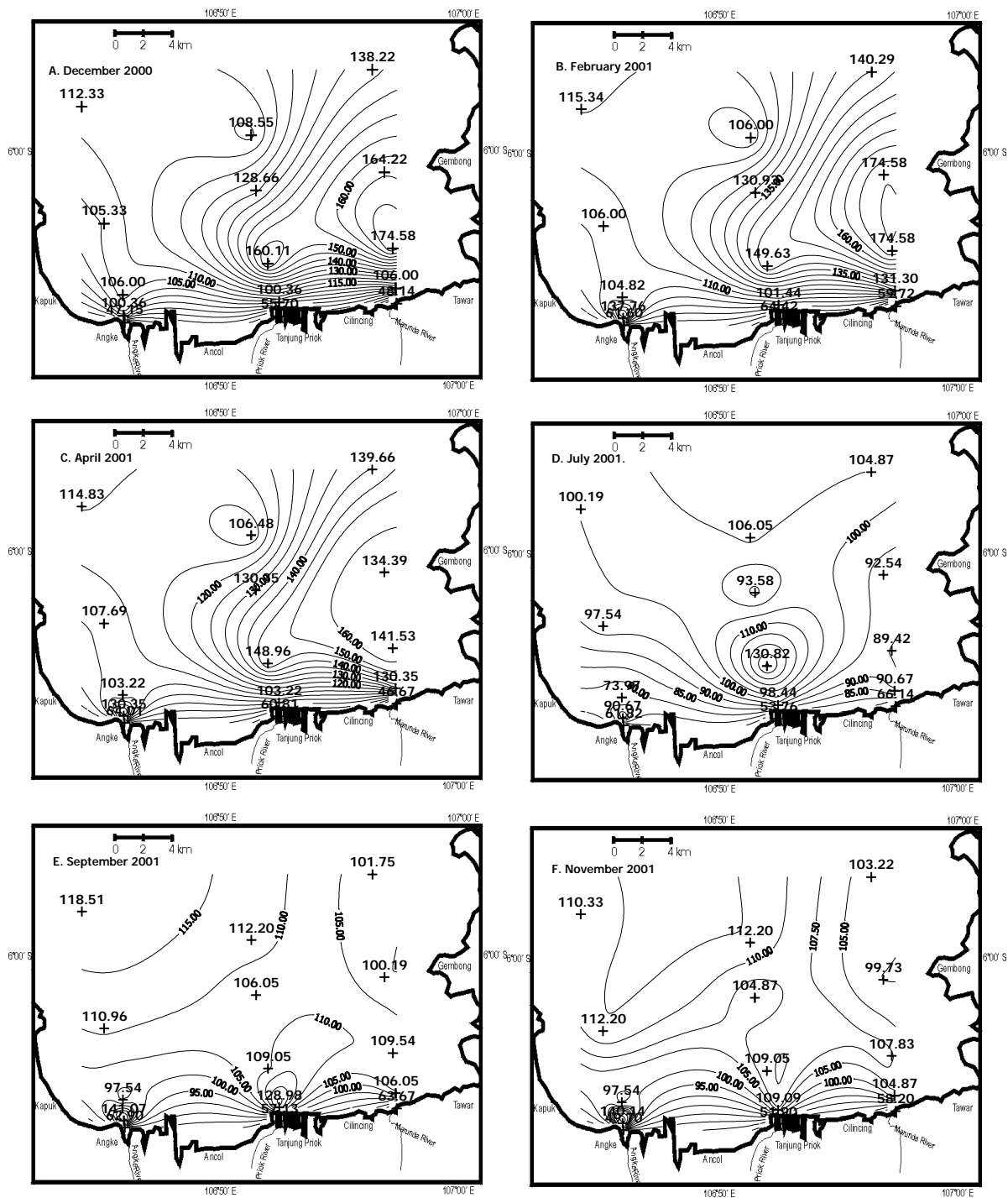
There were significant differences in the degree of oxygen saturation (%) in the bay both between sites and seasons. Fig. 3.10. shows the distribution patterns of dissolved oxygen saturation for each seasonal survey. Throughout the seasons, the river mouth stations were characterised by low saturation values (47.15% - 64.42%), while the other stations were generally well oxygenated (> 90%). The low values at the river mouth stations were commensurate with high attenuation coefficient, low salinity and high turbidity ( $p < 0.01$ ; Pearson's  $r = -0.70, 0.59$  and  $-0.73$ , respectively). High rates of oxygen

consumption due to microbial degradation and other heterotrophic processes might be the main reasons for the poor oxygen condition in these less saline waters. The linear regression analysis showed a strong and positive correlation ( $p < 0.001$ ) between salinity and dissolved oxygen saturation (Fig.3.9.) ( $R^2 = 0.35$ ).

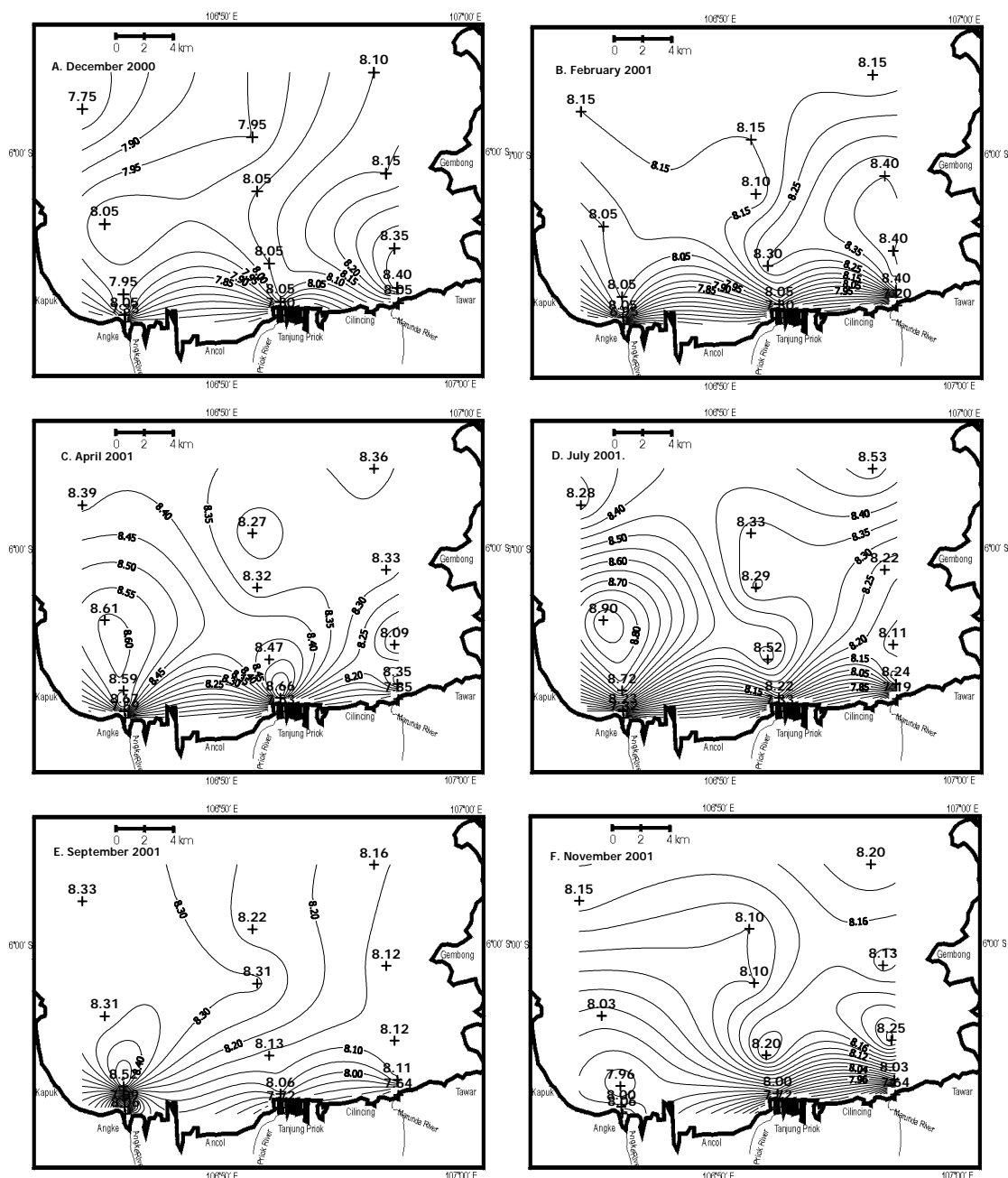
The pH values showed significant spatial and seasonal variations. Highest values were recorded at offshore stations (ranged from 7.75 to 8.72), while the lowest was measured at river mouths (ranged from 6.95 to 8.06). In general (Fig.3.11), low pH prevailed at all river mouth stations and a gradual increased was observed in the more saline waters. Slightly exceptional was observed during December 2000 and February 2001, showing slightly lower pH values in the outer part stations. The pH was significantly correlated with salinity (Pearson's  $r = 0.59$ ,  $p < 0.01$ ), showed by a significant linear relationship between both parameters ( $p < 0.001$ ,  $R^2 = 0.35$ , Fig. 3.9). Low oxygen concentration and high decomposition rate of the river mouth sites may have caused the low pH values.



**Fig. 3.9.** Linear regression between salinity and dissolved oxygen saturation (upper graph) and pH (lower graph) in Jakarta Bay.



**Fig. 3.10.** Dissolved oxygen saturation (%) contours in Jakarta Bay. A: December 2000. B: February 2001. C: April 2001. D : July 2001. E : September 2001 and F: November 2001.



**Fig. 3.11.** pH contours in Jakarta Bay. A: December 2000. B: February 2001. C: April 2001. D : July 2001. E : September 2001 and F: November 2001.

### 3.1.4. Nutrient loads from the 3 rivers

Angke, Marunda and Priok are the main rivers in the area, which significantly contribute to the characteristics of Jakarta Bay (Anna, 1999). Besides their relatively high discharges, their water catchment areas also represent spatial variability of Jakarta City. Angke represents the west part of the city, Priok for the middle and Marunda for the east part. These 3 rivers flow through the city of Jakarta, carrying most of the untreated domestic waste water.

Calculations of the loads of nitrate, nitrite, ammonium, phosphate and silicate at each river were performed by multiplying the monthly river discharge ( $m^3 month^{-1}$ ) by the nutrient concentration of the river (taken from river mouth stations) of the respective months. Since the surveys were not performed on the monthly basis, the 'missing'



months (January, March, May, June, August, October and December 2001) were estimated by using the nutrient concentration values of the closest months. Meanwhile, data of monthly river discharges for the whole year 2001 were completely available (Anonymous, 2002B). The annual loads of nutrients were calculated by summing up the monthly nutrient loads. The monthly and annual loads of each nutrient species at each river are listed in Table. 3.1. From the 3 rivers observed, Angke river contributed the big part of nitrate, nitrite and DIN annual loads (46%, 40% and 38%, respectively for nitrate, nitrite and DIN), while annual loads of ammonium, phosphate and silicate were highly contributed by Priok river (38%, 45% and 37%, respectively). Meanwhile, Marunda river contributed the smallest part of the total loads. These results show that Priok River was the main sources of ammonium, phosphate and silicate for the bay, while Angke was the highest contributor for nitrate and nitrite.

Ammonium and silicate loads were significantly correlated with rainfall, while nitrate, nitrite and phosphate were not. Since DIN in Jakarta Bay was dominated by ammonium, the pattern of DIN loads was commensurate with that of ammonium loads. High load of ammonium during high river discharge period shows that most of the domestic waste water produced by human activities in the city is in the form of ammonium.

**Table.3.1.** Monthly nutrient loads from the 3 rivers observed (ton month<sup>-1</sup>) and the annual loads (ton y<sup>-1</sup>) in Jakarta Bay, during the research period 2001.

<b>Angke River</b>						
Month	NO <sub>3</sub> -N	NO <sub>2</sub> -N	NH <sub>4</sub> -N	DIN	PO <sub>4</sub> -P	SiO <sub>4</sub>
January	43.47	1.43	282.42	327.32	183.37	780.35
February	86.37	2.65	219.52	308.54	146.29	1046.08
March	60.30	1.85	153.25	215.40	102.13	730.29
April	33.42	1.45	216.90	251.77	107.17	70.29
May	35.67	1.55	231.52	268.74	114.39	75.02
June	44.09	0.61	390.48	435.19	84.33	649.91
July	34.95	0.49	309.57	345.01	66.86	515.24
August	38.26	0.53	338.86	377.66	73.18	563.99
September	8.99	0.98	65.02	75.00	21.84	50.71
October	9.66	1.06	69.84	80.56	23.46	54.46
November	3.38	0.56	562.67	566.61	53.18	1888.63
December	3.57	0.59	593.93	598.08	56.14	1993.56
Annual load	402.13	13.75	3433.98	3849.86	1032.34	8418.54
<b>Priok River</b>						
	NO <sub>3</sub> -N	NO <sub>2</sub> -N	NH <sub>4</sub> -N	DIN	PO <sub>4</sub> -P	SiO <sub>4</sub>
January	92.14	0.39	212.50	305.03	193.14	653.69
February	16.48	1.73	110.98	129.19	206.61	259.08
March	10.23	1.07	68.88	80.18	128.23	160.80
April	26.75	0.39	283.48	310.63	93.07	259.62
May	28.56	0.42	302.64	331.62	99.36	277.16
June	33.52	1.43	324.22	359.16	148.78	720.03
July	31.36	1.33	303.39	336.09	139.23	673.77
August	34.33	1.46	332.10	367.89	152.40	737.54
September	1.20	0.45	218.80	220.45	89.66	350.82
October	1.81	0.68	329.95	332.44	135.21	529.03
November	3.13	0.99	488.15	492.27	27.60	2248.34
December	3.40	1.07	530.49	534.97	29.99	2443.35
Annual load	282.90	11.40	3505.59	3799.90	1443.29	9313.22

Table.3.1. Continuation.....

	Marunda River					
	NO <sub>3</sub> -N	NO <sub>2</sub> -N	NH <sub>4</sub> -N	DIN	PO <sub>4</sub> -P	SiO <sub>4</sub>
January	13.64	0.33	31.35	45.32	4.98	214.40
February	27.64	1.34	133.98	162.96	136.28	557.56
March	17.59	0.85	85.28	103.73	86.74	354.88
April	21.56	0.30	123.45	145.32	51.74	128.07
May	23.02	0.32	131.79	155.13	55.24	136.73
June	20.42	0.29	116.91	137.62	49.00	121.29
July	19.47	0.58	182.98	203.03	59.63	440.47
August	21.31	0.63	200.30	222.24	65.27	482.15
September	3.98	0.76	157.42	162.16	61.14	277.05
October	6.54	1.24	258.24	266.01	100.29	454.48
November	4.23	1.14	454.96	460.33	43.77	2062.08
December	4.52	1.22	485.29	491.02	46.69	2199.55
Annual load	183.93	8.99	2361.97	2554.89	760.76	7428.72
Total annual loads from 3 rivers	868.96	34.15	9301.54	10204.65	3236.38	25160.48

### 3.1.5. Dissolved inorganic nutrients

Spatial and temporal nutrient data of Jakarta Bay were analysed with the two-way ANOVA. All nutrient species showed significant spatial differences in nutrient concentrations (ANOVA,  $p < 0.001$ ). Distinct spatial gradients were observed along with increasing salinity (Fig. 3.12 to 3.17). At temporal scale, from the 5 major nutrient species; nitrate, ammonium and silicate concentrations were significantly different.

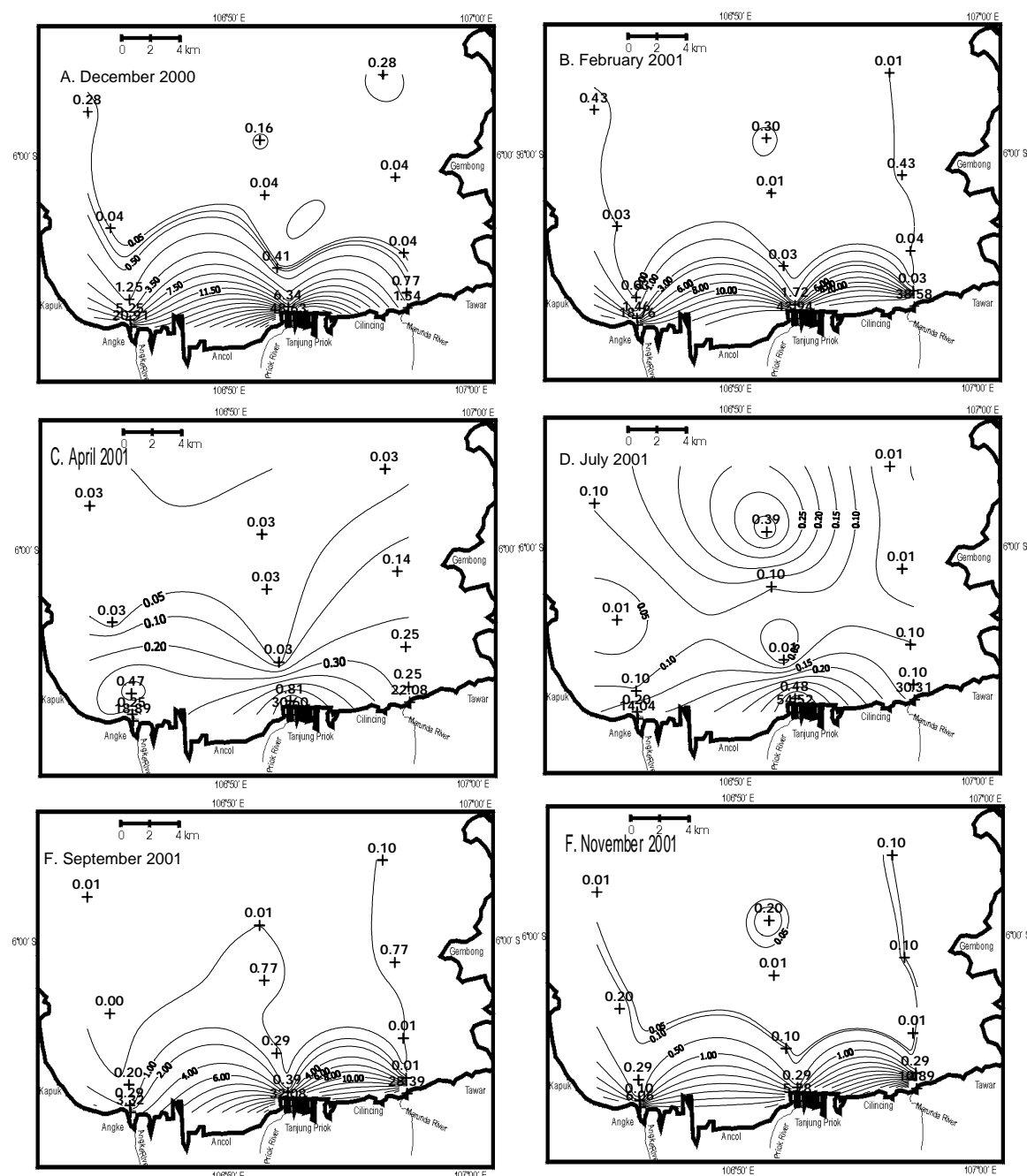
#### 3.1.5.1. Phosphate (PO<sub>4</sub><sup>-3</sup>-P)

Spatial differences were responsible for the variation in phosphate concentrations (SS in ANOVA = 77%,  $p < 0.001$ ), while temporal differences only accounted for 3%. ANOVA showed non significant seasonal differences on phosphate concentrations in the bay. However, a minor fluctuation still occurred, showing a temporal mean maximum value in December 2000 (5.73  $\mu\text{M PO}_4\text{-P}$ ), while the minimum was found in November 2001 (1.63  $\mu\text{M PO}_4\text{-P}$ ). The spatial distribution pattern of phosphate in the bay was comparable at each temporal survey, but the similarity was weaker in the offshore area (Fig. 3.13). High values prevailed in the vicinity of freshwater inputs from the rivers, which is in line with the generally high nutrient concentrations of the rivers. Minimum values of phosphate was observed at station 2 (ranged from 0.001 to 0.198  $\mu\text{M PO}_4\text{-P}$ ), while maximum prevailed at station Priok river mouth (ranged from 5.78 to 54.52  $\mu\text{M PO}_4\text{-P}$ ). Almost at all seasonal surveys, phosphate was mostly concentrated in the area close to Priok River, indicating that Priok River was the main source of phosphate compared to the two other rivers (Angke and Marunda rivers). The pattern of phosphate gradients in the bay was commensurate with those of salinity and turbidity. Pearson's correlation showed strong significant relationship between both salinity and phosphate (Pearson's  $r = -0.82$ ,  $p < 0.01$ ) and turbidity-phosphate (Pearson's  $r = 0.76$ ,  $p < 0.01$ ).

The general spatial pattern of phosphate concentrations showed high values in the inshore waters, which then decreased in the more offshore waters. This rapid decrease is probably not only due to dilution, but might be also caused by a more intensive uptake by phytoplankton, due to the more favourable light conditions at those sites. As

previously mentioned (see sub chapter 3.1.1 : light properties), the light availability ( $Z_{mix}:Z_{eu}$  ratio) for phytoplankton increases in that sites.

An exception from this general pattern was found in September 2001. In that period, high phosphate concentrations were found also in the center and eastern part of the bay (Fig. 3.12. E), indicating occurrence of high phosphate water in the eastern part of the bay, which might be caused by the discharge of the shrimp pond culture. In general, with values ranging from the very low values (almost undetected) in the offshore waters to 6.4  $\mu\text{M PO}_4\text{-P}$  in the inshore waters, the Jakarta Bay is ranging from low nutrified area in the offshore waters to hyper-nutrified area in the inshore waters.



**Fig. 3.12.** Phosphate ( $\mu\text{M PO}_4\text{-P}$ ) contours in Jakarta Bay. A: December 2000. B: February 2001. C: April 2001. D : July 2001. E : September 2001 and F: November 2001.

### 3.1.5.2. Nitrate [ $\text{NO}_3^-$ -N]

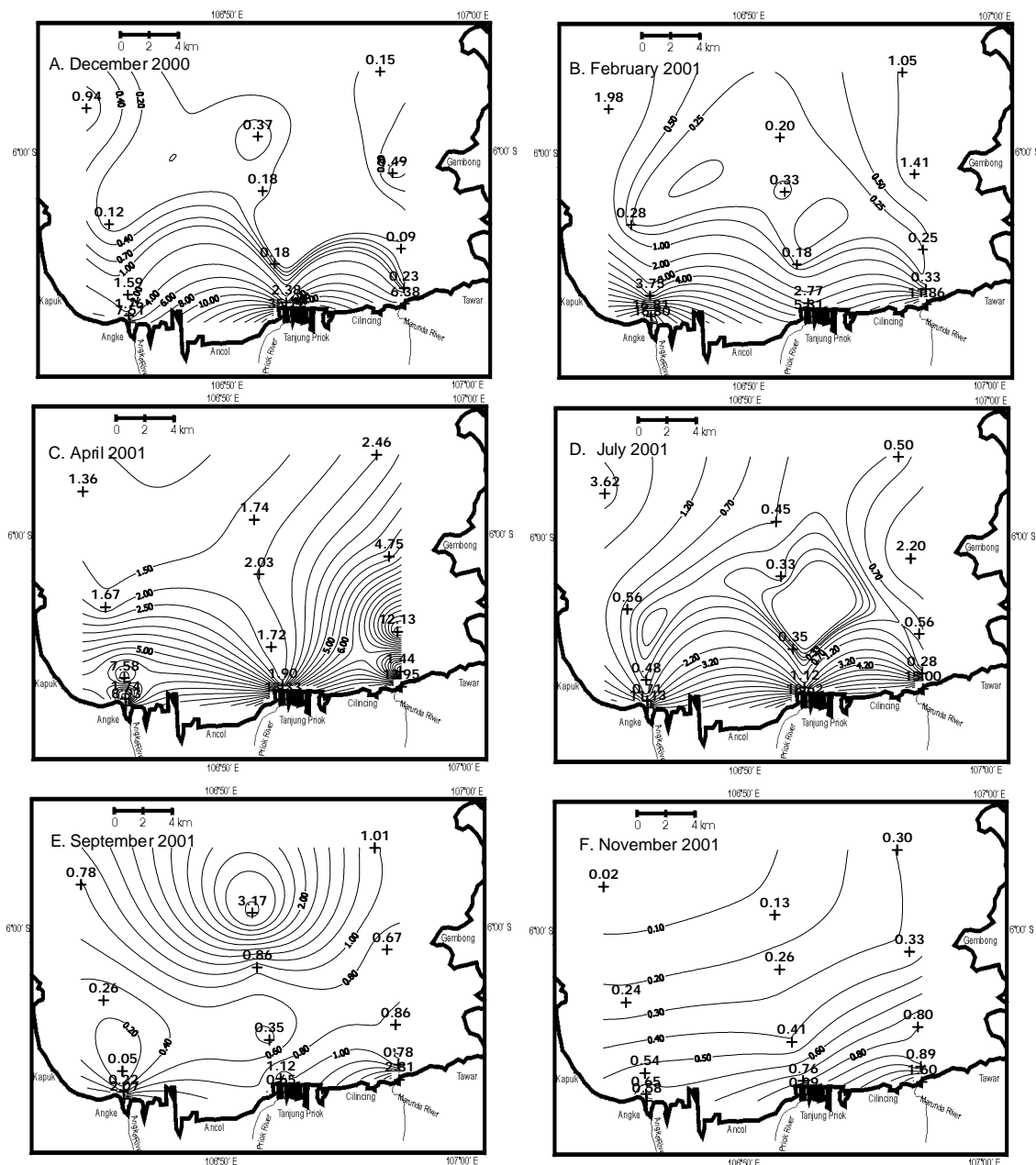
Significant differences in nitrate were observed both on spatial (ANOVA,  $p < 0.001$ ) and temporal scales (ANOVA,  $p < 0.05$ ). The lowest nitrate concentrations were found in offshore waters (ranging from 0.02 to 3.62  $\mu\text{M NO}_3\text{-N}$ ), while maximum values prevailed at river mouths (ranging from 0.58 to 35.17  $\mu\text{M NO}_3\text{-N}$ ). The inshore stations (stations 10, 11 and 12) too, always exhibited elevated nitrate concentrations, ranging from 0.22 to 16.81  $\mu\text{M NO}_3\text{-N}$  (Fig.3.13.).

Statistically significant seasonal fluctuation in nitrate concentration was observed. A maximum temporal mean of nitrate prevailed in April 2001 (5.11  $\mu\text{M NO}_3\text{-N}$ ), while a minimum occurred in November 2001 (0.57  $\mu\text{M NO}_3\text{-N}$ ). This high temporal mean in April 2001 was mostly due to high concentrations in the east part of the bay (stations 7,8 and 9). The high values at easterly stations indicate that there might be another source of nitrate in the eastern part of the bay, besides the three rivers. The intensive shrimp pond cultures at the east coast of the bay, which periodically discharge its waste-water containing high amounts of nitrogen, may have caused these elevated concentrations.

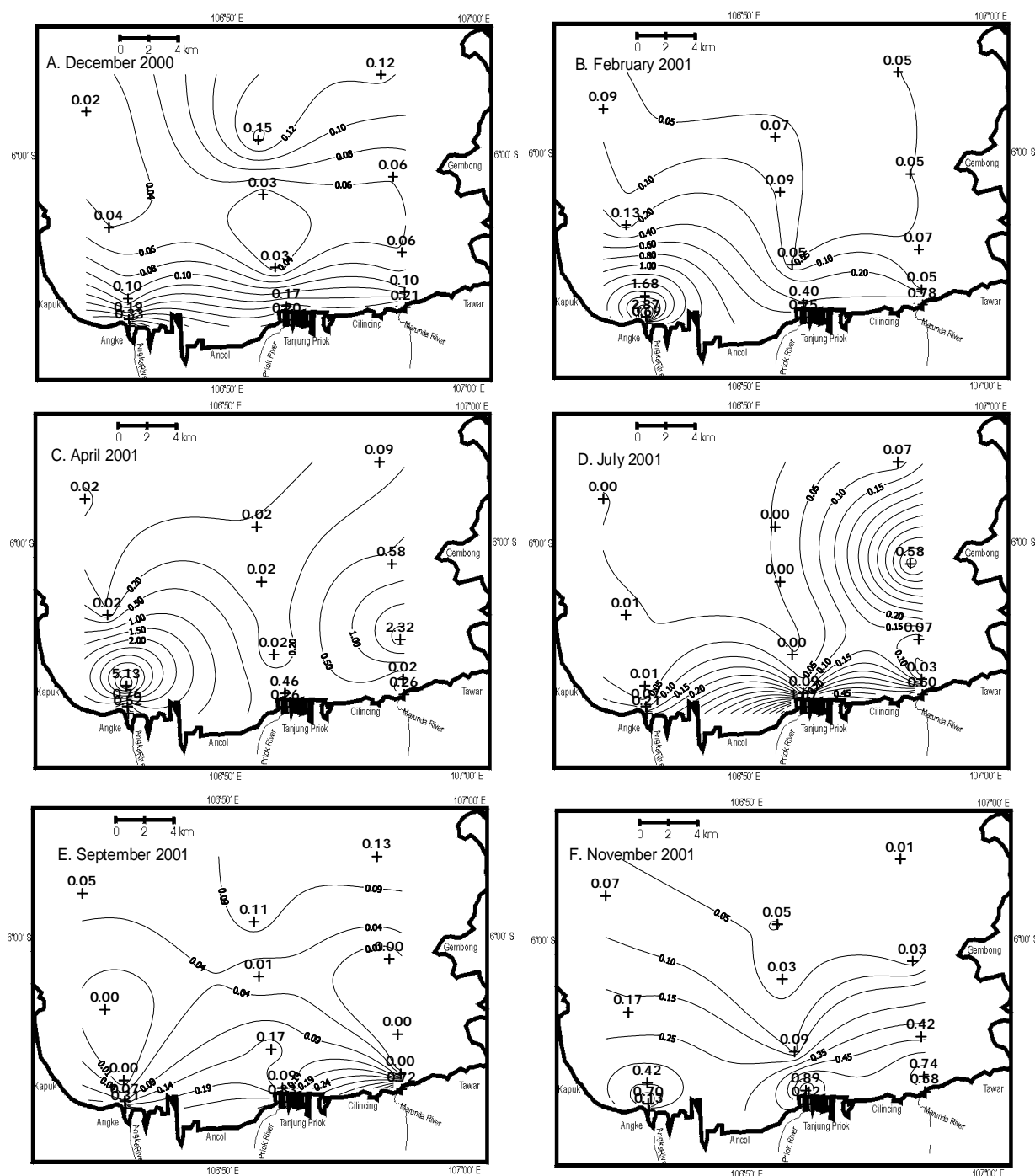
In general, the influence of freshwater played an important role in the pattern of nitrate distribution in the bay. There was a highly significant correlation of nitrate concentration both with salinity and turbidity ( $p < 0.001$  ; Pearson's  $r = -0.59$  and  $r = 0.56$ , respectively).

### 3.1.5.3. Nitrite [ $\text{NO}_2^-$ -N]

Nitrite distribution during all campaigns was slightly different to that of nitrate (Fig. 3.14). No significant difference was found between sites and seasonal surveys (ANOVA,  $p < 0.08$ ). Elevated concentration always prevailed in the river-influenced areas, especially around Angke and Priok rivers, while for Marunda river, nitrite was relatively low. During December 2000, February 2001 and November 2001, nitrite mostly came from Angke and Priok rivers. During July, similar to that of nitrate, nitrite was more concentrated around station 8 (Fig. 3.14 D), indicating the occurrence of high nitrite-content water along the eastern part of the bay. Several measurements showed very low values (undetectable) of nitrite (i.e. stations 1,4,5 and 6 in July 2001 and station 2,3,8 and 9 in September 2001), while the highest prevailed at station 3 (5.13  $\mu\text{M NO}_2\text{-N}$ ).



**Fig. 3.13.** Nitrate ( $\mu\text{M NO}_3\text{-N}$ ) contours in Jakarta Bay. A: December 2000. B: February 2001. C: April 2001. D: July 2001. E: September 2001 and F: November 2001.

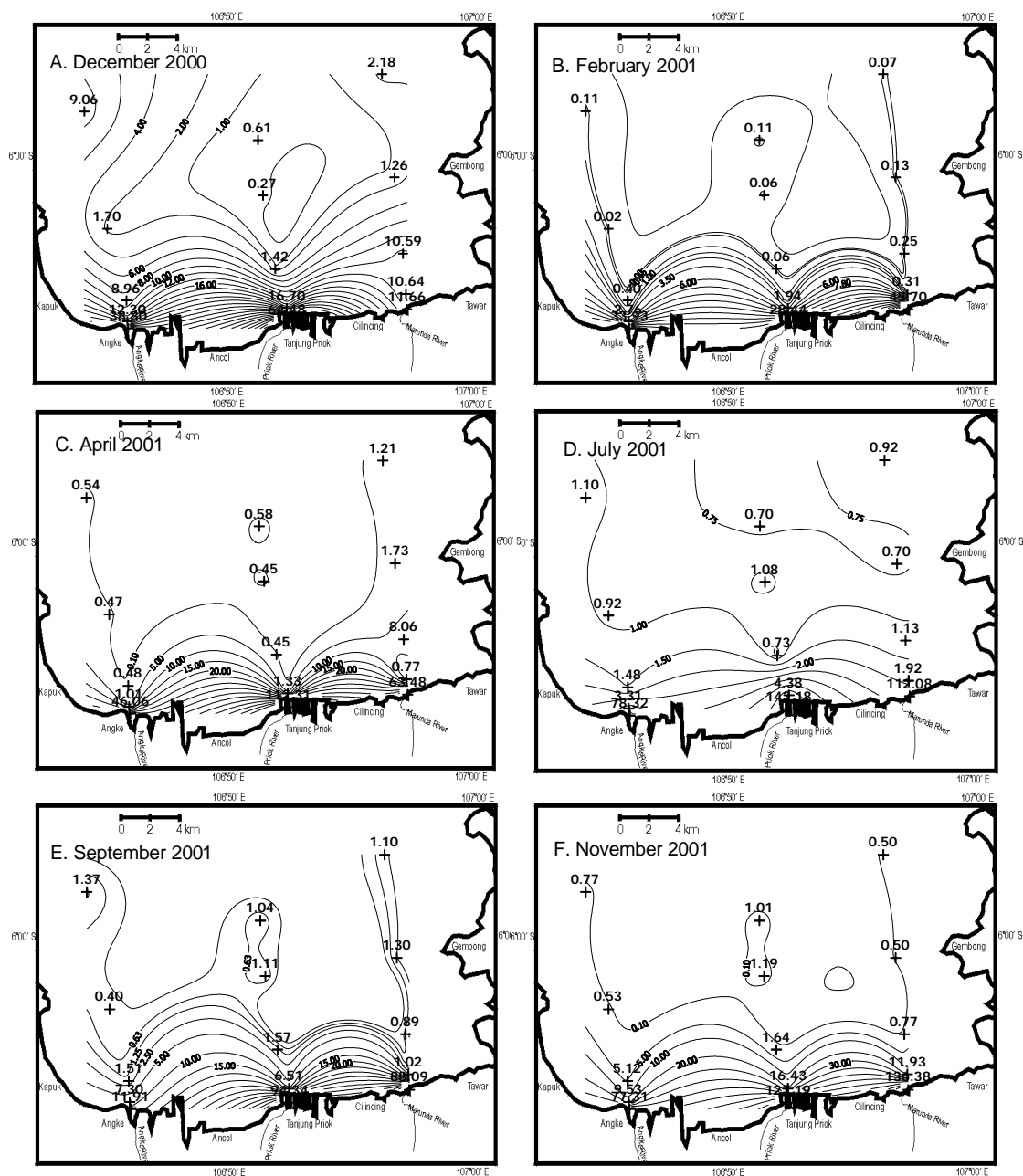


**Fig. 3.14.** Nitrite ( $\mu\text{M NO}_2\text{-N}$ ) contours in Jakarta Bay. A: December 2000. B: February 2001. C: April 2001. D : July 2001. E : September 2001 and F: November 2001.

### 3.1.5.4. Ammonium ( $\text{NH}_4^+\text{-N}$ )

As for the other nutrient species, ammonium exhibited a steep gradient in the riverine-coastal transitional zone, indicating high loads of ammonium from the incoming rivers (Fig. 3.15). Apart from the river mouth stations, ammonium was also high around stations 10, 11 and 12, (the annual average values per station ranged from 4.44 to 7.88  $\mu\text{M NH}_4\text{-N}$ ), which then decreased in the more offshore waters where annual average values per station ranged from 6.67 to 3.62  $\mu\text{M NH}_4\text{-N}$ . Significant differences were found on the spatial ( $p < 0.001$ ) and temporal scales ( $p < 0.05$ ). Similar distribution

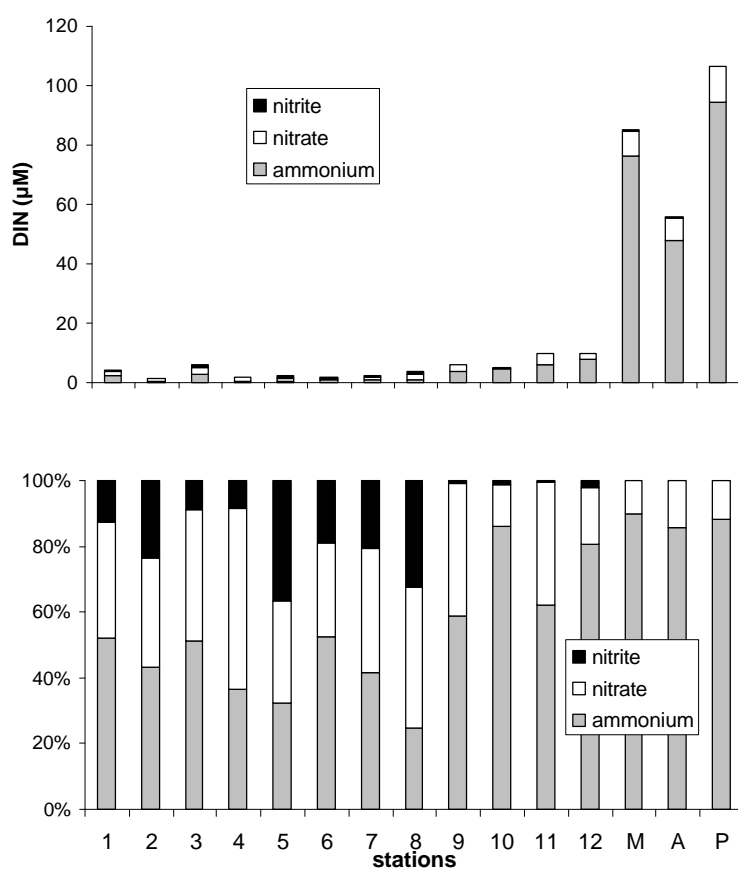
patterns prevailed in most of seasonal surveys, except in April 2001, when high concentrations were found around station 9. It indicates that during that time, ammonium mainly came from the eastern part of the bay. In other seasonal surveys, sources of ammonium were Angke and Priok rivers, with a minor contribution from Marunda river. A minimum temporal mean occurred in February 2001 (7.62  $\mu\text{M NH}_4\text{-N}$ ), while a maximum prevailed in November 2001 (25.79  $\mu\text{M NH}_4\text{-N}$ ), which was caused by the increase of ammonium loads from the river during rainy seasons. During December 2000, high ammonium levels were found in the west part of the bay (Fig. 3.15.A), while in April 2001, elevated concentrations prevailed in the eastern area. Both phenomena might be caused by the influence of waste water from the shrimp pond culture along the western and eastern coast of the bay. However, river discharge was the main factor determining the ammonium distribution. An inversely but strong correlation ( $p < 0.001$ ; Pearson's  $r = -0.81$ ) was observed between salinity and ammonium all over the research period.



**Fig. 3.15.** Ammonium ( $\mu\text{M NH}_4\text{-N}$ ) contours in Jakarta Bay. A: December 2000. B: February 2001. C: April 2001. D: July 2001. E: September 2001 and F: November 2001.

### 3.1.5.5. Dissolved inorganic nitrogen (DIN)

Dissolved inorganic nitrogen (DIN) was calculated by summing up nitrate, nitrite and ammonium. Ammonium is believed as an indicator for domestic-urban pollution, while nitrate is more related to agricultural pollution (runoff of fertilisers from land) (Blair *et al.*, 1999). From Fig. 3.16., it is seen that DIN concentrations in all river mouths and inshore waters stations (stations 6,9,10,11 and 12) were dominated by ammonium (> 50%). Moreover, at all river mouth stations, ammonium formed more than 85% of DIN. Meanwhile, in the offshore stations, nitrate, nitrite and ammonium were have comparable proportions in the DIN. The high proportion of ammonium in the inshore stations and river mouths shows the important role of the incoming rivers in the bay's ammonium concentration. It also indicates that the bay waters were profoundly influenced by urban domestic waste of the city of Jakarta.



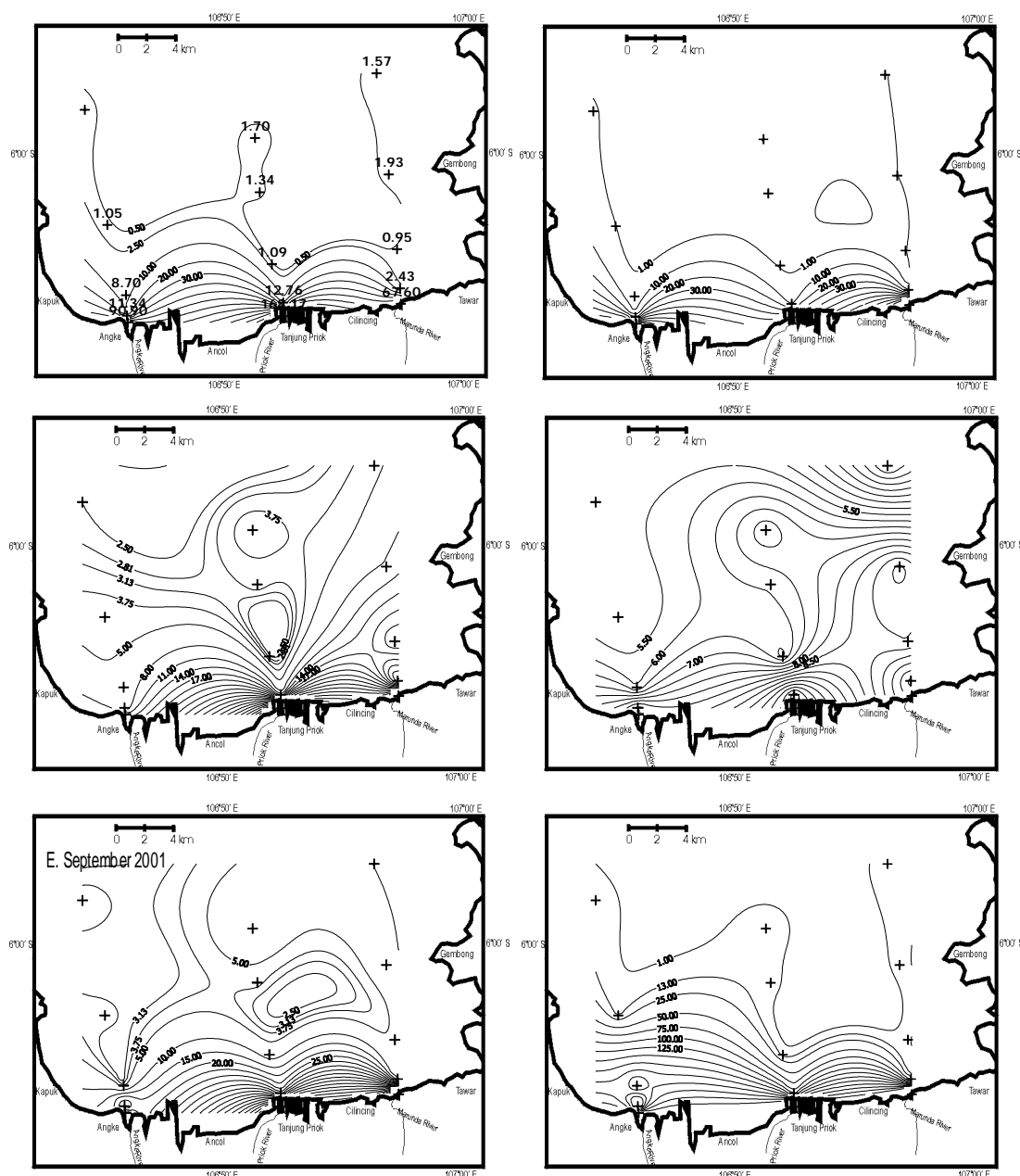
**Fig. 3.16.** Mean total DIN concentration composed of nitrate, nitrite and ammonium (upper graph) and % contribution of each nitrogen species (lower graph) in Jakarta Bay. M = Marunda river mouth ; A = Angke river mouth ; P = Priok river mouth.

### 3.1.5.6. Silicate [ $\text{SiO}_4$ ]

There were significant differences in silicate concentration, both between sites and seasonal surveys (ANOVA,  $p < 0.001$ ). General spatial pattern shows that silicate was high in the inshore waters, then decreased in the more offshore waters, except during the dry season (April and July 2001), when silicate was also elevated in the eastern area of the bay (Fig.3.17.). On a temporal scale, the maximum average occurred during rainy

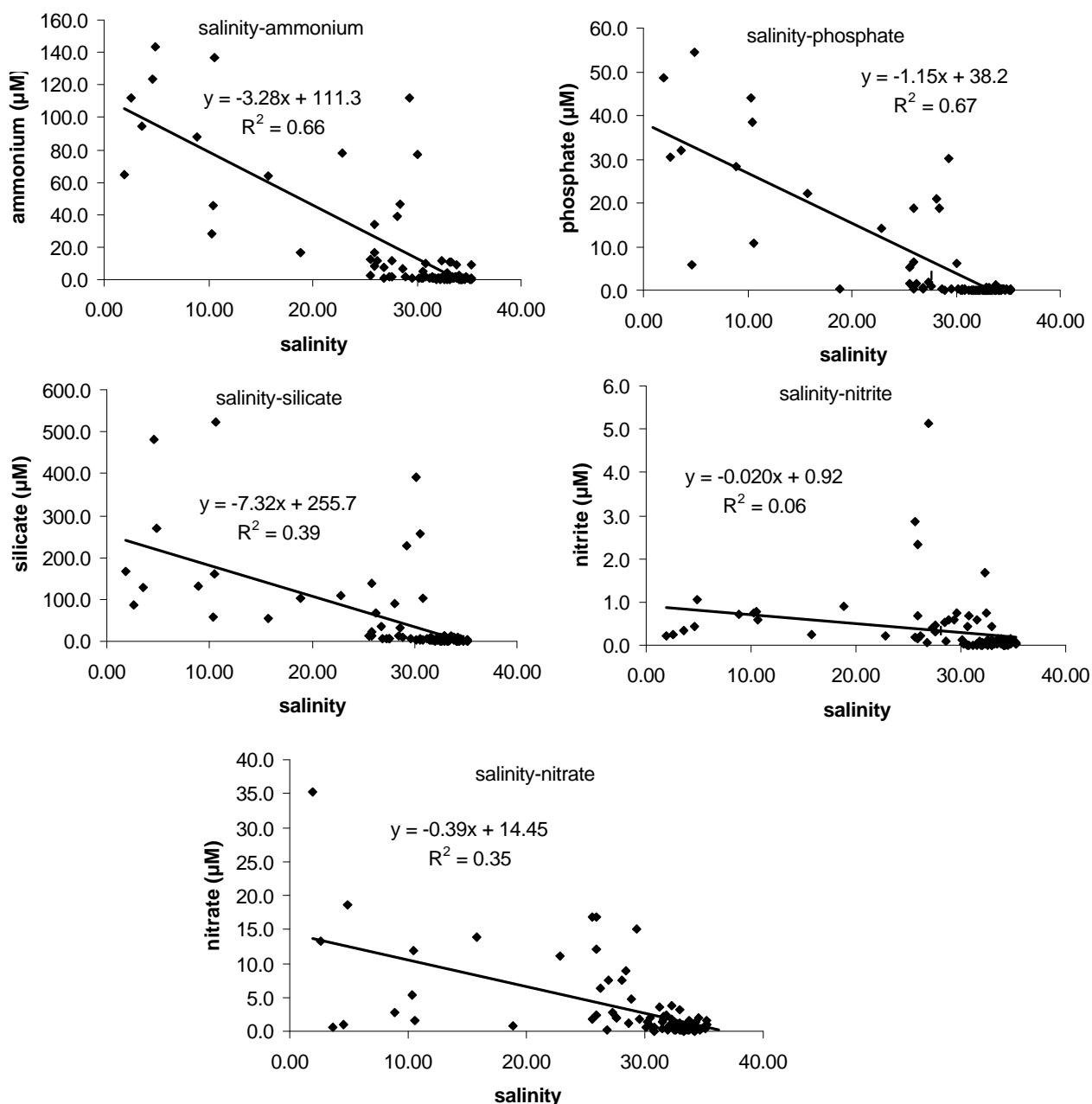


season of November 2001 (around 40  $\mu\text{M}$ ), while the minimum was observed during dry season of April 2001 (around 2  $\mu\text{M}$  Si). Along the year, Angke and Priok rivers seem to be the main sources of silicate in the bay, except during rainy season of November 2001, when the Marunda took over. The low silicate during December 2000 was also related to the low silicate in each river during that period. Silicate minimum was 0.55  $\mu\text{M}$  Si (station 6), while maximum was 524.08  $\mu\text{M}$  Si (Marunda river mouth). Freshwater discharge is held to be the prominent factor for silicate distribution in the bay ( $p < 0.001$ ; Pearson's  $r = -0.63$  and  $r = 0.65$ , for salinity and turbidity, respectively).



**Fig. 3.17.** Silicate( $\mu\text{M}$  Si) contours in Jakarta Bay. A: December 2000. B: February 2001. C: April 2001. D : July 2001. E : September 2001 and F: November 2001.

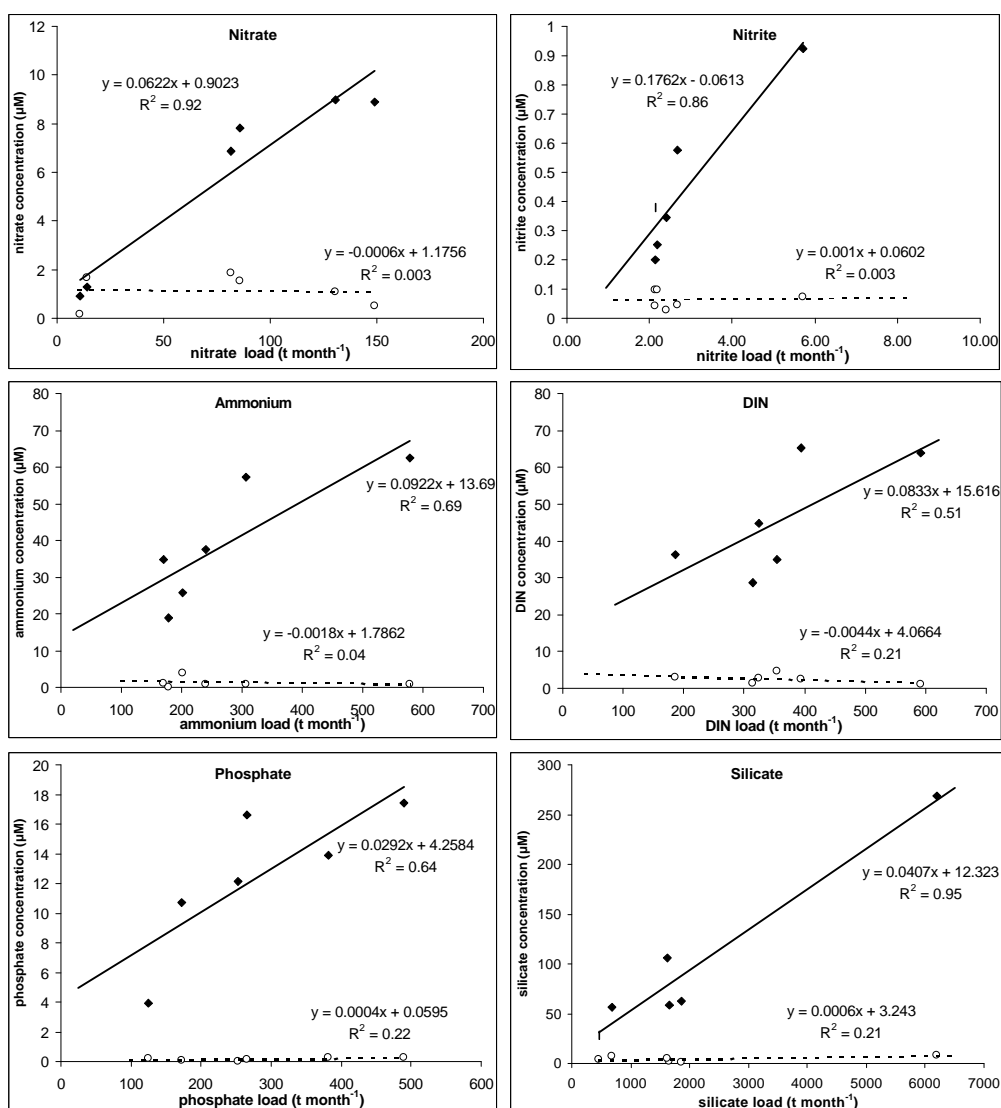
In order to investigate in detail the influence of freshwater discharge in the nutrient distribution, a set of linear regression analysis between salinity and each nutrient species (N = 90) was performed (Fig. 3.18). Results revealed a significant correlation between salinity and all nutrients species, except with nitrite, which showed a weak correlation ( $R^2 = 0.06$ ). This high linear correlation between salinity and almost all nutrient species, underlining the major importance of riverine nutrient loads for the trophic situation in Jakarta Bay.



**Fig. 3.18.** Linear regressions between salinity and nutrients (ammonium, phosphate, silicate, nitrite and nitrate) in Jakarta Bay.

### 3.1.5.7. Correlation between nutrient loads and nutrient concentrations in the bay

Fig.3.19 shows linear regressions between loads of nutrient and the ambient nutrient concentrations in two different sites in the bay. In that figure, linear regression between each nutrient load and the average of inshore nutrient concentrations (stations 10,11 and 12) are drawn in solid lines, while with the average of offshore nutrient concentrations (stations 1,4 and 7) are drawn in dotted lines. Comparison between these 2 linear regressions is performed to observe the role of nutrient loadings through the incoming rivers on the variations of the nutrient concentrations in the bay's waters. Strong linear correlation between nutrient loads and the inshore nutrient concentrations were observed in all nutrient species. At the same time, linear correlation between nutrient loads and the offshore nutrient concentrations shows a weak degree linear correlation in all nutrient species. This shows that the temporal variability of nutrient loads from the incoming rivers is not regulating the temporal variability of nutrient concentrations in the offshore sites of the bay. The strong influence only occurred in the limited area close to the river mouths.



**Fig. 3.19.** Linear regression between each nutrient load and its ambient concentration in the bay. Regression between nutrient load and inshore nutrient concentrations are indicated by solid lines, while regression with offshore nutrient concentrations are drawn in dotted lines.

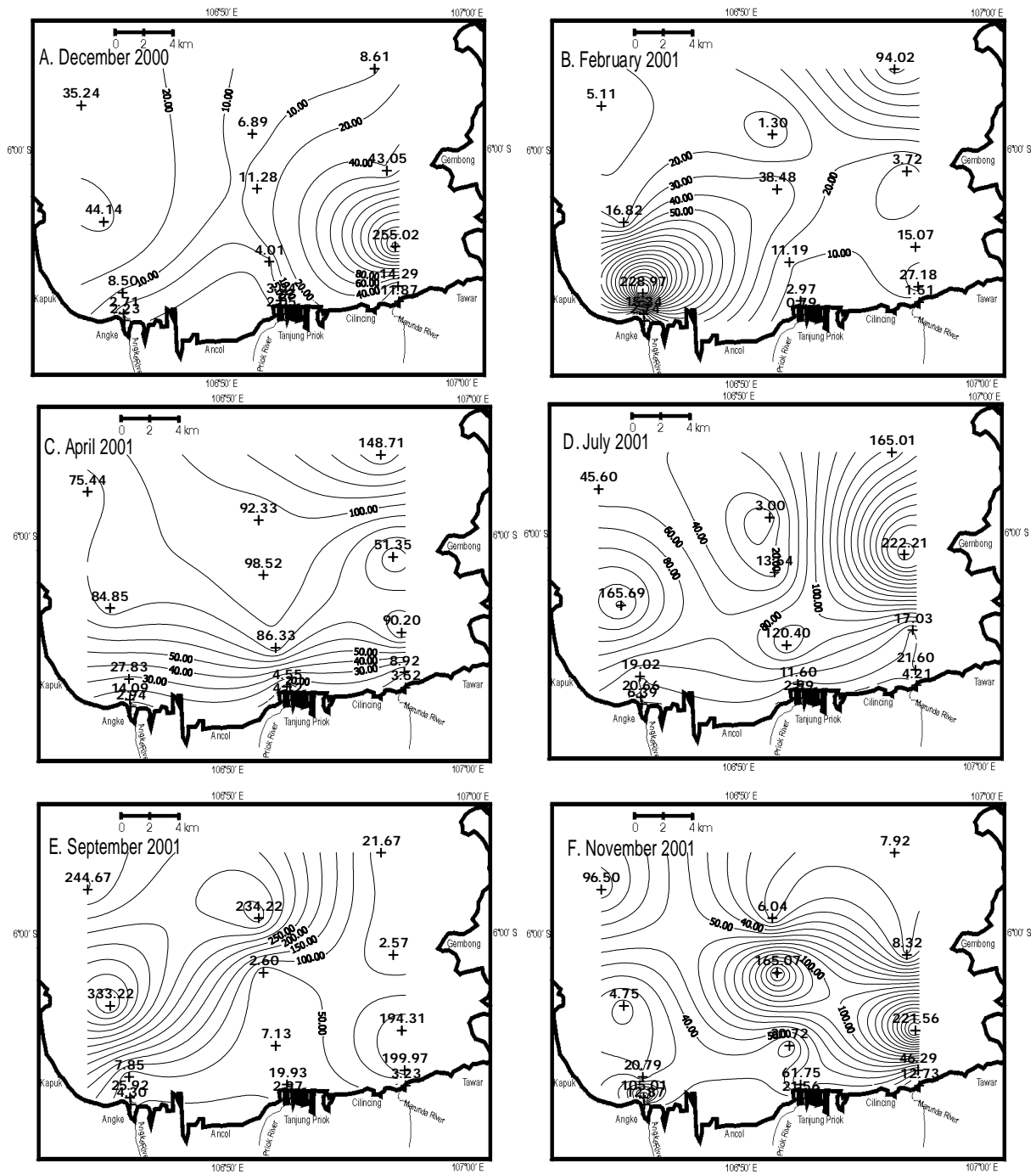
### 3.1.5.8. Molar ratio of dissolved inorganic nitrogen to phosphate (DIN:P) and to silicate (DIN: Si)

Fig. 3.20. illustrates the contours of DIN:P throughout the study period. The N/P ratio in the water is often used as a measure to assess a potential limitation of phytoplankton growth by one of these nutrients. Phytoplankton takes up the nutrients in a physiological ratio of 15:1, often referred to as the Redfield ratio (Redfield *et al.*, 1963). Values higher than 15 may indicate potential phosphorus limitation, by contrast, at values <15 potential nitrogen limitation prevails (e.g. Rick, 1999).

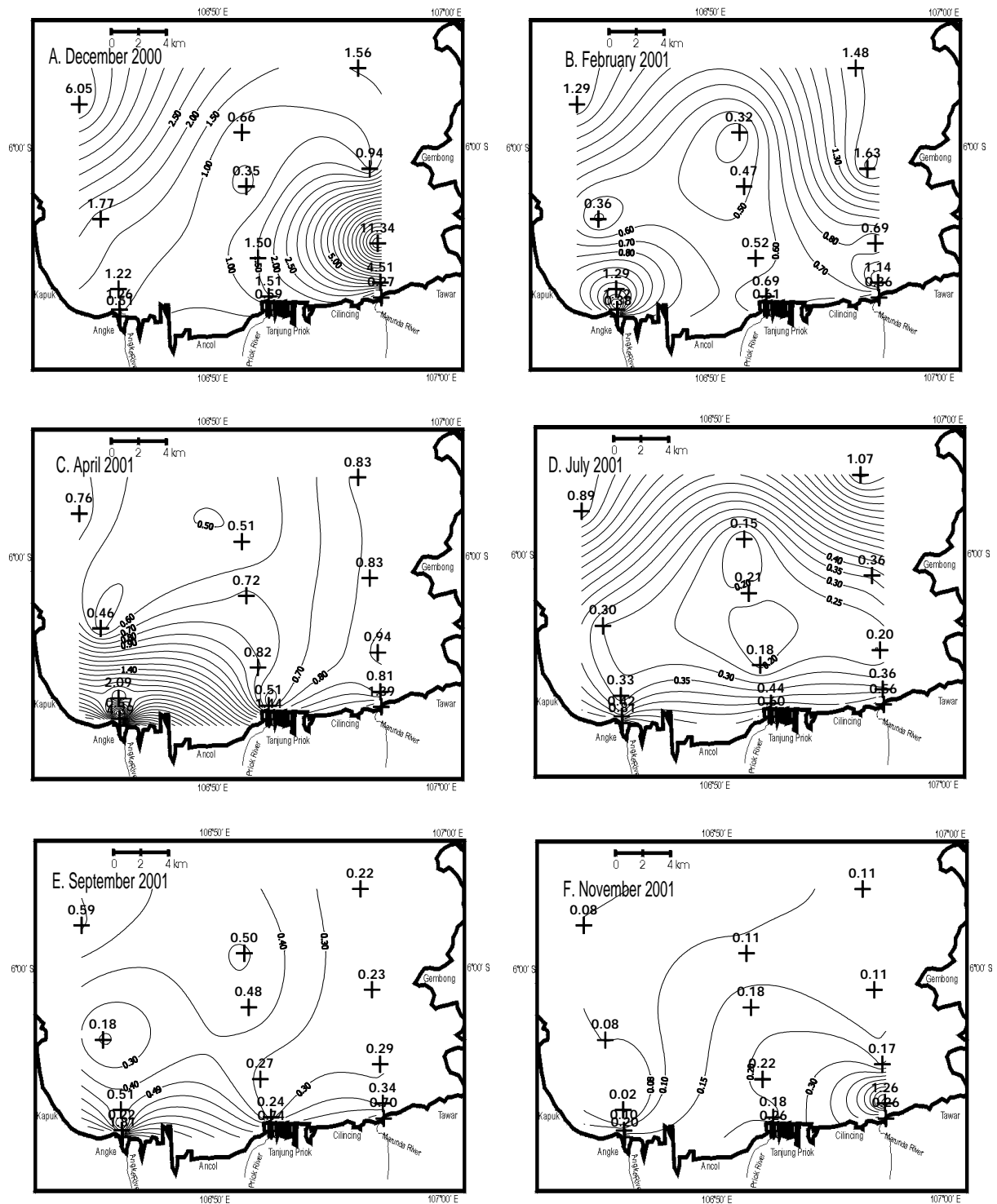
There were no significant differences in the DIN:P ratio both between sites and seasonal surveys. The values were low in the river mouths (< 15, Fig. 3.22), indicating a potential nitrogen limitation for phytoplankton in this region. However, this was mainly caused by the increase of phosphate, instead of nitrogen depletion. In the more offshore waters, this ratio increased, exceeding 200 at the outermost stations (stations 1 and 4). Temporal variation shows the highest mean ratio to prevail in September 2001 (125.09), while the lowest occurred in December 2000 (30.19). Pearson's correlation analysis showed a weak correlation between N/P ratio to both salinity and turbidity ( $p < 0.05$ ; -0.21 and 0.22, respectively), indicating a weak influence of river inflow to this ratio.

The ratio of DIN to silicate is also overviewed aimed to observe the potential of nitrogen relative to silicate limitation (Fig.3.21.). The ratio of DIN to silicate was not significantly different between sites but significantly different between seasons. However, slight spatial fluctuations occurred, showing low value in the middle part of the grid during December 2000 and February 2001. In general, most of all values were low (<1), showing no indication of silicate limitation in the bay (Fig 3.22). Freshwater inflow from rivers seemed to be a continuous source of silicate for the bay. Seasonal variation showed low values during rainy season, which might be related to the increase of silicate load from the rivers.

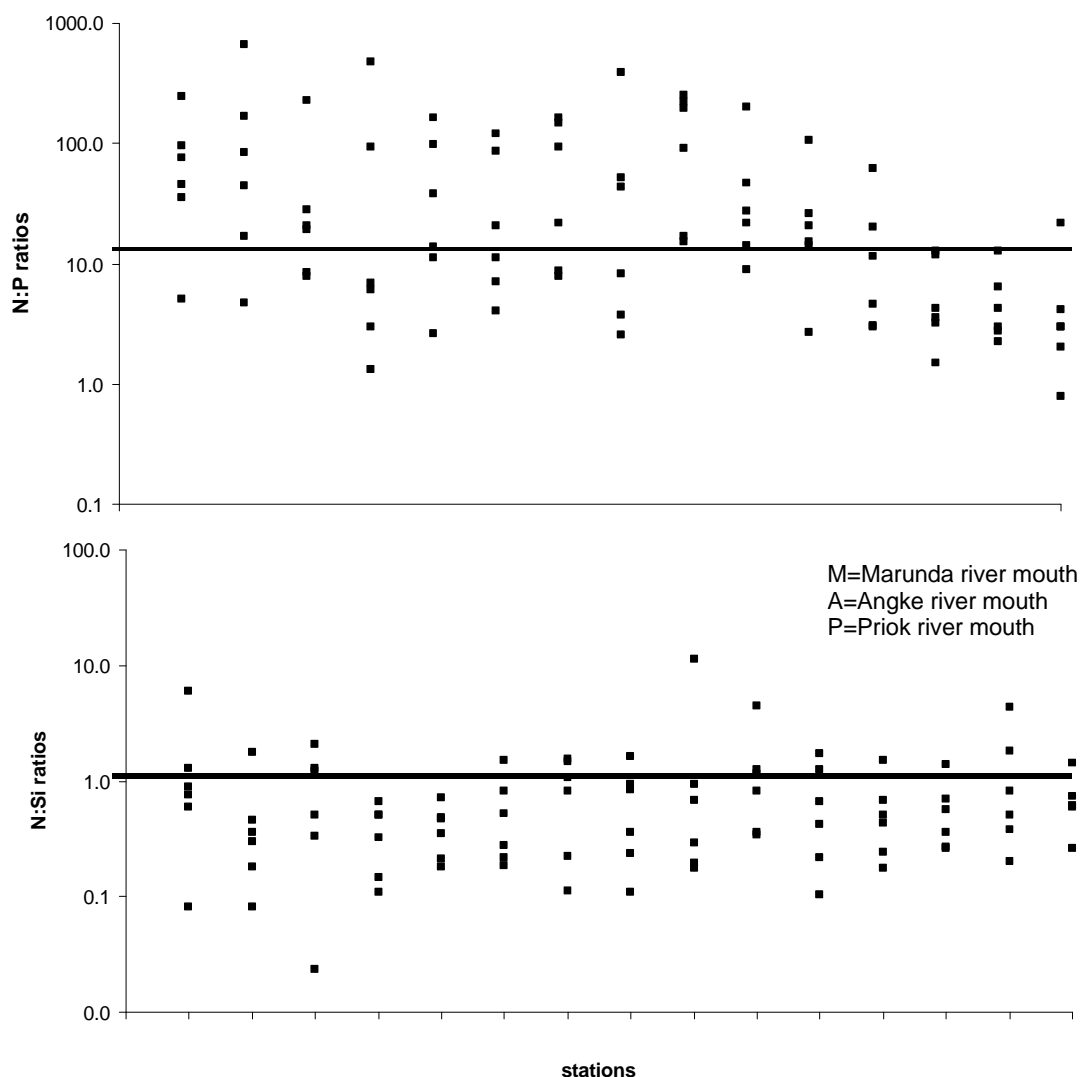
Based on the values of both DIN:P and DIN:Si, phosphate seems to be the potential limiting nutrient in the bay, except at all inshore stations. At these sites, no indication of nutrient limitation were observed. There was no indication of limitation by silicate in the whole study area.



**Fig. 3.20.** DIN : P molar ratio contours in Jakarta Bay. A: December 2000. B: February 2001. C: April 2001. D : July 2001. E : September 2001 and F: November 2001.



**Fig. 3.21.** DIN : Si molar ratio contours in Jakarta Bay. A: December 2000. B: February 2001. C: April 2001. D : July 2001. E : September 2001 and F: November 2001.

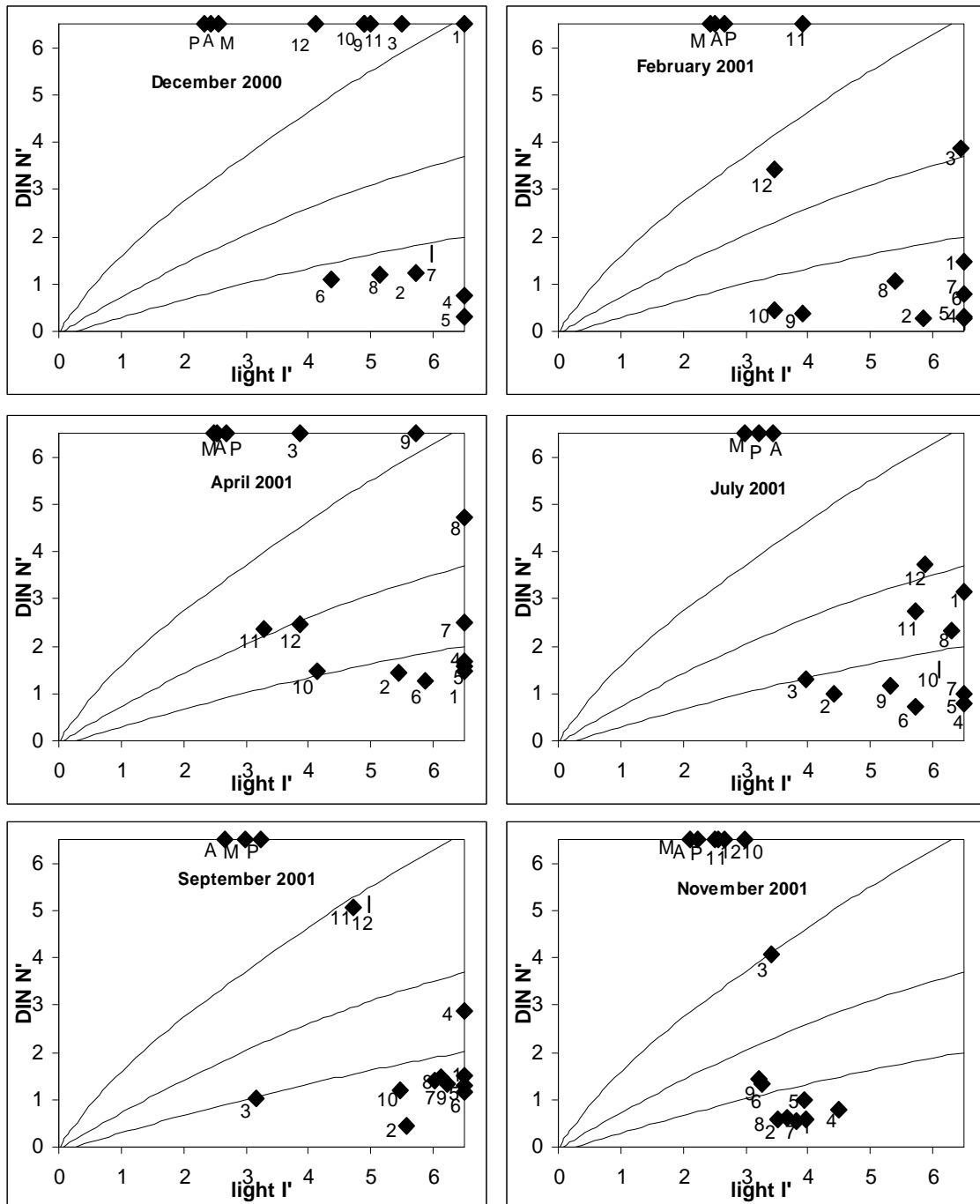


**Fig. 3.22.** Molar ratios of DIN:P (above) and DIN:Si (below) at each station in Jakarta Bay. Horizontal lines indicate where DIN:P is 15 (above) and DIN:Si is 1 (below) (note the logarithmic scales).

### 3.1.6. Phytoplankton growth rate sensitivity to light and nutrients

Based on the procedure developed by Cloern (1999), nutrient concentrations (DIN) and light resources at each station and temporal survey were plotted in a resource limitation map for phytoplankton growth as shown in Fig.3.23 (see chapter : Methods). The results show that the indication of light and nutrient limitation were observed at each seasonal survey. All river mouths and surrounding sites (stations 10, 11 and 12) clustered in the upper part of the diagrams, indicating strong limitation by light, except during July 2001, which showed a weaker light limitation. Strong light limitation was mainly observed during the rainy season (December 2000 and November 2001),

whereas during the dry season (July 2001), nutrient limitation occurred. The middle part of the bay stations clustered in the middle part of the diagrams, indicating relatively weak light limitation. The outer part of the bay stations clustered in the lower right of the diagrams, indicating strong nutrient limitation. In these sites, light availability increases due to significant decrease of turbidity. But in these sites, nutrient reduces due to a weaker influence of the riverine nutrient inflows.



**Fig.3.23.** The light and nutrient resources limitation maps for phytoplankton growth in Jakarta Bay. Dark diamonds show positions of light and nutrient measurements on the resource limitation maps. Numbers indicate sampling stations. (calculations were performed according to the procedure of Cloern, 1999, see methods) M=Marunda river mouth ; A=Angke river mouth; P=Priok river mouth.



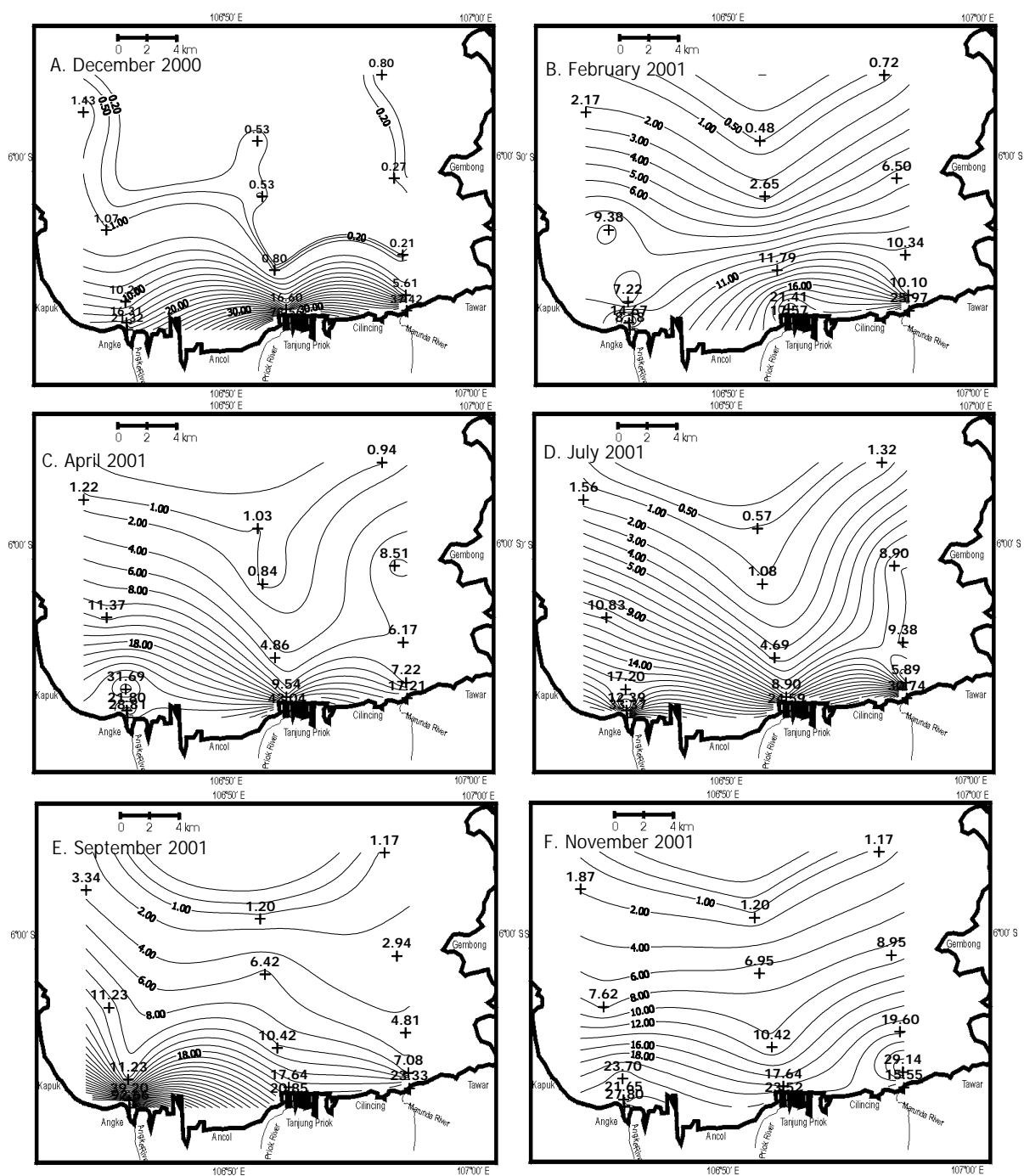
### 3.1.7. Chlorophyll *a*, phytoplankton community and pigments

Chlorophyll *a* content at each temporal survey is shown in Fig. 3.24, showing a clear spatial pattern (ANOVA,  $p < 0.001$ ). This spatial variation accounted for 53% of the variance in chlorophyll *a* concentration data. General spatial variation of chlorophyll *a* was high in the inshore stations and strongly declined in the offshore stations.

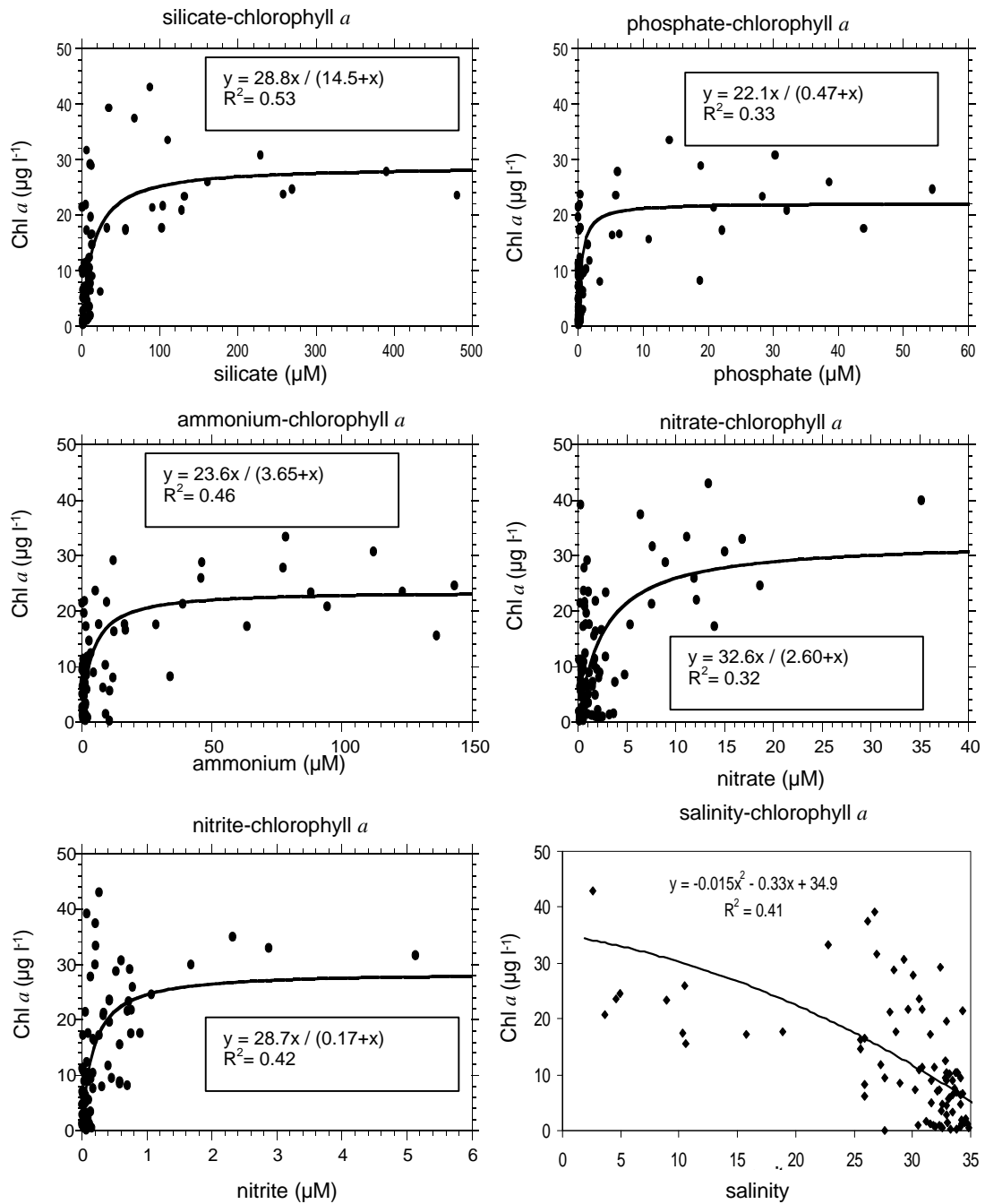
Throughout the year, river mouth stations were high in chlorophyll *a* concentration, ranging from 8.17 to 92.66  $\mu\text{g Chl } a \text{ l}^{-1}$ . In the near-shore stations (stations 10,11,12), chlorophyll *a* slightly decreased, ranging from 5.61 to 39.2  $\mu\text{g Chl } a \text{ l}^{-1}$ . In the middle and outer layer of the bay stations, phytoplankton biomass steeply decreased, ranging from 0.27 to 11.37  $\mu\text{g Chl } a \text{ l}^{-1}$  and from 0.60 to 6.42  $\mu\text{g Chl } a \text{ l}^{-1}$ , respectively. Statistically significant temporal variation in chlorophyll *a* was observed, with February 2001 as the lowest (temporal average 10.23  $\mu\text{g Chl } a \text{ l}^{-1}$ ), whereas September 2001 as the highest concentration (temporal average 17.07  $\mu\text{g Chl } a \text{ l}^{-1}$ ).

An inverse exponential significant correlation was observed between salinity and chlorophyll *a* ( $p < 0.01$ ;  $R^2 = 0.41$ ), supporting the role of the riverine nutrients on phytoplankton biomass (Fig.3.25). Besides showing a strong inverse exponential correlation between salinity and chlorophyll *a*, Fig. 3.25. also shows a hyperbolic relationship (saturation) between each nutrient species to chlorophyll *a*. All nutrient species concentrations were significantly hyperbolic correlated with chlorophyll *a* concentrations ( $p < 0.01$ ;  $R^2$  were 0.53, 0.33, 0.46, 0.32 and 0.42, for silicate, phosphate, ammonium, nitrate and nitrite, respectively). This shows that phytoplankton biomass increases in direct proportion to low external nutrient concentrations, but gradually levels off and becomes saturated at higher nutrient concentrations. This is in keeping with the hyperbolic classical relationship theory between nutrient concentration and phytoplankton biomass (Dring, 1982).

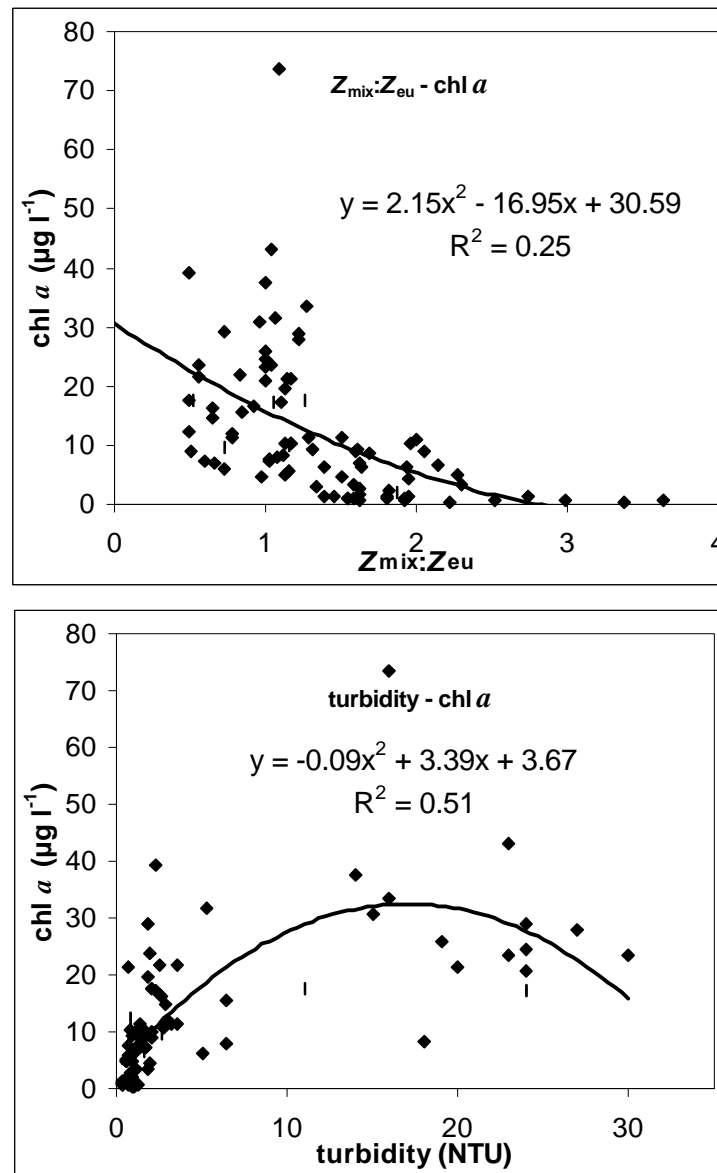
In addition (Fig.3.26.), exponential regressions between light properties parameters ( $Z_{\text{mix}}-Z_{\text{eu}}$  and turbidity) to chlorophyll *a* also show strong exponential relationship ( $p < 0.005$ ;  $R^2 = 0.25$  and  $0.51$ , for  $Z_{\text{mix}}-Z_{\text{eu}}$  and turbidity respectively). This shows that phytoplankton biomass is exponentially regulated by the light availability in the water column.



**Fig. 3.24.** Chlorophyll *a* contours ( $\mu\text{g Chl } a \text{ l}^{-1}$ ) in Jakarta Bay. A: December 2000. B: February 2001. C: April 2001. D : July 2001. E : September 2001 and F: November 2001.



**Fig.3.25.** Hyperbolic relationship between concentrations of silicate, phosphate, ammonium, nitrate, nitrite to chlorophyll *a* and exponential relationship between salinity to chlorophyll *a* in Jakarta Bay.

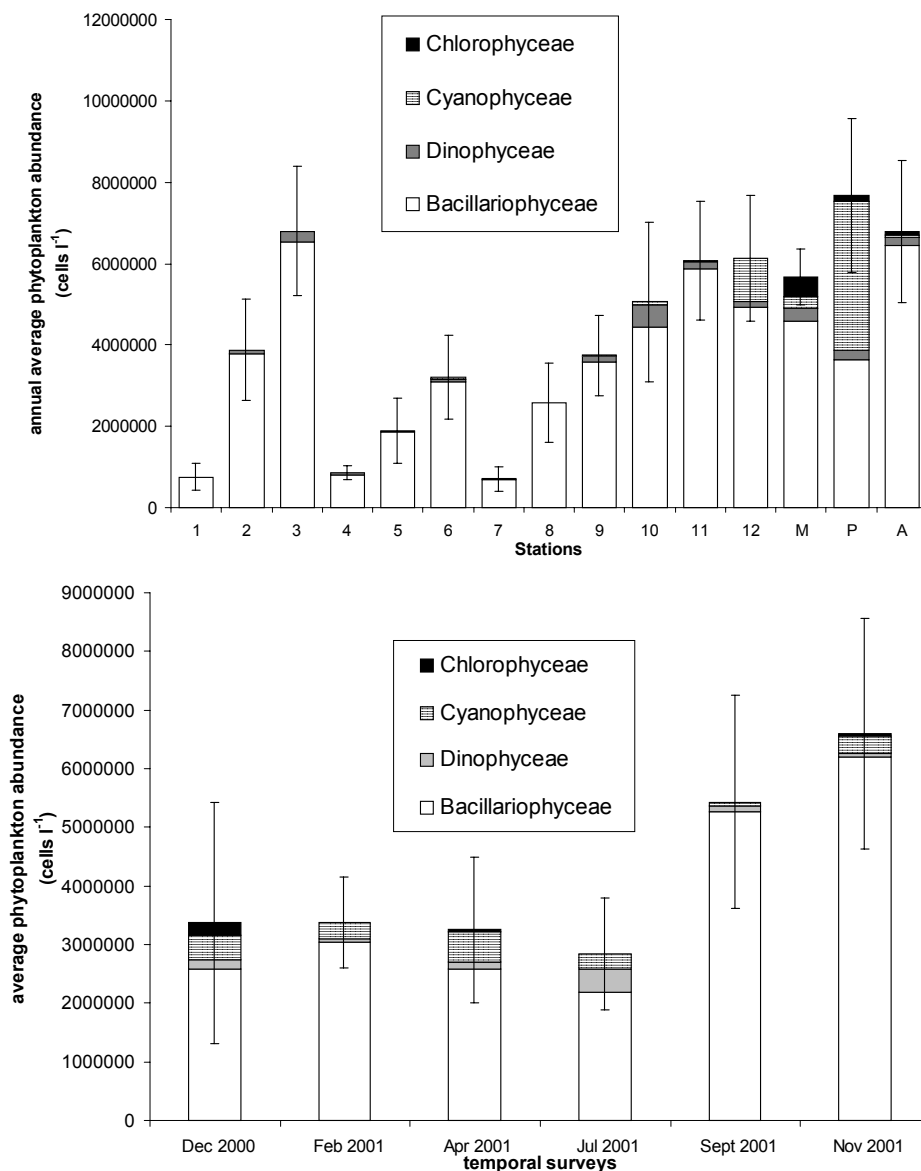


**Fig.3.26.** Exponential relationship between  $Z_{mix}:Z_{eu}$  and turbidity to chlorophyll *a* in Jakarta Bay.

Fig.3.27 shows the annual average of phytoplankton abundance at each station and each temporal survey. The figure shows that in Jakarta Bay, phytoplankton community was dominated by diatoms (*Skeletonema costatum* and *Chaetoceros debilis* and *Pseudonitzschia* spp), especially in the more offshore stations. At the inshore stations including river mouths, dinoflagellates (*Ceratium* spp.) and cyanobacteria (*Trichodesmium* spp.) increased (Fig.3.27). There were significant differences in phytoplankton abundance between temporal surveys and sites (ANOVA ;  $p < 0.001$ ). In each temporal survey, high phytoplankton abundance was observed at the stations of river mouths, 10,11,12 and 3 (around  $6 \times 10^6$  cells l<sup>-1</sup>). In the middle of the bay, phytoplankton abundance slightly decreased to around  $2.5 \times 10^6$  cells l<sup>-1</sup>, whereas in the offshore stations showed a decrease to around  $0.8 \times 10^6$  cells l<sup>-1</sup>. This pattern fits with the pattern of decreasing nutrient concentrations in the bay.

At a temporal scale, September and November 2001 exhibited an elevated value of phytoplankton abundance, which are commensurate with the increase of nutrients during high-rainfall period. Meanwhile, July 2001 was the lowest in phytoplankton abundance, which was closely related to the low nutrients period. It is also commensurate with the chlorophyll *a* pattern, which reached a maximum in September 2001. Pearson's correlation showed a strong and positive correlation between phytoplankton abundance and chlorophyll *a* concentration ( $p < 0.001$ ;  $r = 0.75$ ). This high correlation is also indicating a low variation on phytoplankton species composition in the study area.

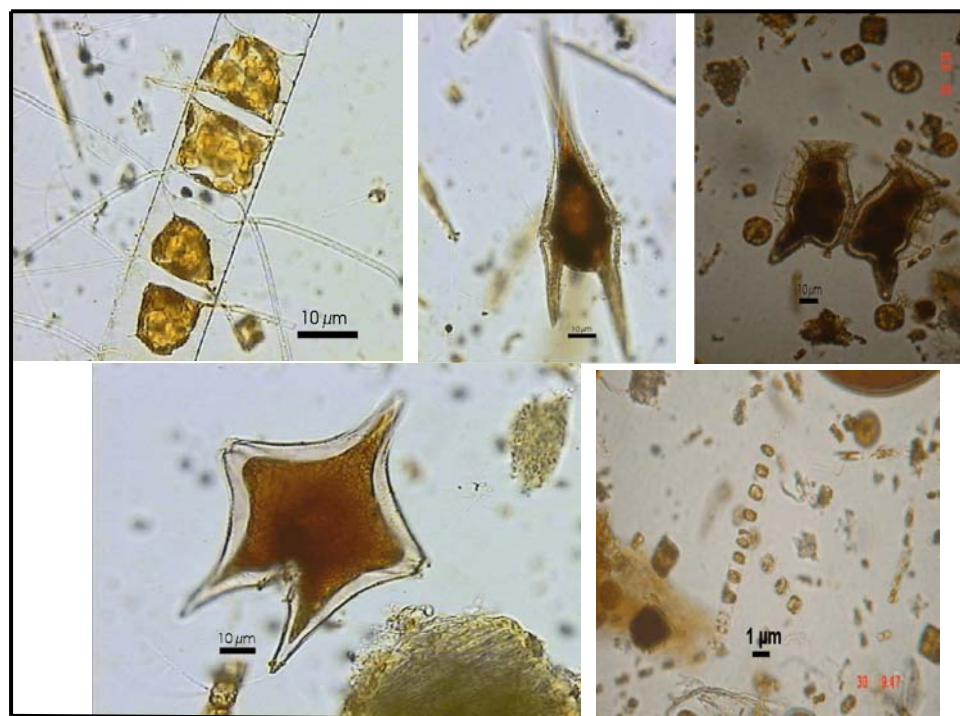
Positive significant ( $p < 0.01$ ) correlations between silicate, ammonium, nitrate and phosphate to phytoplankton abundance were observed, indicating a high influence of these nutrients on phytoplankton growth ( $p < 0.01$ ; Pearson's  $r = 0.38, 0.31, 0.28$  and  $0.26$ , respectively).



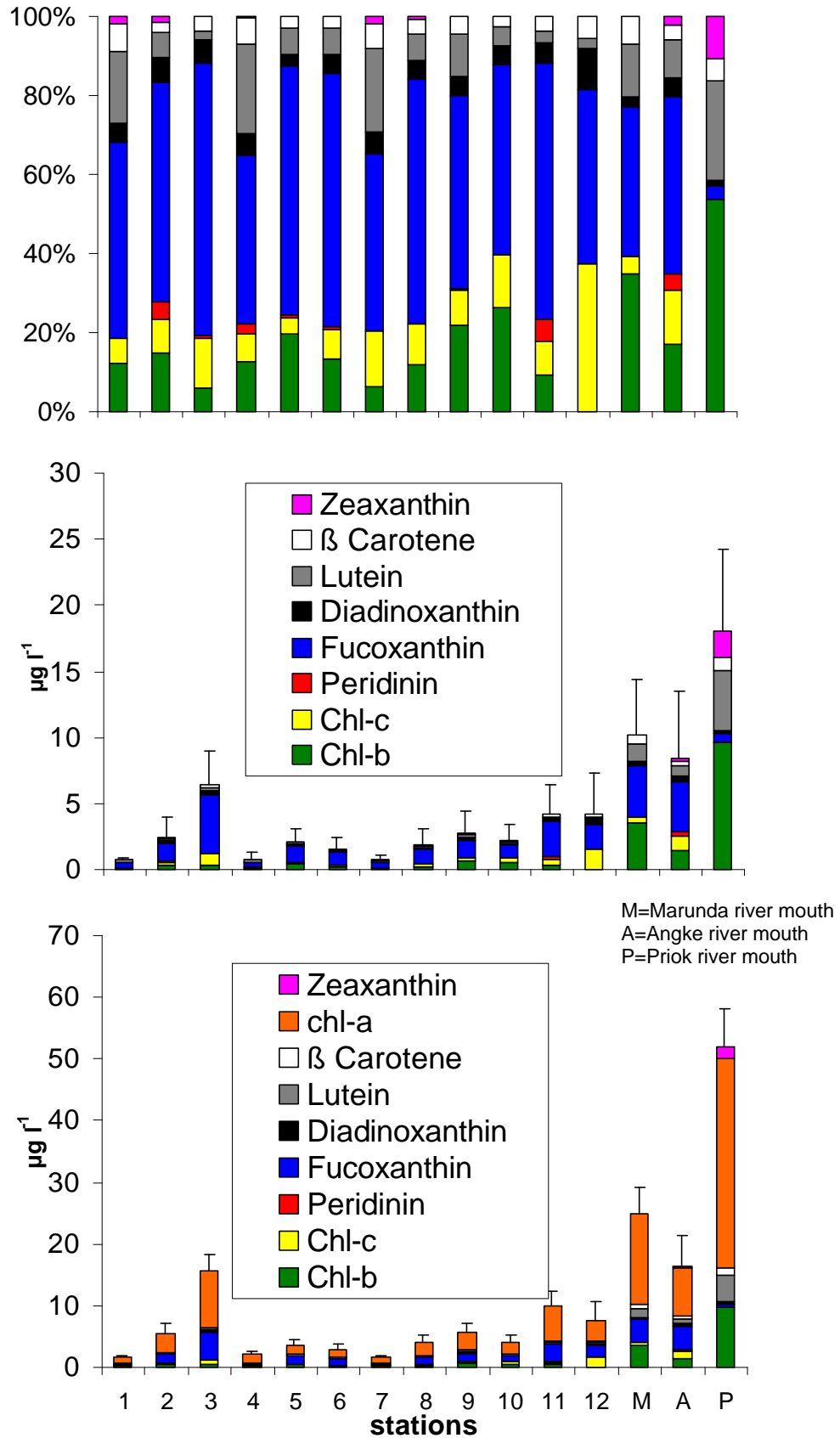
**Fig. 3.27.** Annual average abundance of phytoplankton (cells l<sup>-1</sup>) at the sampling stations in Jakarta Bay (upper graph) and average for all stations in the different sampling periods (lower graph). Bars are standard deviations calculated from 6 data (upper graph) and from 15 data (lower graph). M, P and A are Marunda, Priok and Angke river mouths respectively.

Besides microscopic group identification, phytoplankton groups were identified through determination of its algal pigments by means of HPLC. The results show that pigments of chlorophyll *a*, *b*, *c*, peridinin, fucoxanthin, diadinoxanthin, lutein, zeaxanthin and  $\beta$  carotene were observed. Those pigments are used as a biomarker for dinoflagellates (peridinin and chlorophyll *c*), diatoms (fucoxanthin, diadinoxanthin and chlorophyll *c*), and chlorophyceae (lutein and chlorophyll *b*) (Jeffrey *et al.*, 1997).

Fig.3.29 shows distribution of annual average of pigment concentrations at each station in the study area. Almost at all stations, except at stations 1, 5 and Priok River mouth, fucoxanthin dominated the phytoplankton pigments (>50%), indicating the dominance of diatoms. At stations 1, 5 and Priok River mouth, chlorophyll *b* and lutein dominated pigment composition (>40%). Microscopic identification showed that a representative of the genus *Scenedesmus* spp. was responsible for the high content of chlorophyll *b* and lutein. Dinoflagellates were also found at almost all sites, but in low concentrations (around 15%), marked by the pigments peridinin and chlorophyll *c*. Zeaxanthin (marker for cyanobacteria) was found only in low concentrations, especially at river mouth stations. *Trichodesmium* spp. was responsible for the occurrence of this pigment.



**Fig.3.28.** Pictures of the dominant phytoplankton in Jakarta Bay. In clockwise order : *Chaetoceros* spp., *Ceratium furca*, *Dinophysis caudata*, *Skeletonema costatum* and *Protoperdinium claudicans*.



**Fig. 3.29.** Annual average values of each phytoplankton pigment in Jakarta Bay. Percentage of annual average pigment concentrations (upper graph), comparison of annual average pigment concentrations without Chl *a* (middle graph) and including Chl *a* (lower graph). Bars are standard deviations calculated from 6 data.

### 3.1.8. Planktonic primary production

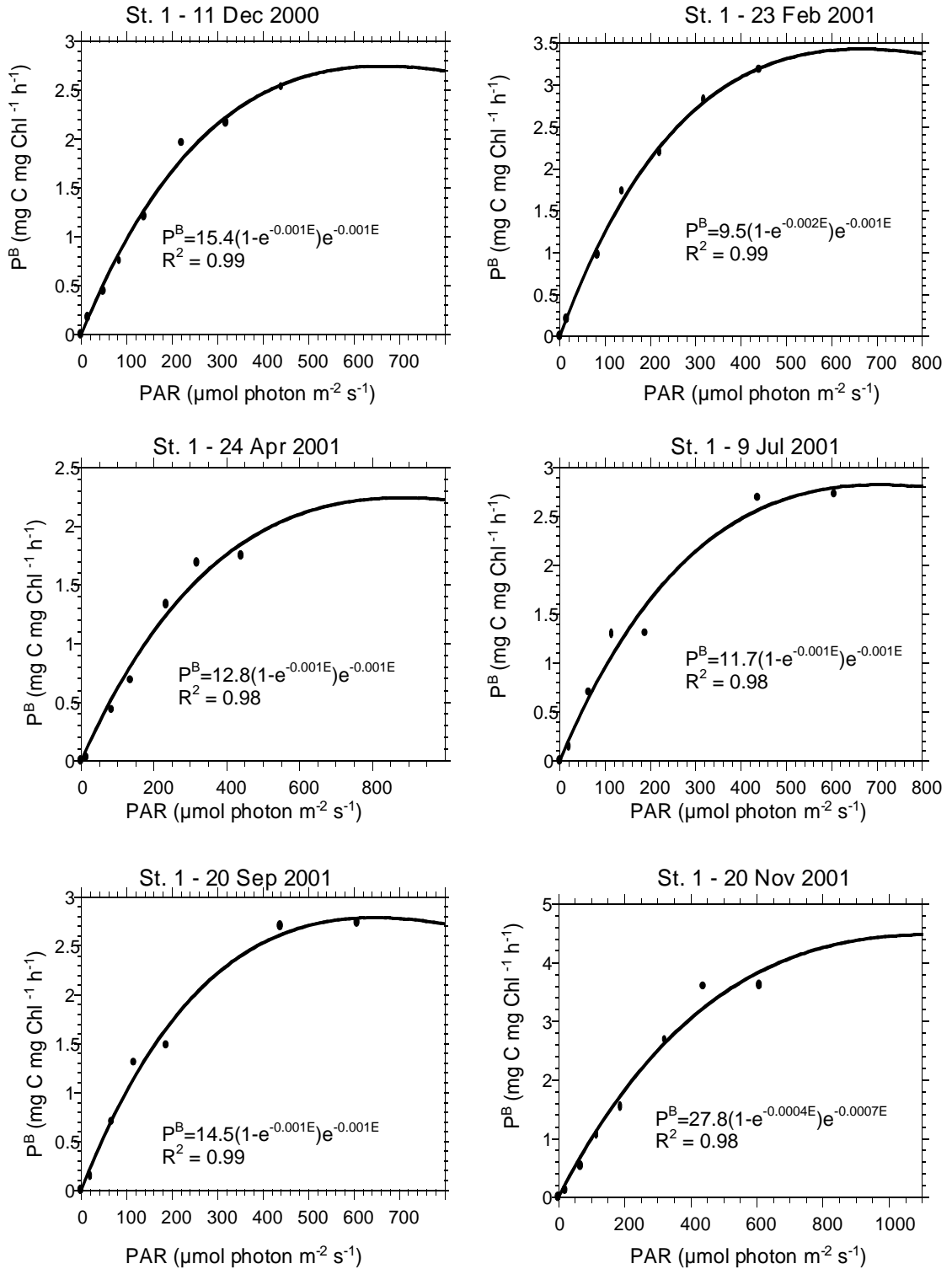
The results of the P-E incubations for 3 stations are shown in Fig. 3.30 A,B and C for the 6 temporal surveys. Based on these P-E relationships, the chlorophyll-specific maximum photosynthetic rate ( $P_{\max}^B$ ) ranged from 2.23 to 4.48, 2.05 to 15.22 and 5.55 to 17.63 mg C mg Chl<sup>-1</sup> h<sup>-1</sup> for stations 1, 5 and 10, respectively (Fig. 3.31.A). The  $P_{\max}^B$  values were significantly ( $p < 0.001$ ) correlated with  $\alpha^B$ , light saturation,  $Z_{\text{mix}} : Z_{\text{eu}}$  ratio and daily PP (Pearson's  $r = 0.66, 0.59, 0.83$  and  $0.53$ , respectively).

Another PE parameter is the slope of the P versus E curve ( $\alpha^B$ ) (Fig. 3.31.B), indicator for the rate of photosynthetic efficiency. Comparison between sites shows a similar trend : the highest always prevailed at station 10, while the lowest prevailed at station 1. At station 1, it ranged from 0.007 to 0.011 mg C mg Chl<sup>-1</sup> h<sup>-1</sup> ( $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$ ). At station 5, it ranged from 0.011 to 0.055 mg C mg Chl<sup>-1</sup> h<sup>-1</sup> ( $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$ ), while at station 10, it ranged from 0.028 to 0.065 mg C mg Chl<sup>-1</sup> h<sup>-1</sup> ( $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$ ). This parameter was significantly and positively correlated with daily PP, chlorophyll *a*, phytoplankton abundance and light attenuation coefficient ( $p < 0.01$ ; 0.88, 0.58, 0.59, and 0.65, respectively), while with  $Z_{\text{eu}}$ ,  $Z_{\text{mix}}$ , and  $Z_{\text{mix}} : Z_{\text{eu}}$ , it was negatively correlated (-0.68, -0.84, -0.77, respectively).

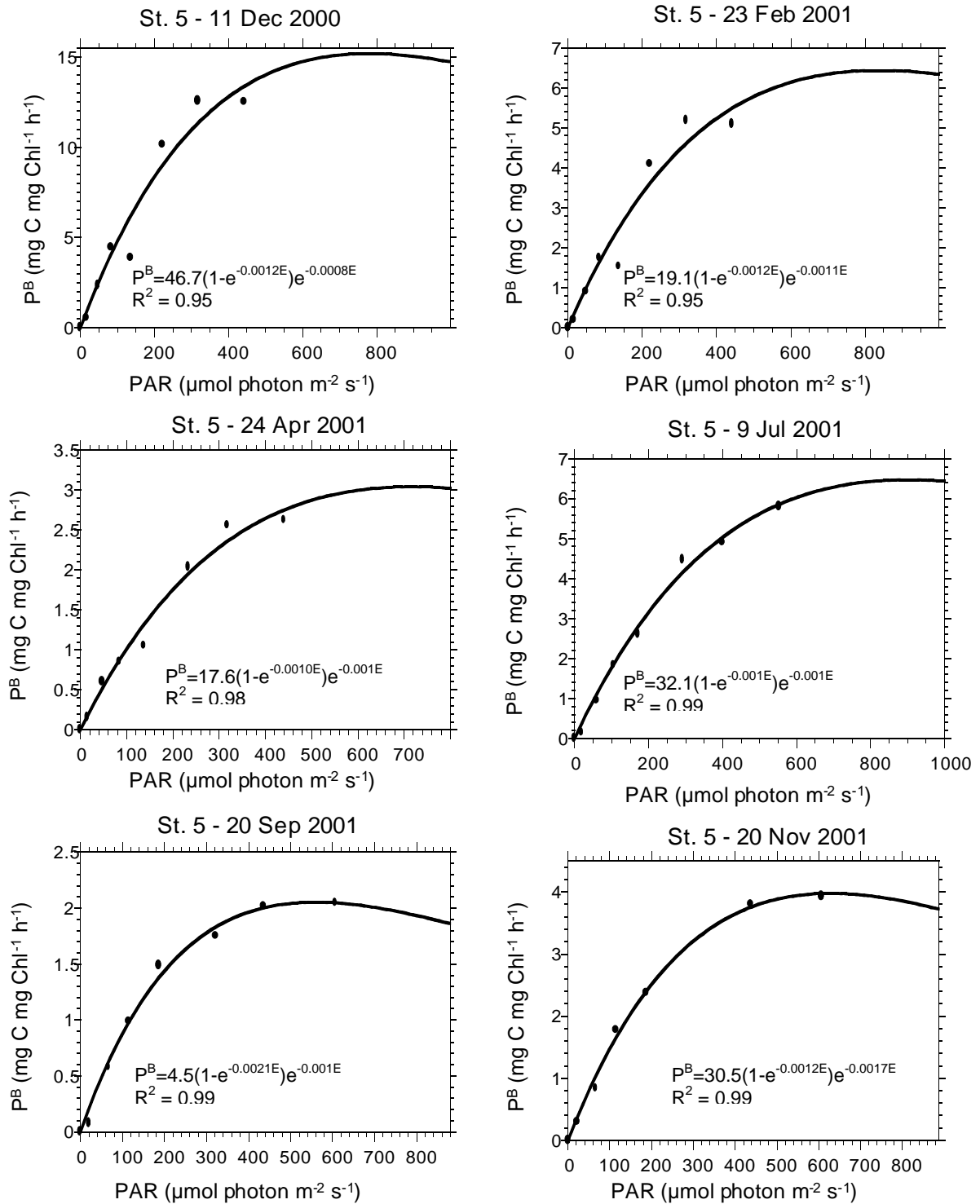
$E_k$  values were relatively high throughout the year (Fig. 3.31.C), indicating acclimation to strong light. They ranged from 182 to 835  $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$ . There was no clear trend between sites.

Daily water column primary production data show a clear trend between sites and time of samplings (Fig. 3.31.D). The highest was determined at station 10 and then decreased at station 5 and finally the lowest was measured at station 1. At station 1, it ranged from 55 (April 2001) to 211 mg C m<sup>-2</sup> d<sup>-1</sup> (July 2001). At station 5, it ranged from 69 (April 2001) to 456 mg C m<sup>-2</sup> d<sup>-1</sup> (December 2000) and at station 10, it ranged from 609 (April 2001) to 2484 mg C m<sup>-2</sup> d<sup>-1</sup> (November 2001). This pattern is commensurate with the pattern of ammonium, nitrite, phosphate, chlorophyll *a*, phytoplankton abundance and attenuation coefficient ( $p < 0.01$ ; Pearson's  $r = 0.65, 0.71, 0.26, 0.85, 0.84$  and  $0.62$ , respectively). Two-way Anova resulted in significant differences between sites and temporal surveys. Seasonal variations show that the high values occurred during rainy seasons (December 2000, February 2001 and November 2001), while low values prevailed during dry season (April 2001 and July 2001).

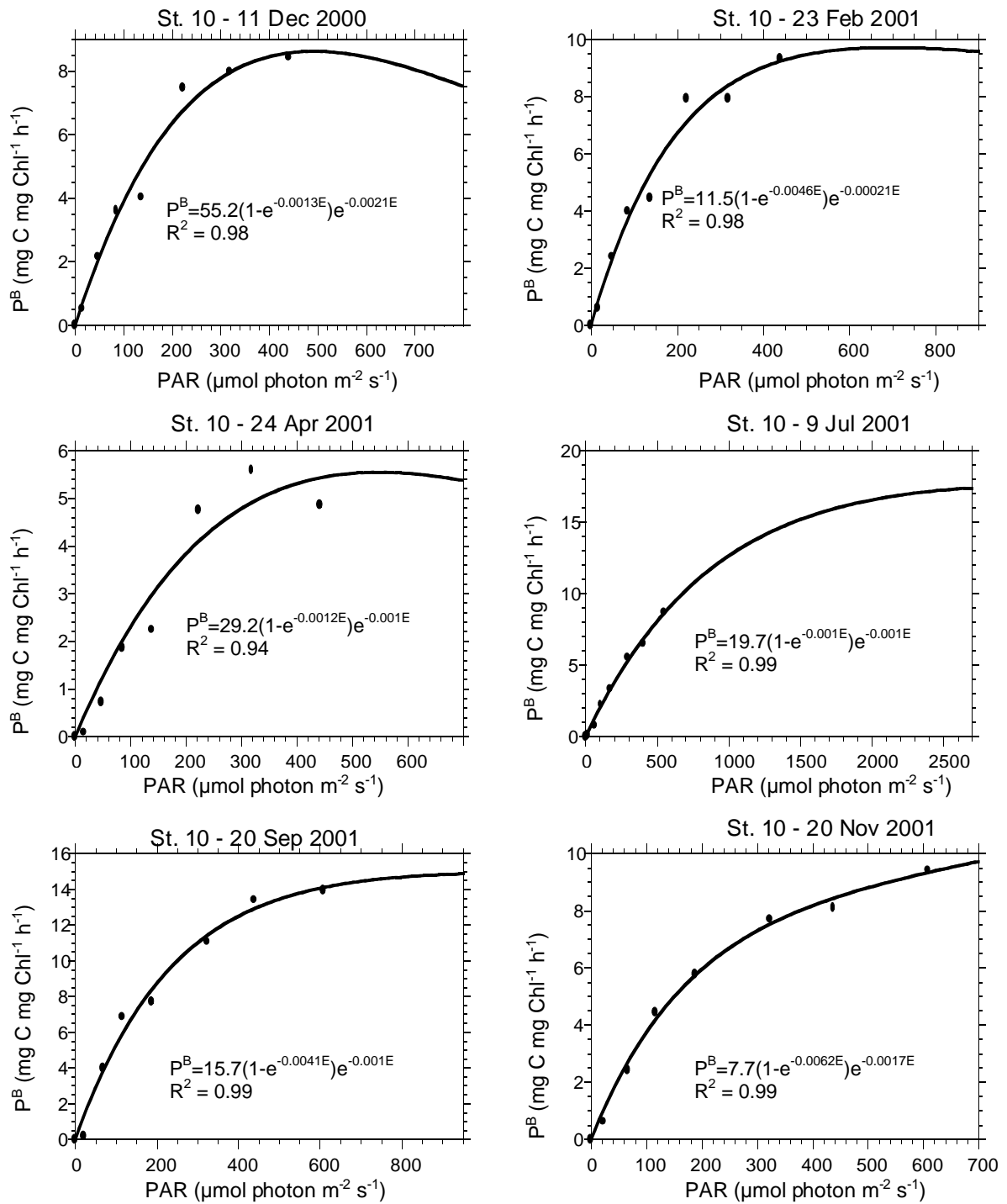




**Fig. 3.30.A.** P-E curves of phytoplankton primary production at station 1 Jakarta Bay, during 6 different surveys (note different scales).



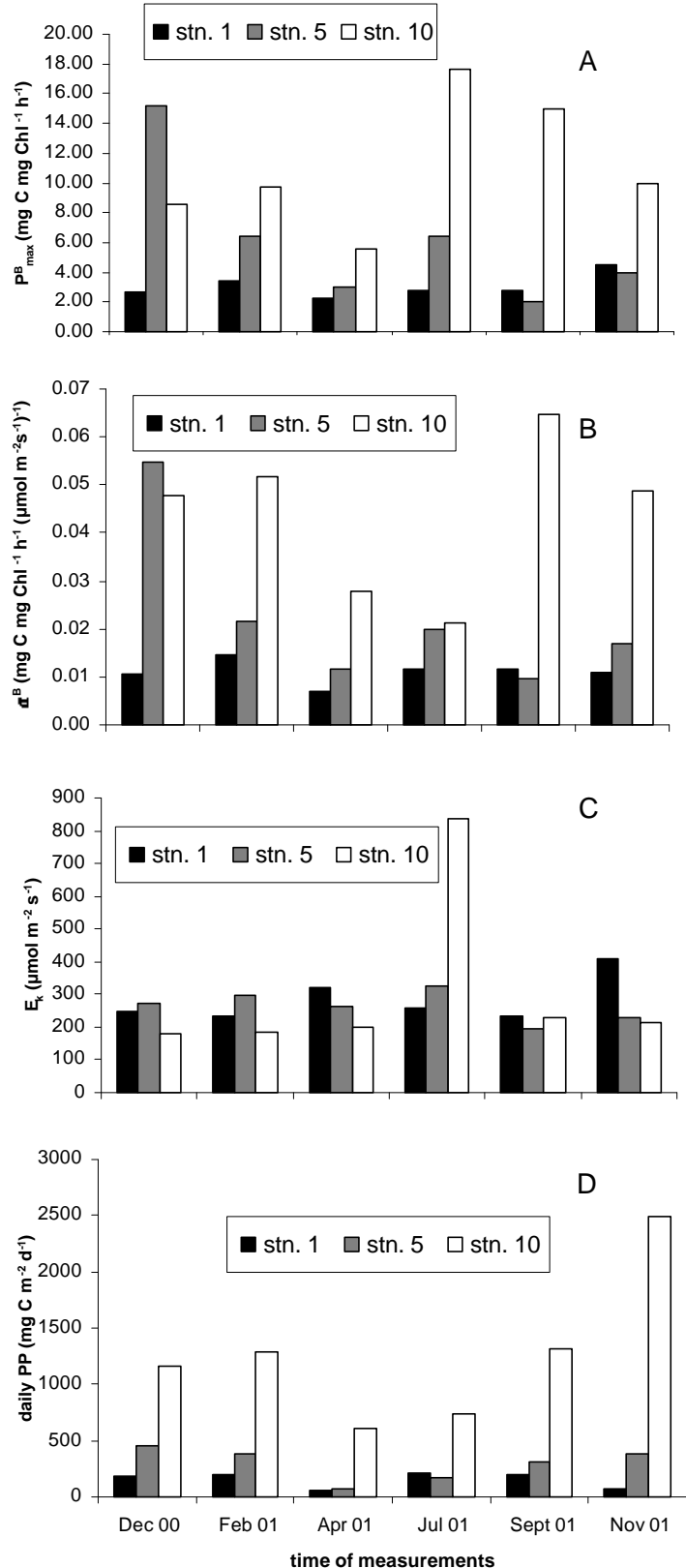
**Fig. 3.30.B.** P-E curves of phytoplankton primary production at station 5 Jakarta Bay, during 6 different temporal surveys (note different scales).



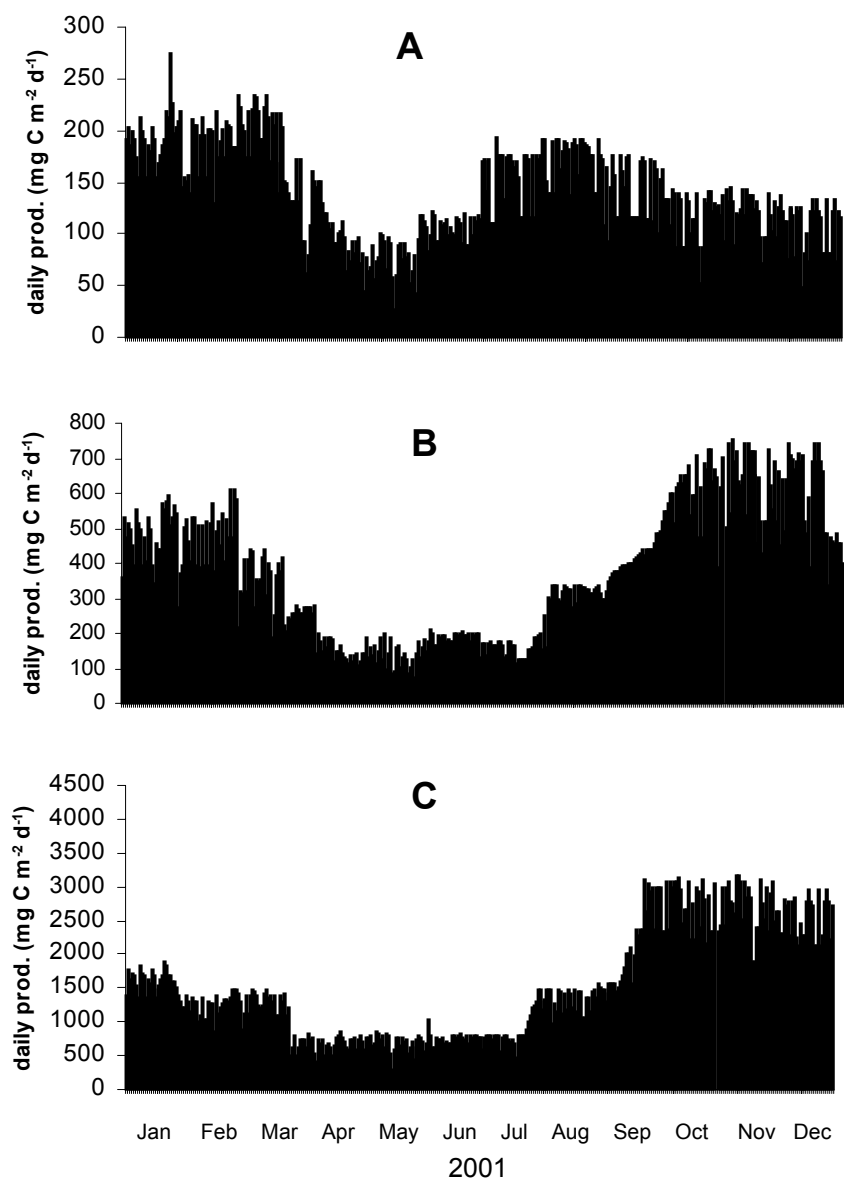
**Fig. 3.30.C.** P-E curves of phytoplankton primary production at station 10 Jakarta Bay, during 6 different temporal surveys (note different scales).

Annual primary productions were calculated for each station by summing up the daily water column production throughout the year of 2001 (in Fig. 3.32: the total dark area under the curve lines). Since the measurements were performed 6 times in the whole study period (all measurements represent seasonal variation in one year period), estimates of daily primary production for the whole dates during the year 2001 was performed based on each survey's P-E curve. For example, the P-E curve developed by measurement in December 2000 was used for the calculation of daily primary production in the period of January 2001, while P-E curve of February 2001 was used for the daily production calculation in the months of February and March 2001, etc. Meanwhile, the daily irradiance data were available for the whole year and utilised as a continuous input for the calculation of daily primary production. A linear interpolation was used to reduce steep variation in daily PP values throughout the year.

Annual primary production accounted for 46.48 g C m<sup>-2</sup> y<sup>-1</sup>, 119.08 g C m<sup>-2</sup> y<sup>-1</sup> and 503.09 g C m<sup>-2</sup> y<sup>-1</sup> for station 1, 5 and 10, respectively. With regards to the trophic state of a coastal ecosystem (Nixon, 1995), Jakarta Bay varied from oligotrophic at station 1 (<100 g C m<sup>-2</sup> y<sup>-1</sup>), mesotrophic at station 5 (between 101-300 g C m<sup>-2</sup> y<sup>-1</sup>) and hypereutrophic at station 10 (>500 g C m<sup>-2</sup> y<sup>-1</sup>).



**Fig. 3.31.** Annual cycle of P versus E parameters and daily production in Jakarta Bay. (A) maximal rate of Chl-specific photosynthesis ( $P^B_{max}$ ); (B) slope ( $\alpha^B$ ); (C) light saturation parameter ( $E_k$ ) and (D) daily primary production (PP).



**Fig. 3.32.** Annual primary production in Jakarta Bay 2001 (A) station 1 ; (B) station 5 and (C) station 10 (note different vertical axis scales).

### 3.1.9. Nutrient addition experiment

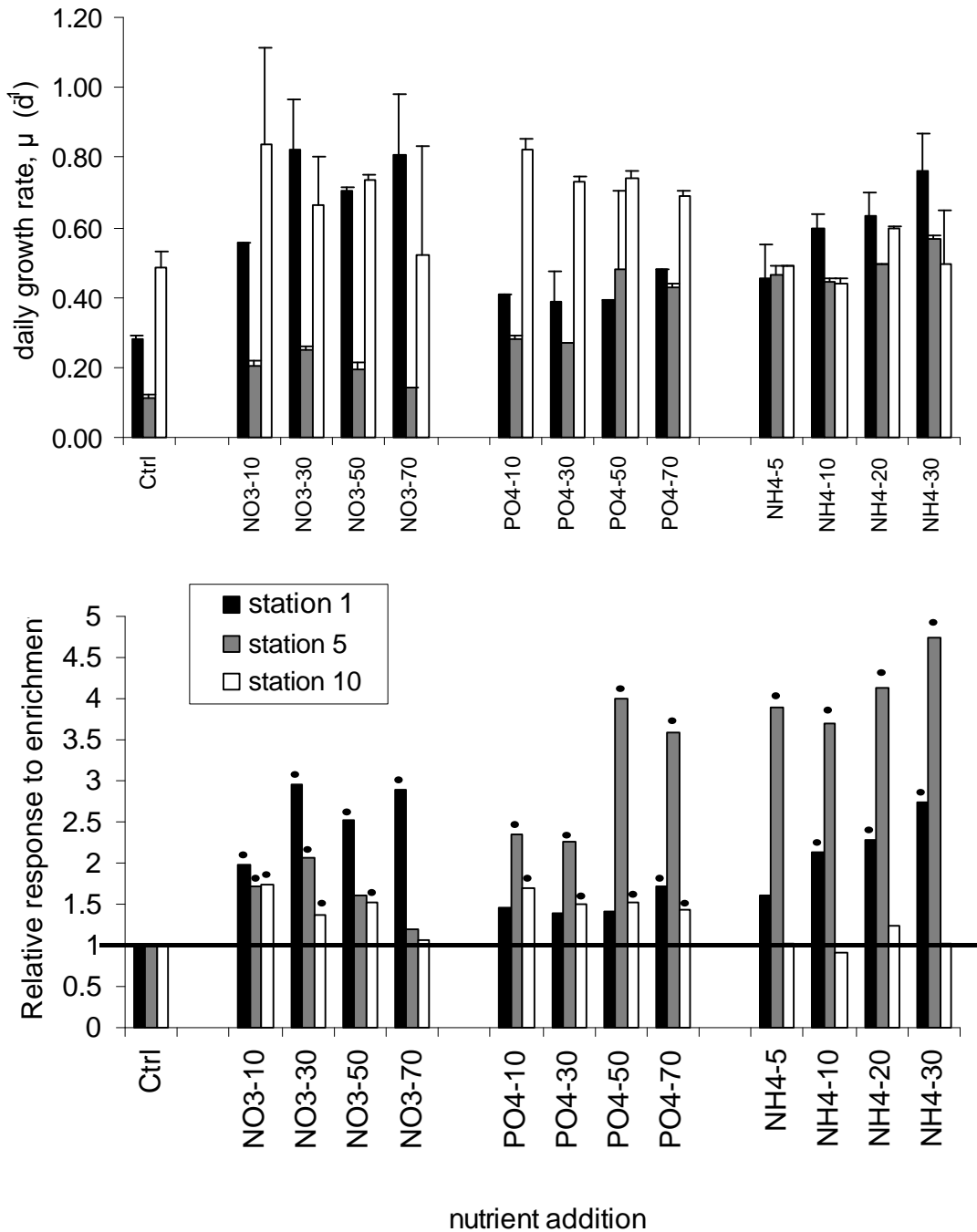
Nutrient addition experiment was carried out to observe the growth responses of phytoplankton assemblages toward addition of nutrients. Phytoplankton assemblages were taken from different nutrient level sites in Jakarta Bay. Station 1 represents a relatively low nutrient site, station 5 represents a moderate nutrient site, whereas station 10 represents a high nutrient site. The experiment was conducted for 30 hours (from 8 August 2001 till 10 August 2001). Table 3.2. and Fig. 3.33. summarise the results of nutrient addition experiments on the growth of phytoplankton (represented as chlorophyll *a*). The 'natural' phytoplankton growth rate ( $\mu$ ) (control at Table 3.2) varied between  $0.12 \text{ day}^{-1}$  (station 5) to  $0.48 \text{ day}^{-1}$  (station 10), showing a higher growth rate of the rich-nutrient phytoplankton assemblage than that of the poor-nutrient sites. Bioassays showed a significant ( $p < 0.01$ ) increase on

phytoplankton growth rate at station 1 towards addition of  $\text{NO}_3\text{-N}$  (all dosages),  $\text{PO}_4\text{-P}$  (only at 70  $\mu\text{M}$   $\text{PO}_4\text{-P}$ ) and  $\text{NH}_4\text{-N}$  (at dosages of 10, 20 and 30  $\mu\text{M}$   $\text{NH}_4\text{-N}$ ). At station 5, a significant increase on growth occurred towards addition of  $\text{NO}_3\text{-N}$  (at low dosages 10 and 30  $\mu\text{M}$   $\text{NO}_3\text{-N}$ ),  $\text{PO}_4\text{-P}$  (all dosages) and  $\text{NH}_4\text{-N}$  (all dosages). And at station 10, a significant increase was observed towards addition of  $\text{NO}_3\text{-N}$  (at dosages 10, 30 and 50  $\mu\text{M}$   $\text{NO}_3\text{-N}$ ) and  $\text{PO}_4\text{-P}$  at all dosages. These results indicate potential limitation of  $\text{NO}_3\text{-N}$  and  $\text{NH}_4\text{-N}$  at station 1 (offshore waters), while  $\text{PO}_4\text{-P}$  and  $\text{NH}_4\text{-N}$  were the limiting nutrients at station 5 (middle part of the bay), whereas station 10 (inshore waters) was limited by  $\text{NO}_3\text{-N}$  and  $\text{PO}_4\text{-P}$ .

**Table 3.2.** Average daily growth rate for phytoplankton assemblages at different nutrient addition dosages at stations 1,5 and 10 in Jakarta Bay. \* = t-test significantly different to control ( $p < 0.05$ ). Growth rates ( $\mu = \ln(\text{Nt}/\text{No})/t$ ) were calculated by using chlorophyll *a* as growth indicator.

Nutrient concentration ( $\mu\text{M}$ )	St-1	St-5	St-10
Control (without nutrient addition)	0.28	0.12	0.48
<b><math>\text{NO}_3\text{-N}</math></b>			
10	0.55 *	0.21 *	0.84*
30	0.82 *	0.25 *	0.66*
50	0.70 *	0.19	0.73*
70	0.81 *	0.14	0.52
<b><math>\text{PO}_4\text{-P}</math></b>			
10	0.41	0.28*	0.82 *
30	0.39	0.27*	0.73 *
50	0.39	0.48 *	0.74 *
70	0.48 *	0.43 *	0.69 *
<b><math>\text{NH}_4\text{-N}</math></b>			
5	0.45	0.47 *	0.49
10	0.60 *	0.44 *	0.44
20	0.64 *	0.50 *	0.60
30	0.76 *	0.57 *	0.50

There was no significant change in species composition during bioassay. The dominant species was *Skeletonema costatum* and growth rates on the basis chlorophyll *a* was concomitantly followed by a change of phytoplankton cell numbers.



**Fig. 3.33.** Nutrient bioassays of phytoplankton community growth in Jakarta Bay. Biomass increase (chlorophyll *a*) in response to enrichment with NO<sub>3</sub>-N, PO<sub>4</sub>-P and NH<sub>4</sub>-N relative to control. Bars are standard deviations (upper graph).

● = significantly higher growth rate than control (t-test,  $p < 0.05$ ).

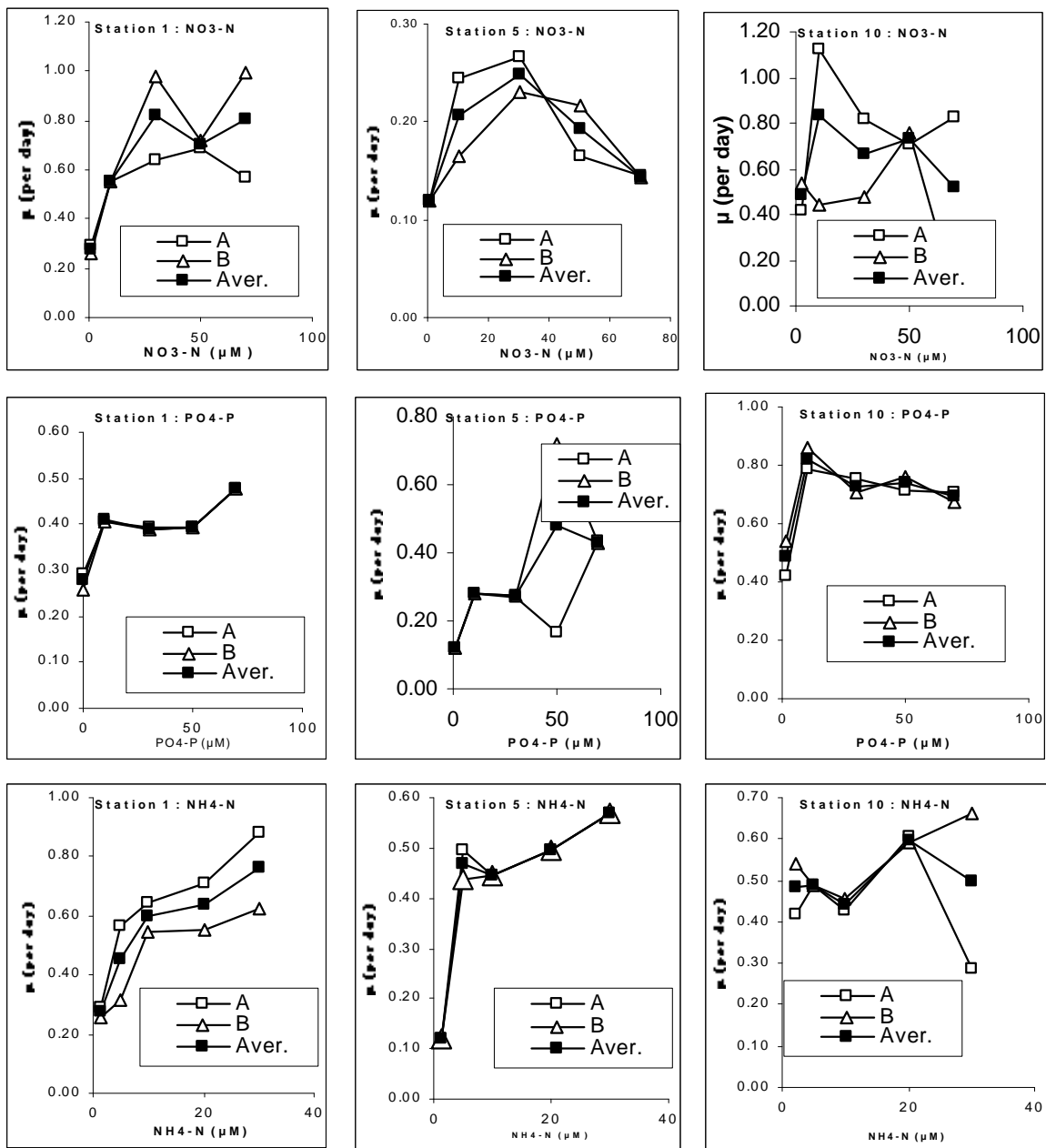
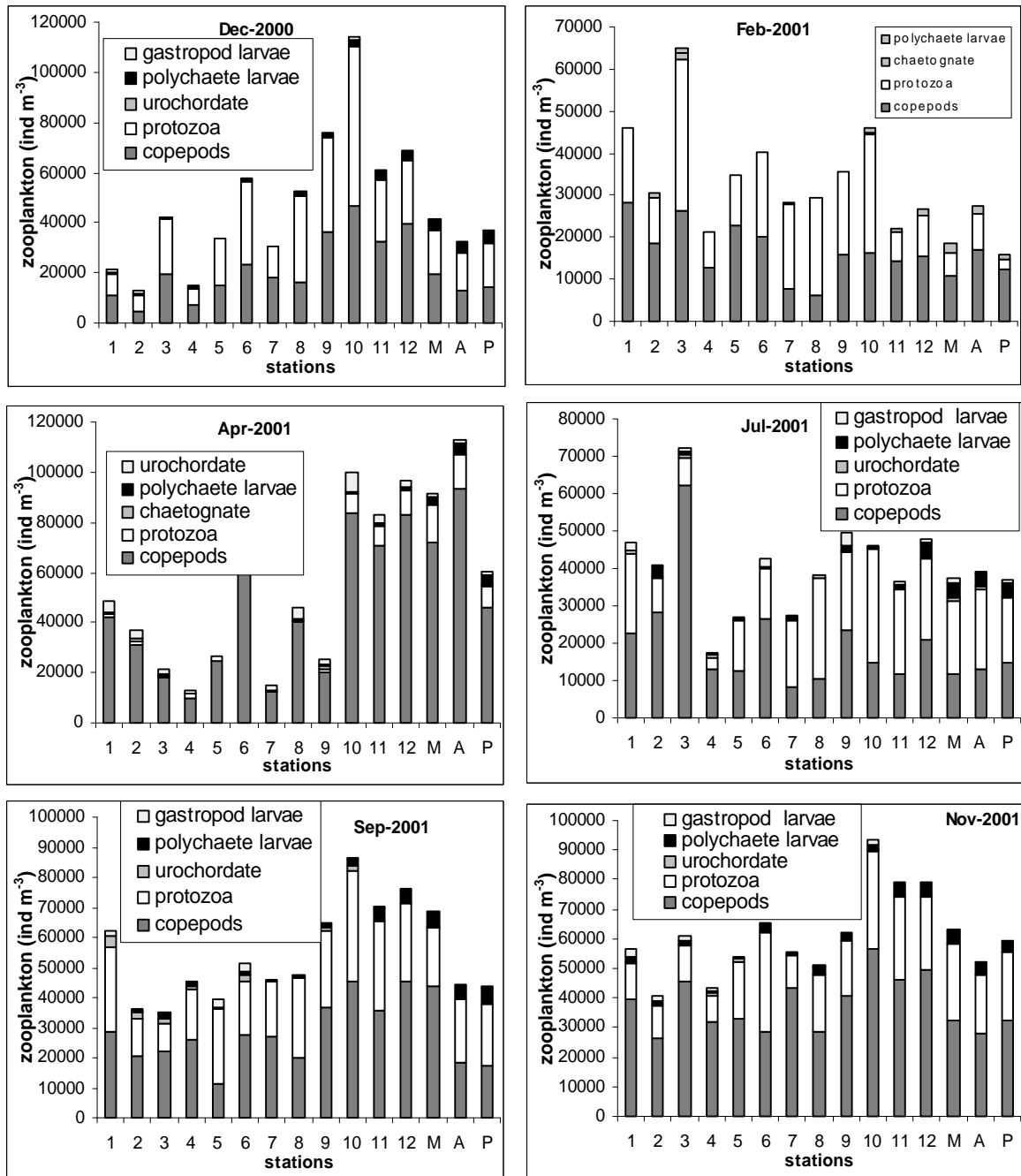


Fig. 3.34. Growth rates of phytoplankton assemblages at different nutrient addition dosages in stations 1,5 and 10, Jakarta Bay.



### 3.1.10. Zooplankton community

In general, zooplankton communities at all stations were dominated by marine copepods and then followed by protozoa (Fig.3.35). The other groups were found in minor proportions such as gastropod larvae, polychaete larvae and urochordates. There was a significant difference in zooplankton abundance between sites (ANOVA,  $p < 0.001$ ), but there was no significant difference between temporal surveys, showing a low seasonal variation. Zooplankton was less abundant at the outer stations and river mouth stations, but they were abundant along the inshore stations and in the middle part of the bay. This fits with the distribution pattern of phytoplankton biomass and cell



**Fig.3.35.** Zooplankton groups at each sampling station and temporal survey in Jakarta Bay. M = Marunda river mouth ; A = Angke river mouth and P = Priok river mouth.

abundance ( $p < 0.001$ ,  $R = 0.77$ ), showing a strong link between predators (zooplankton) and preys (phytoplankton).

In this study, the occurrence of gastropod and polychaete larvae at several sampling sites was observed. The gastropod larvae (mollusc) were more abundant at the outer sites of the bay, while polychaete larvae were more abundant along the inshore and river mouth stations. The occurrence of the larvae is an indication of the occurrence of the adult organisms in the respective areas. Gastropods are strongly associated with a more sandy high-oxygen substrate, while polychaetes were more associated with muddy low-oxygen sediment (Nybakken, 1988).

### 3.1.11. Cluster and Principal Component Analysis

A cluster analysis based on similarity index was performed (by means of Minitab Software) to evaluate similarities between stations and temporal surveys. The grouping process was performed on the basis of 32 environmental variables measured at each station during the whole study period. These variables were : dissolved inorganic nutrients, chlorophyll *a*, salinity, turbidity, temperature, oxygen saturation, pigments (9 pigments), phytoplankton abundance,  $Z_{mix}$ ,  $Z_{eu}$ ,  $Z_{mix}:Z_{eu}$ , secchi depth readings, pH, N:P and N:Si ratio, light attenuation coefficient, and average water column irradiance (*lav.*). To support the cluster analysis, a Principal Component Analysis (PCA) was performed, utilizing the 32 variables similar to those used in the cluster analysis.

Fig. 3.36. and 3.37. show a tree-diagram and PCA, respectively. Cluster analysis of the Jakarta Bay stations resulted in 4 main groups of stations, which are : (1) stations 1,4 and 7 ; (2) stations 5, 2, 6, 9 and 8 (3) stations 3, 12, Angke, 11, Marunda and 10 ; and (4) the station at Priok river mouth.

Group 1 was located at the outer part of the bay. The tree-diagram shows that these stations show in a high degree of similarity (above 95%) and the biplot PCA diagram shows that this group was characterized by low nutrients, low chlorophyll *a*, low phytoplankton abundance, high salinity, low turbidity, high secchi disk readings, and a high  $Z_{mix}:Z_{eu}$  ratio.

The second group consists of stations 5,2,6,9 and 8, located in the middle part of the bay characterized by high values in secchi depth readings, high nitrite, high salinity and high N:P ratio, but moderate in  $Z_{eu}$ ,  $Z_{mix}:Z_{eu}$  ratio, chlorophyll *a*, phytoplankton abundance, pigments and nutrients.

The third group consists of stations 3,12, Angke, 11, Marunda and 10, located in the inshore waters characterized by high values in average water column irradiance, chlorophyll *a*, phytoplankton, pigments, turbidity, attenuation coefficient and nutrients, but they were low in  $Z_{eu}$ ,  $Z_{mix}:Z_{eu}$  ratio, nitrite, secchi depth readings, oxygen saturation, N:P ratio and salinity. This group actually can be further divided into 2 sub-groups : (1) stations 3, Angke river mouth and 11, and (2) stations Marunda river mouth and 10.

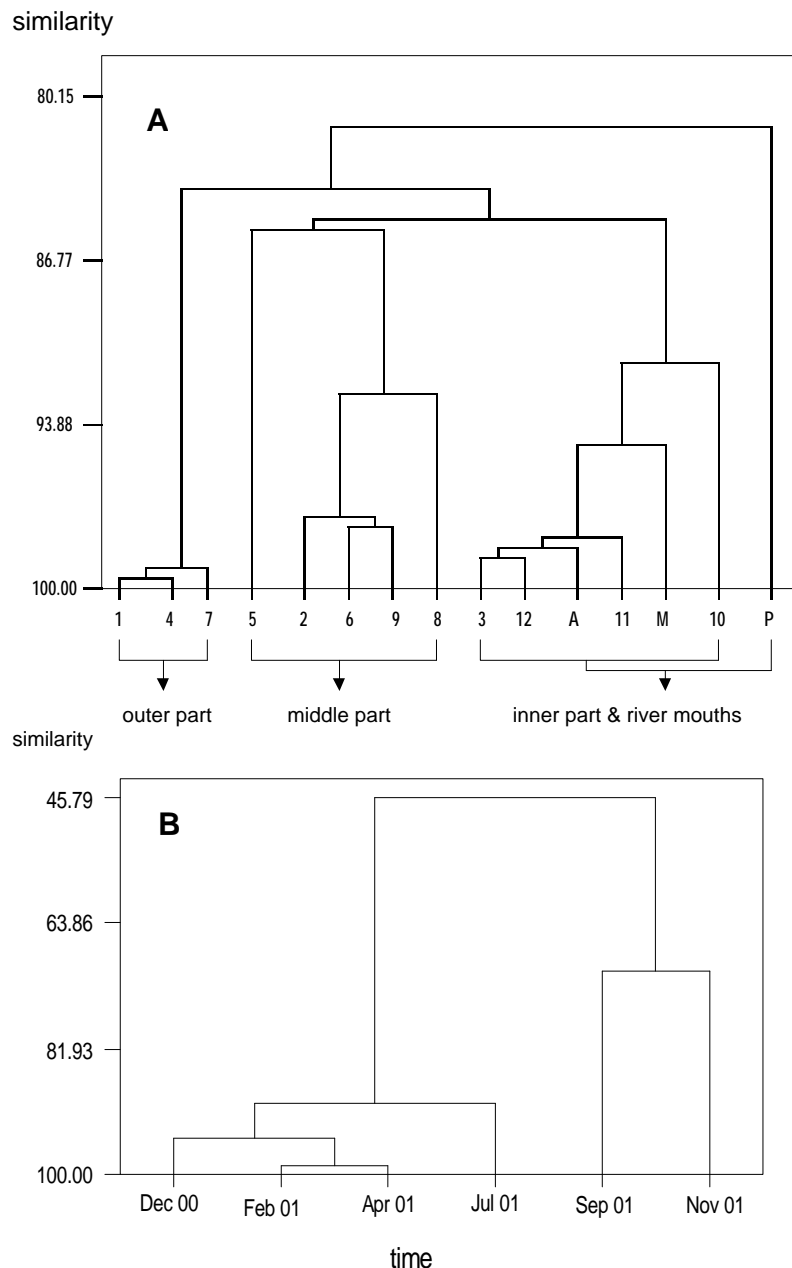
The last group was Priok river mouth. This station was strongly characterized by high turbidity, nutrients, chlorophyll *a* and pigments and phytoplankton abundance. Meanwhile, this station was low in  $Z_{eu}$ , secchi depth readings,  $Z_{mix}:Z_{eu}$  ratio, and salinity.

Cluster analysis based on the temporal surveys (Fig. 3.36.B.) showed that there were 2 groups along the study period. First group consists of surveys in December 2000, February 2001, April 2001 and July 2001, while the second group consists of survey in September 2001 and November 2001. In more detail, the first group can be further divided into 3 sub-groups : (1) December 2000 ;(2) February 2001 and April 2001 and (3) July 2001. Biplot PCA analysis showed that the second group (September and November 2001) characterized by high values in ammonium, silicate, chlorophyll *a*, phytoplankton, N:P ratio and turbidity but they were low in salinity, oxygen saturation, N:Si ratios and  $Z_{mix}:Z_{eu}$  ratio.

The PCA biplot diagram (Fig.3.37) shows that there are 2 axis (factors) resulted from reduction of 32 factors (number of variables). As its main purpose, the PCA combines more than 2 factors (variables) into 2 factors through reduction of these factors. In Jakarta Bay, the variables of  $Z_{mix}:Z_{eu}$ , I average, phytoplankton abundance and chlorophyll *a* are highly related to factor 2, while the others variables are highly related to factor 1.

**Fig. 3.36.**

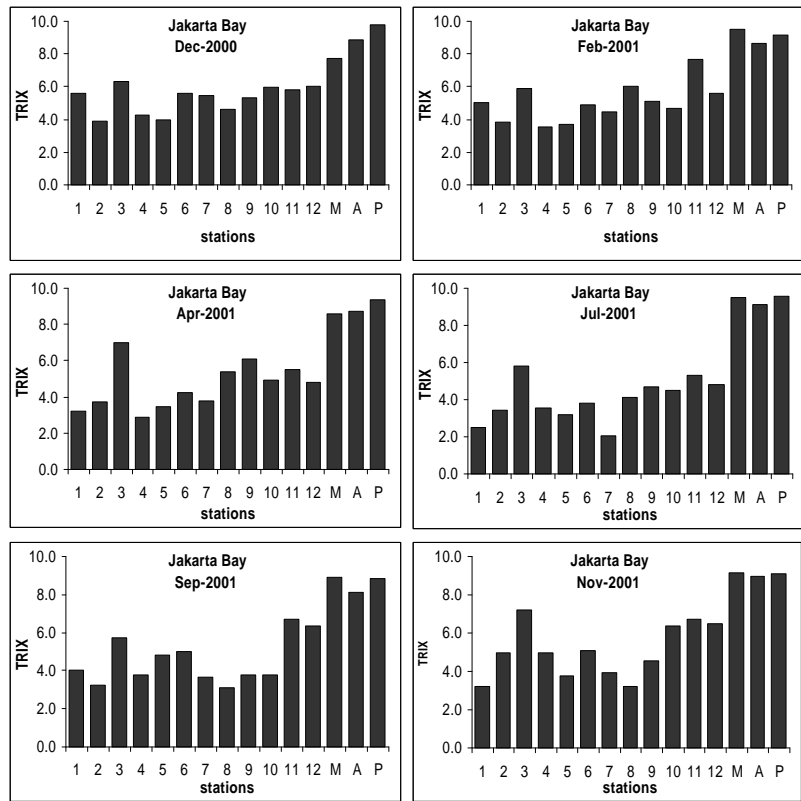
Cluster diagram of stations (A) and temporal surveys (B) in Jakarta Bay. M=Marunda river mouth, A=Angke river mouth, P=Priok river mouth





This classification is also based on the primary production values of the area (e.g. Nixon, 1995), which showed a hyper-eutrophic in the river mouth and its surroundings, decrease down to eutrophic in the middle and finally mesotrophic in the outer part of the bay.

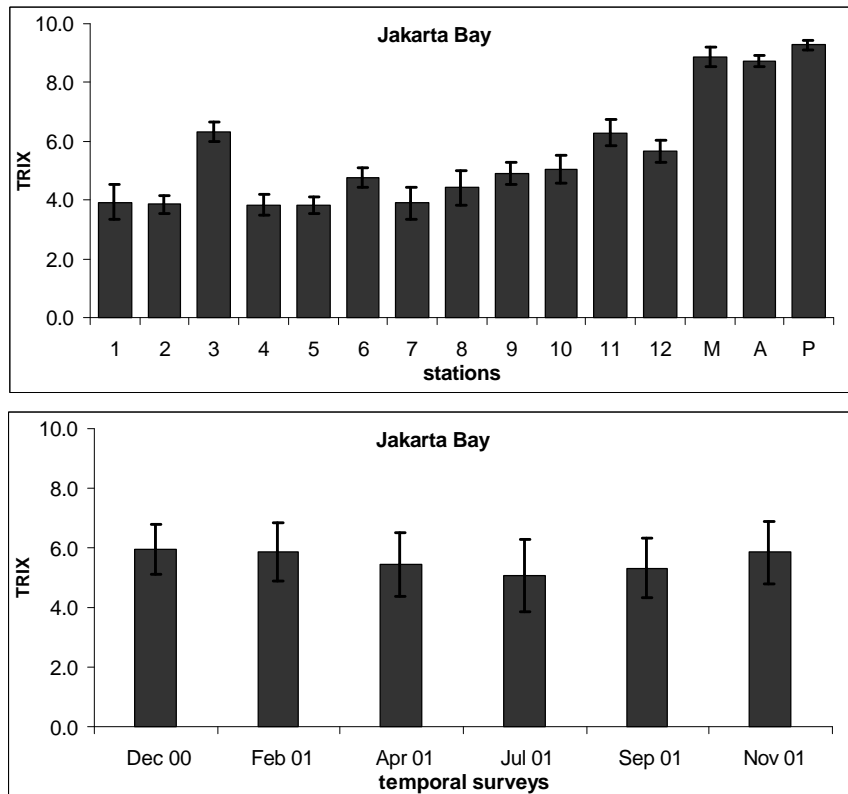
Temporal variation was not significant, with a minimum average of TRIX in July 2001 (5.06) and a maximum in December 2000 (5.94) (Fig.3.39). The TRIX average of February 2001 and November 2001 were also slightly higher compared to that of April, July and September 2001. This relative stability in trophic state is different to that of temperate waters, which shows a strong seasonal variation, ranging from low trophic state in winter and high state during spring (Ærtebjerg *et al.*, 2001). In temperate waters, during winter, even if the nutrients are high, production is low, resulting in low values for TRIX.



**Fig. 3.38.** TRIX for each measurement time in Jakarta Bay. M = Marunda river mouth, A = Angke river mouth and P = Priok river mouth.

**Fig.3.39.**

Average TRIX values in spatial (above) and temporal (below) scales in Jakarta Bay. M = Marunda river mouth; A = Angke river mouth ; P = Priok river mouth. Bars are standard deviation calculated from 6 temporal data (upper graph) and 15 spatial data (lower graph).



## 3.2. Discussion on Jakarta Bay

### 3.2.1. Parameters related to underwater irradiance

Comparison between light resource relative to nutrient resource (DIN) (Cloern , 1999 : see results chapter) showed that phytoplankton communities in the river mouths and inshore waters of Jakarta Bay were potentially limited by light resource rather than nutrient resource (DIN). In these sites, the incoming rivers increase water turbidity, reducing light penetration into water column. In the offshore waters, as the influence of river discharges weakens, the turbidity decreases, increasing underwater irradiance. However, phytoplankton and their light requirements are not only depend on underwater irradiance, but also depend on their position in the water column towards the light available for conducting net photosynthesis (Lucas *et al.*, 1998). Although the water is turbid, but if the mixed depth of the water body is similar or less than its euphotic depth, the phytoplankton will always in the illuminated part of water column, where light is sufficiently available for net primary production. This concept is known as  $Z_{mix}:Z_{eu}$  ratio, which is often used to predict bloom initiation and net primary production (Kocum *et al.*, 2002, Tillmann *et al.*, 2000). Low ratio is may indicate a longer mean resident time of phytoplankton in the illuminated part of the water column than in the dark, thus leading to a higher net production.

Jakarta bay with its relatively small water depth (average depth of 8.4 m) is always completely mixed till the bottom layer and stratification is likely never to occur, except in a limited area, close to the river mouths, due to differences in salinity (Suyarso, 1995). Accordingly, the whole bay is assumed as a mixed zone ( $Z_{mix}$ ). The ratios of  $Z_{mix}$  to  $Z_{eu}$  have been calculated, resulting in a variation in values. In Jakarta Bay,  $Z_{mix}:Z_{eu}$  ratios were lower (<1) in the inshore waters compared to those of the offshore waters (>1), showing that light-availability is better in the inshore waters than in the offshore waters. In the inshore waters, although light attenuation coefficients were high, but due to its shallower depth, the  $Z_{mix}:Z_{eu}$  ratios were low. Inversely, in the more offshore waters, although light attenuation coefficients were low, increase in water depth resulted in high  $Z_{mix}:Z_{eu}$  ratios. This is different from the observation made by Tillmann *et al.* (2000) in the Wadden Sea, which showed that  $Z_{mix}:Z_{eu}$  ratios were depend to water depth only.

Seasonal variation in the  $Z_{mix}:Z_{eu}$  ratio was high, showing increase ratios during the rainy season. During the rainy season, when the river discharge increases, the turbidity also increases, resulting in lower euphotic depths and in turn enhances the  $Z_{mix}:Z_{eu}$  ratios.

### 3.2.2. Nutrient loads and concentrations

Estimates of nutrient loads for the whole study area were based on the 3 rivers observed: Angke, Marunda and Priok. Selection of those 3 rivers was based on the spatial representation of their catchment area. Angke River represents the western part of Jakarta City, Priok River the middle part and Marunda River the eastern part. The mean discharges of these 3 rivers were  $27.8 \text{ m}^3 \text{ s}^{-1}$ ,  $14.7 \text{ m}^3 \text{ s}^{-1}$  and  $11.7 \text{ m}^3 \text{ s}^{-1}$  for Angke, Priok and Marunda, respectively. The other 10 rivers, which also flow through the city and finally into the bay, have a total mean discharge of  $58.5 \text{ m}^3 \text{ s}^{-1}$ .

Nutrient load estimates showed that from these 3 rivers, Priok River was the biggest contributor of ammonium and phosphate, Angke River for nitrate, nitrite and silicate while Marunda contributed the least. Silicate is generally believed to be less associated with human activities (except damming, but this does not occur in the area) (Livingston, 2002). Ammonium seems to be the major inorganic nutrient form of the domestic waste water in Jakarta City. Total annual loads of ammonium and DIN from the three rivers accounted for 9302 t y<sup>-1</sup> and 10205 t y<sup>-1</sup>, respectively, while for phosphate, nitrate and silicate were 3236 t y<sup>-1</sup>, 869 t y<sup>-1</sup> and 25160 t y<sup>-1</sup>, respectively. If it is assumed that there is no significant variation in nutrient concentration between rivers and the 3 observed rivers have 48% discharge of the total river discharges, the total annual load of ammonium, DIN, phosphate, nitrate and silicate to the bay can be estimated to be 19379 t NH<sub>4</sub>-N y<sup>-1</sup>, 21260 t DIN y<sup>-1</sup>, 6741 t PO<sub>4</sub>-P y<sup>-1</sup>, 1810 t NO<sub>3</sub>-N y<sup>-1</sup> and 52416 t Si y<sup>-1</sup>, respectively.

Comparison to previous nutrient load estimates for Jakarta Bay calculated by Anna (1999) shows that estimate of ammonium load in the present study is lower, while loads of phosphate and nitrate are higher. Her calculations showed that the loads of ammonium, phosphate and nitrate were 37310 t NH<sub>4</sub>-N y<sup>-1</sup>, 2440 t PO<sub>4</sub>-P y<sup>-1</sup> and 1398 t NO<sub>3</sub>-N y<sup>-1</sup>, respectively. Lack of regular monitoring data in the area limits evaluation on the trends in nutrient loads.

Relatively high seasonal variation of riverine nutrient loads was observed in this study, showing high values during the rainy season and low values during the dry season. During the rainy season, higher precipitation causes increase of river discharges, and in turns increase nutrient loads in the rivers.

Comparison between nutrient loads and nutrient concentration in the recipient waters showed that the nutrient concentration in the whole bay waters was not only governed by the loads of nutrients from the 3 rivers observed in this study. Along the bay's coastline, besides rivers, scattered sources of nutrients exist. Shrimp pond cultures at both west and east part of the bay, the international ship-harbour in the middle of the bay, several fishing harbours, industrial activities and many other human activities are responsible for the high nutrients concentrations in the bay.

In Jakarta Bay, the annual average concentrations of phosphate, DIN, and silicate were 5.1 μM PO<sub>4</sub>-P, 20.1 μM DIN and 44.8 μM Si, respectively. Comparison with earlier studies, this study results were comparable (e.g. Suyarso, 1995). Comparison with the Johor Strait (Singapore) (Gin *et al.*, 2000), these study results are slightly higher. In the Johor Strait, annual average of phosphate, and DIN were 1.4 μM PO<sub>4</sub>-P and 17.4 μM DIN, respectively.

The concentrations of dissolved inorganic nutrients showed strong spatial and seasonal variations. The high values of nutrients always prevailed at river mouths and surrounding sites, while in the more offshore waters, the nutrient concentrations rapidly declined. A steep gradient of nutrient concentrations occurred in the riverine-marine transitional zone. DIN ranged from 18 to 162 μM N in the river mouths and steeply decreased to 1 to 22 μM N in the immediate seaward sites. This steep gradient is a common phenomenon in estuaries due to dilution with water low in nutrients, as shown in the Rhone estuary, where nitrate was 110 μM at the river mouth and went down to 2 μM at the sea sites (Bianchi *et al.*, 1994). In the offshore waters of Jakarta Bay, nutrients sharply decreased, which could

be caused by dilution with low nutrient waters, but also be due to a rapid uptake by phytoplankton.

On a seasonal basis, strong fluctuation in nutrient concentrations was observed, showing a high peak in November 2001 (rainy season), and the low peak in April and July 2001 (dry season), especially for nitrate, ammonium and silicate. Seasonal variation in Jakarta Bay was previously observed by Praseno and Kastoro (1980) and Suyarso (1995), who showed higher values of nutrients during the rainy season compared to the dry season, which mostly due to increase of nutrient loads from the rivers.

### 3.2.3. Phytoplankton biomass and community

Annual average of phytoplankton biomass in Jakarta Bay accounted for  $13.20 \mu\text{g Chl } a \text{ l}^{-1}$  (ranging from  $0.5 \mu\text{g Chl } a \text{ l}^{-1}$  to  $92 \mu\text{g Chl } a \text{ l}^{-1}$ ), to be which makes that this area can be classified as a eutrophic area, especially in the inshore waters (e.g. according to Nixon, 1995). Comparison to earlier studies, phytoplankton biomass of this study in Jakarta Bay was in the same range. Previous investigations performed in the area (Arinardi, 1995) showed that during the rainy season, chlorophyll *a* content was higher than during the dry season, with maxima of  $7.5 \mu\text{g Chl } a \text{ l}^{-1}$  around Angke river mouth. Investigations done by Kaswadji *et al.* (1993) showed that chlorophyll *a* around Marunda river and eastern part of the bay ranged from  $5.24 \mu\text{g Chl } a \text{ l}^{-1}$  to  $17.50 \mu\text{g Chl } a \text{ l}^{-1}$  which are comparable with this study result. In this study, the mean chlorophyll *a* concentration of the inshore waters was  $15.2 \mu\text{g Chl } a \text{ l}^{-1}$ .

Steep spatial gradients of phytoplankton biomass occurred with a mean annual value in the river mouths of  $31.4 \mu\text{g Chl } a \text{ l}^{-1}$ , decreasing to  $15.8 \mu\text{g Chl } a \text{ l}^{-1}$ ,  $7.8 \mu\text{g Chl } a \text{ l}^{-1}$  and  $2.2 \mu\text{g Chl } a \text{ l}^{-1}$  in the inner, middle and outer parts of the bay, respectively. In the inner part sites, high nutrient concentrations and optimum light availability condition supports a better biomass accumulation rather than in the more offshore waters. In these more saline waters, besides relatively low in nutrients, the light availability for net production of phytoplankton also reduces, thus, in combination, resulting in unfavourable condition for accumulation of phytoplankton biomass. This rapid decrease of phytoplankton biomass in the more offshore waters might be also due to an intensive grazing on phytoplankton by zooplankton and the green-mussels (*Perna viridis*), which are widely cultured by local fishermen in the bay. A phytoplankton biomass control through mollusc grazing seems to be an effective way as part of a top-down control of coastal eutrophication. In the Hudson estuary and San Francisco Bay (USA), mussels play an important role in phytoplankton biomass control and able to decline around 85% of phytoplankton biomass (Jassby *et al.*, 2002 ; Cloern, 2001). Cultures of this filter feeder animal have been started since 1987 as an alternative activity of the fishermen. It has increased, involving more fishermen and more yield has been obtained in the last 15 years (Anonymous, 1999).

Although grazing rates of zooplankton on phytoplankton were not specifically measured in this study, the data on zooplankton may indicate the possibility of intensive grazing. Zooplankton community in the area was dominated (>60%) by marine copepods (*Paracalanus* spp, *Acartia* spp. and *Nauplius*). Estuarine copepods have been shown to be effective grazers able to ingest about 50% of the phytoplankton biomass per day (Alpine and Cloern, 1992). However, the effectiveness of zooplankton grazing varies



greatly per seasonal and among estuaries, and ranged from 15% to almost 90% of the primary production.

A seasonal increase in phytoplankton biomass occurred during the rainy season. This is in accordance with the increase of nutrients in the bay during the rainy season, due to the increase of nutrient loads. This conforms with Gin *et al.* (2000), who stated that, a seasonal variation of phytoplankton biomass in the tropical Singaporean waters was mostly due to the increase of nutrient discharges during the rainy season.

Phytoplankton communities in Jakarta Bay were mainly dominated by diatoms (*Skeletonema costatum* and *Pseudonitzschia* spp.), followed by dinoflagellates (*Ceratium* spp. and *Dinophysis* spp.), cyanophyceae (*Trichodesmium* spp.) and chlorophyceae (*Scenedesmus* spp.). The three latter groups mostly occurred in the inner part of the bay, especially in the river mouth sites. This distribution pattern conforms with previous studies done by Arinardi (1995), Kaswadi *et al.* (1993) and Adnan (1994). Arinardi (1995) found that diatoms (mainly *Skeletonema costatum*) were more abundant (reached  $25.26 \times 10^6$  cells  $m^{-3}$ ) in the offshore waters, while dinoflagellates occurred in the more inshore waters, especially close to the river mouths. Comparison to Singaporean tropical waters gives a similar pattern, showing a dominance of diatoms in the more offshore waters (Gin *et al.*, 2000).

The increased numbers of dinoflagellates and cyanophyceae in the river mouths might be related to the decrease of the DIN:PO<sub>4</sub> ratio and relatively calm waters. Dinoflagellates prefer to occur in the calm waters rather than in turbulent waters (Margalef, 1978). Hesse *et al.* (1995) revealed the dominance of dinoflagellates in the stratified part of the German Bight, during periods of calm weather and high nutrients. Meanwhile, in the period of low DIN:PO<sub>4</sub> ratio, and brackish waters of river mouths, cyanophyceae (*Trichodesmium* spp) are at advantage, due to its ability to fix N<sub>2</sub> directly from the water (Hood *et al.*, 2000) and low salinity preferences (Arinardi, 1995).

Finally, it is clearly seen that the variation of phytoplankton biomass in Jakarta Bay was regulated by the variation of nutrient concentrations, showing high values in the inshore waters and during the rainy season and low values in the offshore waters and during the dry season. This conforms with the classical relationship theory between nutrients and phytoplankton biomass (e.g. Margalef, 1978).

### 3.2.4. Planktonic primary production

At spatial and temporal scales, differences in primary production estimates were observed, which are in accordance with the phytoplankton biomass gradient, showing a steep decrease in the more offshore waters and lower values during dry period. In general, this reflects the important role of phytoplankton biomass in primary production variation (e.g. Tillmann *et al.*, 2000 ; Kocum *et al.*, 2002).

The primary production estimates obtained in this study were gross particulate primary production values. The technique used did not incorporate the production of dissolved organic matter. A study done in the Wadden Sea (Tillmann *et al.*, 2000), showed variable values in the contribution of dissolved production on total production (ranging from 19 % to 278 % with a mean value of 63%). The short incubation time used probably gives an

estimate of the gross primary production, which does not include respiratory losses (Tillmann *et al.*, 2000 ; Jassby *et al.*, 2002).

Estimates of annual primary production in the area ranged from 45 g C m<sup>-2</sup> y<sup>-1</sup> (station 1 in the offshore waters) to 503 g C m<sup>-2</sup> y<sup>-1</sup> (station 10 in the inshore waters). In the middle part of the bay annual primary production estimate was 119 g C m<sup>-2</sup> y<sup>-1</sup>. Comparison to other studies done in the same area and other sites in Indonesian estuaries showed that the results obtained from this study were comparable (e.g. Nontji, 1984 ; Kaswadji *et al.*, 1993). Kaswadji *et al.* (1993) used the dark-light bottle oxygen method, which resulted in values ranging from 166 to 214 g C m<sup>-2</sup> y<sup>-1</sup> for the river mouths area in the eastern estuary of Jakarta Bay. Nontji (1984) resulted in a range of 49 to 301 g C m<sup>-2</sup> y<sup>-1</sup> primary production in Jakarta Bay. The relatively low primary production estimate for outer part of Jakarta Bay is in accordance with the low estimate value (23 g C m<sup>-2</sup> y<sup>-1</sup>) done by Nontji (1984) for the Seribu Islands (outer site of Jakarta Bay).

The estimate of primary production based on P vs E relationships is well established (e.g. Tillmann *et al.*, 2000). For a well-mixed estuary like Jakarta Bay, this method seems appropriate as used in some other mixed estuaries like the Wadden Sea (Tillmann *et al.*, 2000), the Colne estuary (England) (Kocum *et al.*, 2002), the Ems Dollard estuary (the Netherlands) (Colijn, 1983) and other well-mixed estuaries. Comparison between in situ and laboratory incubations on the values of primary production has performed by Colijn (1983), resulting a good agreement with a mean difference of only 5 %.

One of the advantages of this technique is its ability to determine the photosynthetic characteristics of the phytoplankton assemblages, which then can be used to determine the production of the system and the factors for its spatial dynamics.  $P_{max}^B$  values of the Jakarta Bay phytoplankton assemblages ranged from 2.05 at station 5 (relatively low-nutrient site) to 17.63 mg C mg Chl<sup>-1</sup> h<sup>-1</sup> at station 10 (high-nutrient site). The results showed a clear trend with higher values at nutrient rich site compared to that of nutrient poor site, underlining the prominent nutrient effects on the variability of  $P_{max}^B$ . Other parameters such as water temperature and light are weakly related to the variation of these  $P_{max}^B$  values. Comparison with other  $P_{max}^B$  values from other estuaries showed that this study values were comparable. Mean  $P_{max}^B$  value of the Wadden Sea phytoplankton assemblage was 4.5 mg C mg Chl<sup>-1</sup> h<sup>-1</sup> (Tillmann *et al.*, 2000). In the Wadden Sea, this value was highly correlated with water temperature, and reached a high value during high temperature period (> 20°C). On the contrary, in the Colne estuary, UK, Kocum *et al.* (2002) found that  $P_{max}^B$  values were not correlated with temperature. In Jakarta Bay, temperature was not a main factor of production variability explaining only around 12 % of the variability of  $P_{max}^B$ . The variability of  $P_{max}^B$  was largely explained by light attenuation coefficient (49%) and nutrient concentrations (56%).  $P_{max}^B$  also depends on the species composition of the phytoplankton community which varied in chlorophyll *a* contents (Tillmann *et al.*, 2000). Diatoms have higher chlorophyll *a* content than other phytoplankton groups such as dinoflagellates, which leads to lower values of Chl-normalized photosynthetic parameters (Tillmann *et al.*, 2000). However, it is probably a minor factor since the phytoplankton assemblages at almost all stations were dominated by diatoms all over the year. Jakarta Bay always has a high water temperature throughout the year (annual mean was 29.7°C). This might be the reason of the generally high  $P_{max}^B$  values in the study area.

The average photosynthetic efficiencies ( $\alpha^B$ ) showed a similar trend with  $P_{\max}^B$ , with high values at nutrient rich sites and low values at nutrient poor sites (ranging from 0.01 to 0.06). This is also outlining the strong nutrient effects on the variability of photosynthetic efficiency. If they are compared to that of Wadden Sea phytoplankton assemblages, the values were comparable (Tillmann *et al.*, 2000).

The  $E_k$  values (ranging from 182 to 835  $\mu$  mol photons  $m^{-2} s^{-1}$ ) were relatively high throughout the study period, suggesting a good acclimatisation on high light intensities. Comparison with  $E_k$  values of other tropical phytoplankton assemblages resulted in comparable values. Phytoplankton assemblages in Hurun Bay, Indonesia, have an annual mean  $E_k$  value of 273  $\mu$  mol photons  $m^{-2} s^{-1}$  (Tambaru, 2000). Meanwhile, comparison of  $E_k$  values with temperate waters, the  $E_k$  values of this study were slightly higher. The Wadden Sea phytoplankton assemblages have an annual mean  $E_k$  value of 216  $\mu$  mol photons  $m^{-2} s^{-1}$  (Tillmann *et al.*, 2000), while the Eastern English Channels has a mean value of 102  $\mu$  mol photons  $m^{-2} s^{-1}$ .  $E_k$  values has been widely used as an indicator of light acclimated state (Tillmann *et al.*, 2000), and this high series of  $E_k$  values in Jakarta Bay showed that the phytoplankton assemblage in the study area were adapted to strong light intensities.

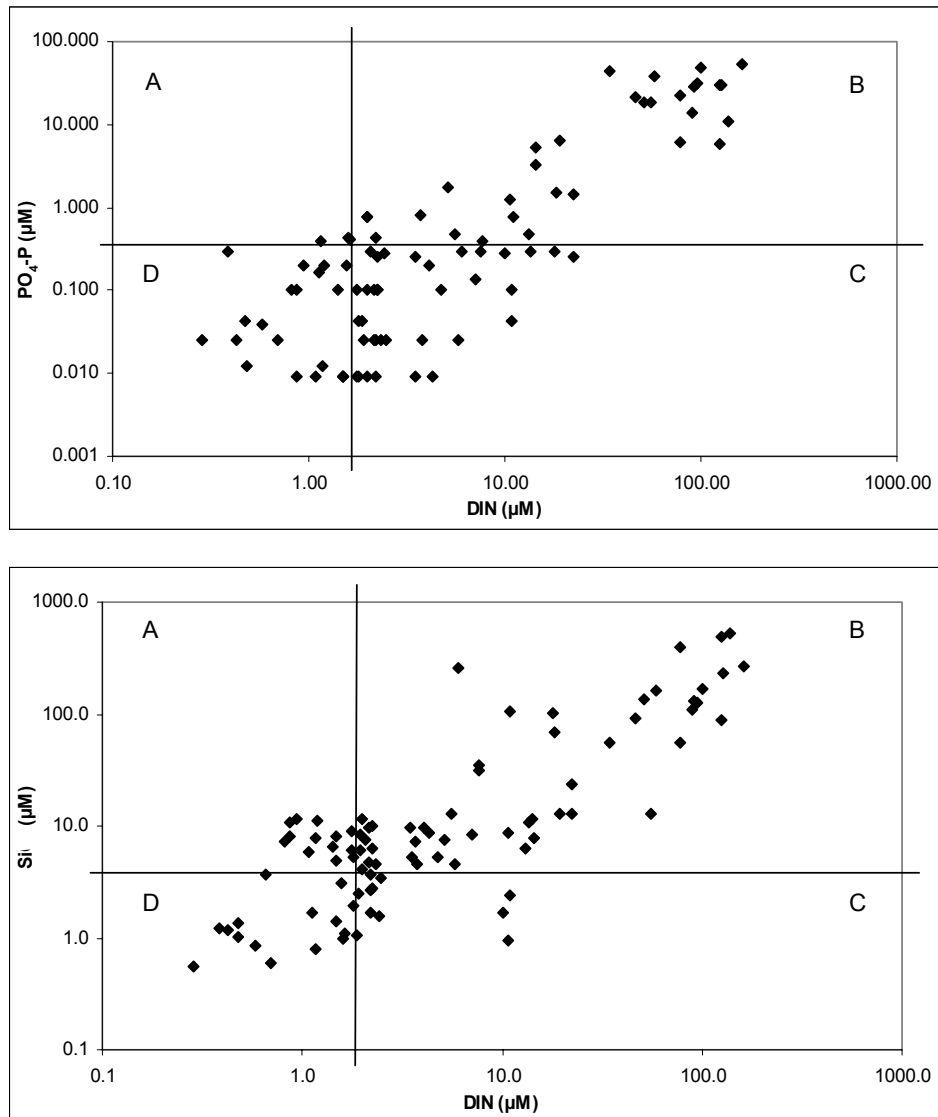
As a conclusion, based on the primary production estimates, Jakarta Bay has 3 distinct primary production areas : high level in the inshore waters, moderate level in the middle part of the bay and low level in the outer part of the bay. This decrease pattern of primary production down the bay is pointing out the prominent role of nutrient variability in the variability of primary production values.

### 3.2.5. Nutrient limitation on phytoplankton growth

To identify which nutrient acts as a limiting element, a combination of techniques such as nutrient enrichment bioassays, molar ratios between ambient inorganic nutrients, and comparison to nutrient threshold values, were used. Results of these different techniques were in agreement. Based on the nutrient enrichment bioassays, it was shown that the phytoplankton assemblages from the three stations in Jakarta Bay responded significantly towards phosphate enrichment, pointing out the strong potential limitation of phosphate. This is in accordance with the indication of phosphate limitation observed through DIN:P ratio, which showed a strong potential limitation of phosphate at all stations, except at the river mouth stations. In the river mouth areas, phosphate was sufficiently available at a level which is unlikely to limit the phytoplankton growth. At these sites, DIN:P ratios were low, indicating no potential limitation of phosphate but a tendency of N limitation. However, compared to DIN threshold for phytoplankton growth ( $> 2 \mu M$  DIN ; Tillmann *et al.*, 2000), the DIN concentration at these sites was sufficiently to allow growth of phytoplankton. The decrease of DIN:P ratio was not caused by lack of N, but due to the increase of phosphate.

The DIN : Si ratio was low at all sites of the bay, and no clear trend could be observed. Around 79% of the values were  $<1$ , indicating no potential limitation of silicate throughout the bay. Compared to the silicate threshold for phytoplankton growth ( $>5 \mu M$ ), most of the stations showed values above this threshold. Freshwater inflow from rivers seemed to be a continuous source of silicate for the bay. Besides the 3 river observed, there are 10

other small rivers which flow into the bay. These altogether ensure a sufficient supply of silicate for the bay.



**Fig.3.40.** Plot of DIN and  $\text{PO}_4$  (upper graph) and DIN and silicate (lower graph) against assumed nutrient thresholds values. The D area on each figure defines the region for which nutrient concentrations are below published half-saturation constants for nutrient uptake of natural phytoplankton populations, while the B area indicates the region where ambient nutrient concentrations are above these thresholds.

At seasonal scale, DIN:P ratios of the rainy season were slightly higher than those of the dry season, which was caused by the increase of N loads from the incoming rivers. Meanwhile, there was a weak seasonal variation in the DIN:Si ratio, which was caused by the proportional seasonal changes of the N and Si loads.

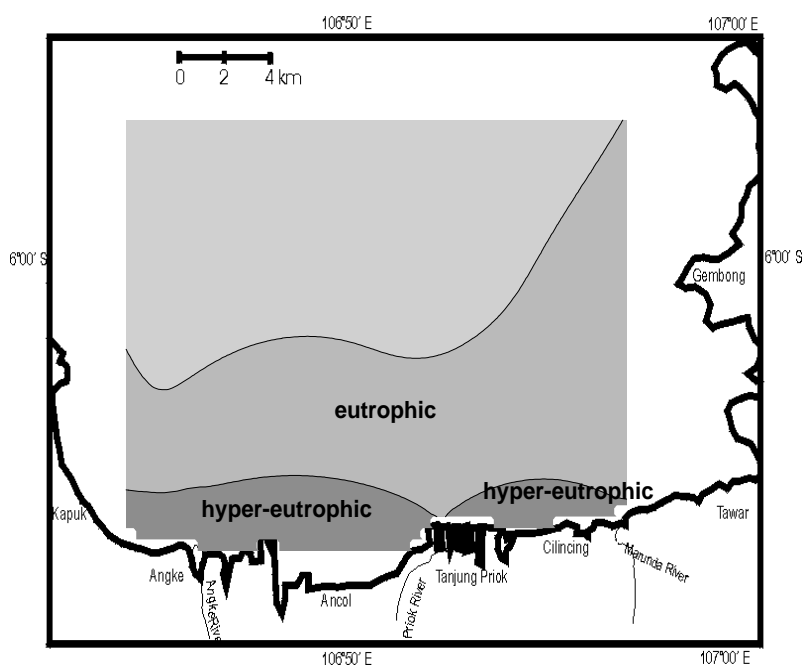
Fig. 3.40 shows a plot of nutrient concentrations in Jakarta Bay, which is divided into 4 regions, which are characterized by different levels of the half saturation constants of nutrient uptake ( $K_s = 2 \mu\text{M}$  DIN;  $K_s = 0.5 \mu\text{M}$   $\text{PO}_4$ ; and  $K_s = 5 \mu\text{M}$  Si). The values used as a threshold for phytoplankton growth was taken from the upper range of half-saturation

constants given by Fisher *et al.* (1988) for coastal phytoplankton species. All data located in region B indicate that the nutrient concentrations are above both phosphate - DIN thresholds and silicate – DIN thresholds. Meanwhile, area D indicates data that are below the minimum limit for phytoplankton growth. Almost from all seasonal surveys, nutrient concentrations of the river mouths and inshore waters always located above their threshold values. In total, 32 of 90 measurements were located above the 3 thresholds of silicate, DIN and phosphate and 17 measurements were located below the thresholds of all those 3 nutrients. The rest of the measurements were partially limited either by phosphate, DIN or silicate (61, 23 and 38 measurements, respectively). Hence, it can be concluded that phosphate likely is of major importance for planktonic production in Jakarta Bay, while other nutrients (DIN and silicate) are assumed to play a minor role in the growth of phytoplankton in the area.

### 3.2.6. Area zonation and trophic states

Through spatial cluster and PCA, Jakarta Bay can be divided into 3 distinct areas: 1) inner part of the bay, including river mouths ; 2) middle part of the bay and 3) outer part of the bay. The inner part of the bay was strongly characterised by high concentration of dissolved inorganic nutrients, high chlorophyll *a* concentration, high phytoplankton abundance, high turbidity, low salinity, low secchi disk readings, low  $Z_{mix} : Z_{eu}$  ratio and high attenuation coefficient. Conversely, the outer part of the bay featured low values of those parameters mentioned, while the middle part of the bay was characterised by intermediate values of those parameters.

This division of the bay is in accordance with the spatial trophic state clustering results, which was performed by involving 4 main organic pollution-related parameters: chlorophyll *a*, oxygen saturation, nitrogen and phosphate. Calculation of TRIX resulted in 3 distinct trophic states of Jakarta Bay (according to TRIX criteria : Caiaffa, 1999 and primary production levels : Nixon, 1995) (Fig.3.41.), showing hyper-eutrophic waters at all river mouth sites and inshore waters, then a decrease down the bay into eutrophic (middle part) and mesotrophic state in the outer part of the bay. Hyper-eutrophic levels in the inshore waters are caused by a strong influence of domestic waste water of the huge Jakarta City urban area. A steep decrease of the eutrophic state to a lower level in the more offshore sites shows a



**Fig.3.41.** Projection map of spatial trophic states of Jakarta Bay waters calculated based on TRIX (Caiaffa, 1999) and Nixon (1995).

strong natural capability of Jakarta Bay in reducing effects of strong eutrophication from the land. A set of hydrodynamic factors are involved, such as a relatively short water residence time, which seems to be a powerful physical buffer towards strong nutrient enrichment from the urban area of Jakarta City. With approximately a 5 days water residence time (Koropitan, pers.comm.), materials related to eutrophication seem to be shortly accumulated in the bay, rapidly renewed by a lower-nutrient containing water coming from the adjacent Java Sea. The relatively open-shape and a free connection with the Java Sea, is an advantage for Jakarta Bay through the rapid renewal with the relatively clean waters of the Java Sea.

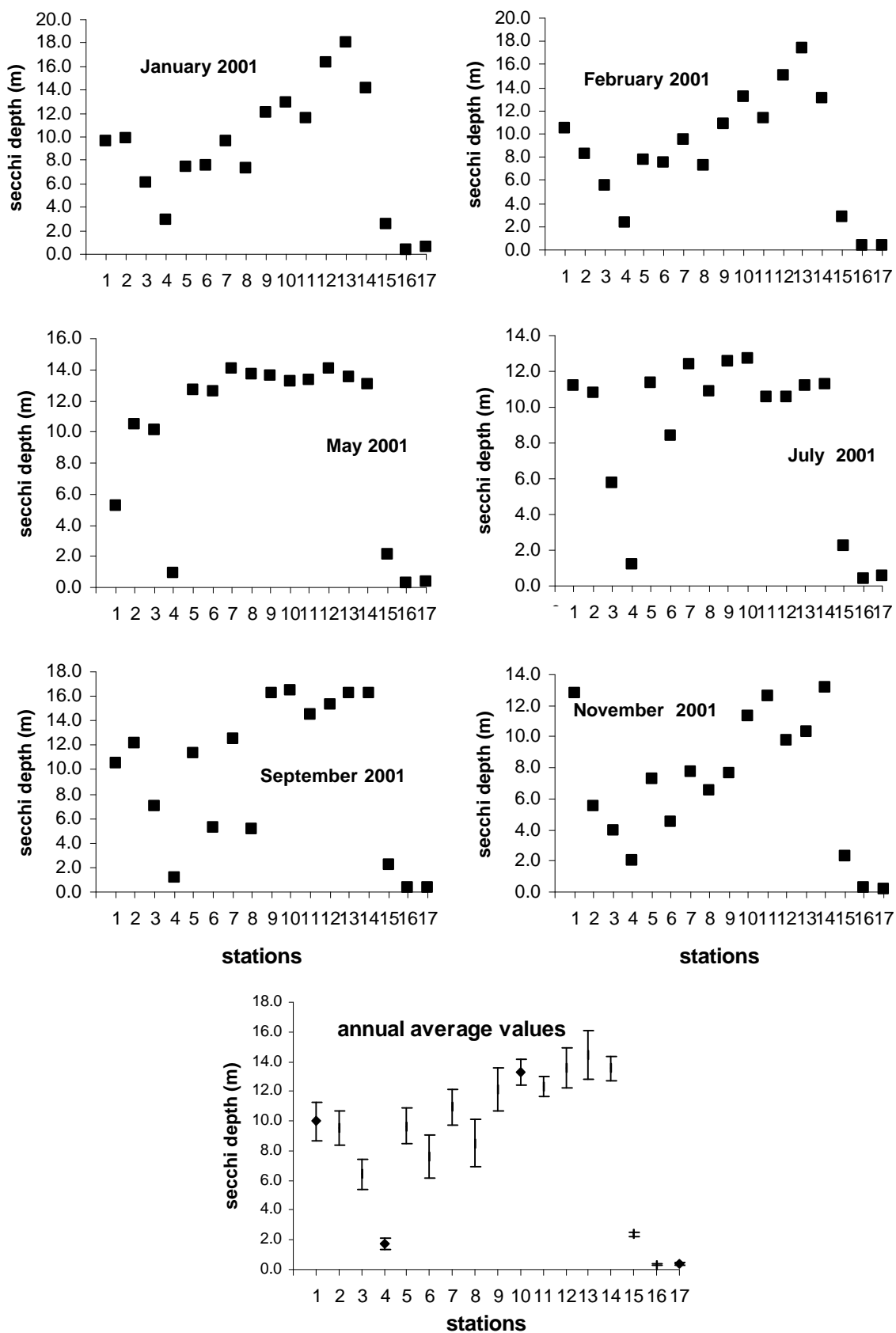
## 4. Results and discussion : Lampung Bay.

### 4.1. Results

#### 4.1.1. Secchi depth, light-attenuation, $Z_{\text{mix}}:Z_{\text{eu}}$ ratio and water temperature

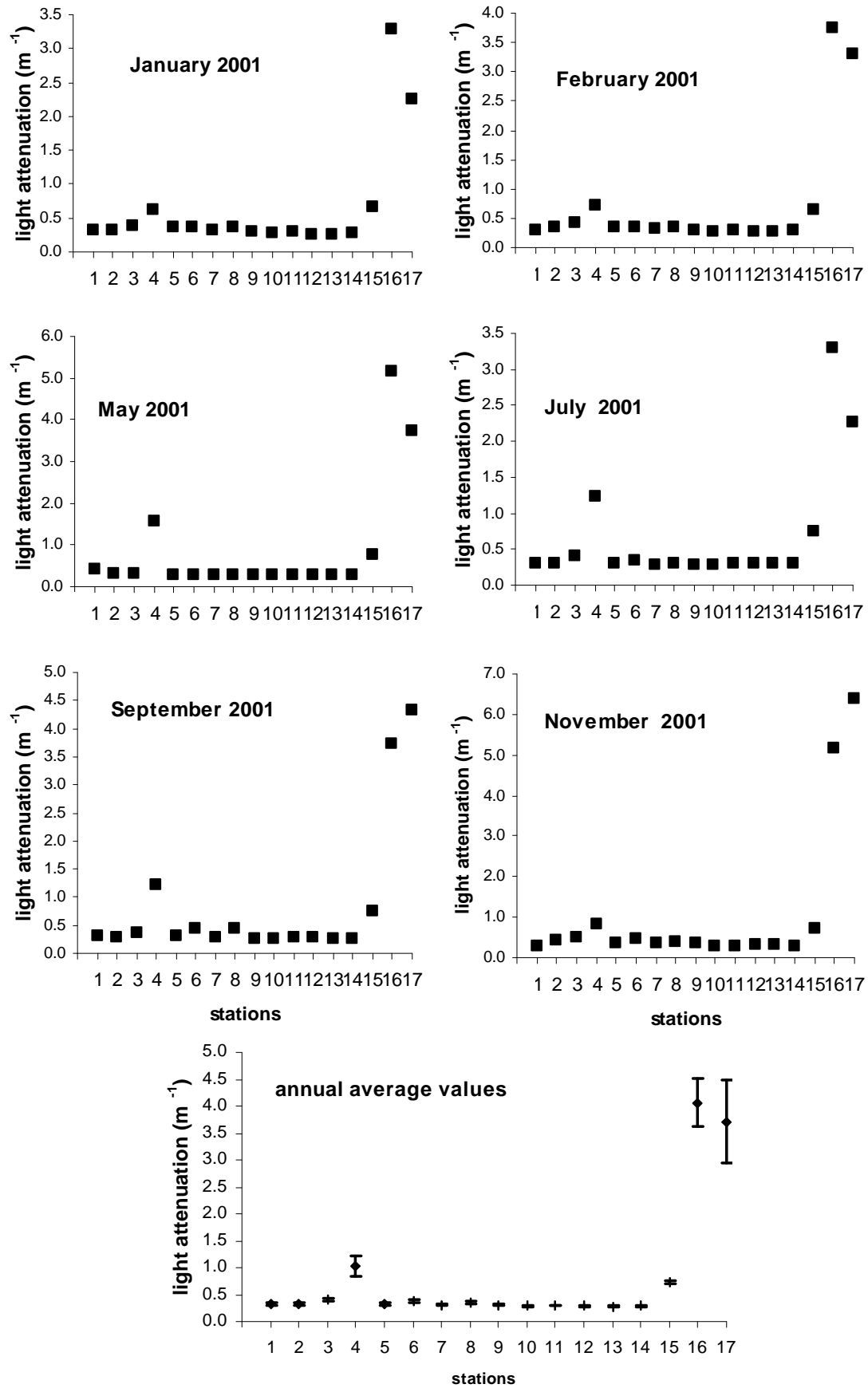
Secchi depth values of each temporal survey and their annual average at each station are shown in Fig.4.1. Significant influences in Secchi depth were observed between the sampling sites and temporal surveys (Anova ;  $p < 0.001$ ). Lowest Secchi depth was recorded at both river mouths (ranging from 0.20 to 0.6 m), reflecting the high turbidity of the river waters, while the highest always prevailed at station 13 (ranging from 10.3 to 18.1 m). The minimum annual average accounted for 0.33 m (Kota Karang river mouth), while the maximum annual average was 14.45 m (station 13). Consequently, the lowest vertical light-attenuation coefficients prevailed at station 13 (ranging from  $0.26 \text{ m}^{-1}$  to  $0.31 \text{ m}^{-1}$ ), while the highest prevailed at both river mouths (ranging from  $2.26 \text{ m}^{-1}$  to  $6.4 \text{ m}^{-1}$ ). Annual average value of this variable varied between  $0.28 \text{ m}^{-1}$  (stations 13 and 14) to  $4.06 \text{ m}^{-1}$  (Kota Karang river mouth). There was significant difference in the value of attenuation coefficient between sites and seasons (ANOVA,  $p < 0.05$ ). Besides of the river mouths, stations 4 and 15, which are located in the vicinity, also exhibited high light attenuation coefficients. Secchi depth and attenuation coefficient were well significantly correlated with salinity and turbidity ( $p < 0.001$  ; Pearson's  $r = 0.68, -0.63, 0.90$  and  $-0.93$ , respectively), indicating a prominent role of river inflow on this parameter.

As can be traced from the previous studies (Wiryawan *et al.*, 1999) the water column of Lampung Bay is vertically homogenous. Thus, the depth of the mixed layer ( $Z_{\text{mix}}$ ) is defined as the whole water depth. There was a significant difference in the  $Z_{\text{mix}}:Z_{\text{eu}}$  values between sampling sites, but not between the different seasons. In general, all river mouths and river plume stations (stations 4 and 15) exhibited low  $Z_{\text{mix}}:Z_{\text{eu}}$  values, (ranging from 0.46 to 1.19), while at the middle and outer parts of the bay high ratios prevailed, ranging from 1.41 to 2.26 (Fig.4.3). The annual average of this variable ranged from 0.52 (Way Lunik river mouth) to 2.05 (station 14).  $Z_{\text{mix}}:Z_{\text{eu}}$  ratios were significantly correlated with  $K$  and  $Z_{\text{eu}}$  values ( $p < 0.01$  ; Pearson's  $r = -0.36$  and  $0.46$ ), indicating the strong impact of turbidity and euphotic depth on this variable, but not significantly correlated with mixing depth ( $Z_{\text{mix}}$ ).

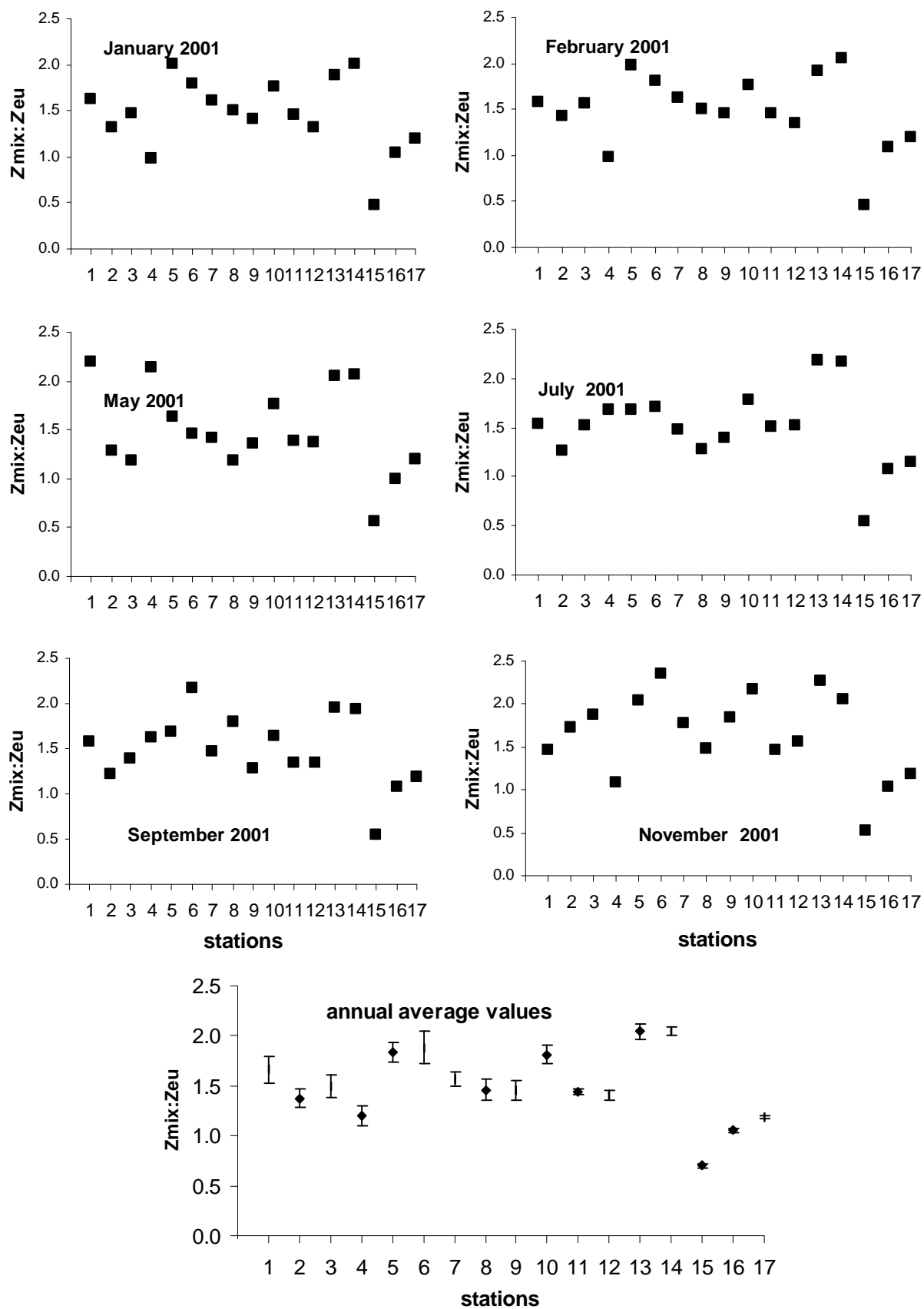


**Fig. 4.1.** Secchi disk readings (m) at each sampling station and survey, and its annual average in Lampung Bay. 16 = Kota Karang river mouth; 17 = Way Lunik river mouth. Bars are standard deviations calculated from 6 data.

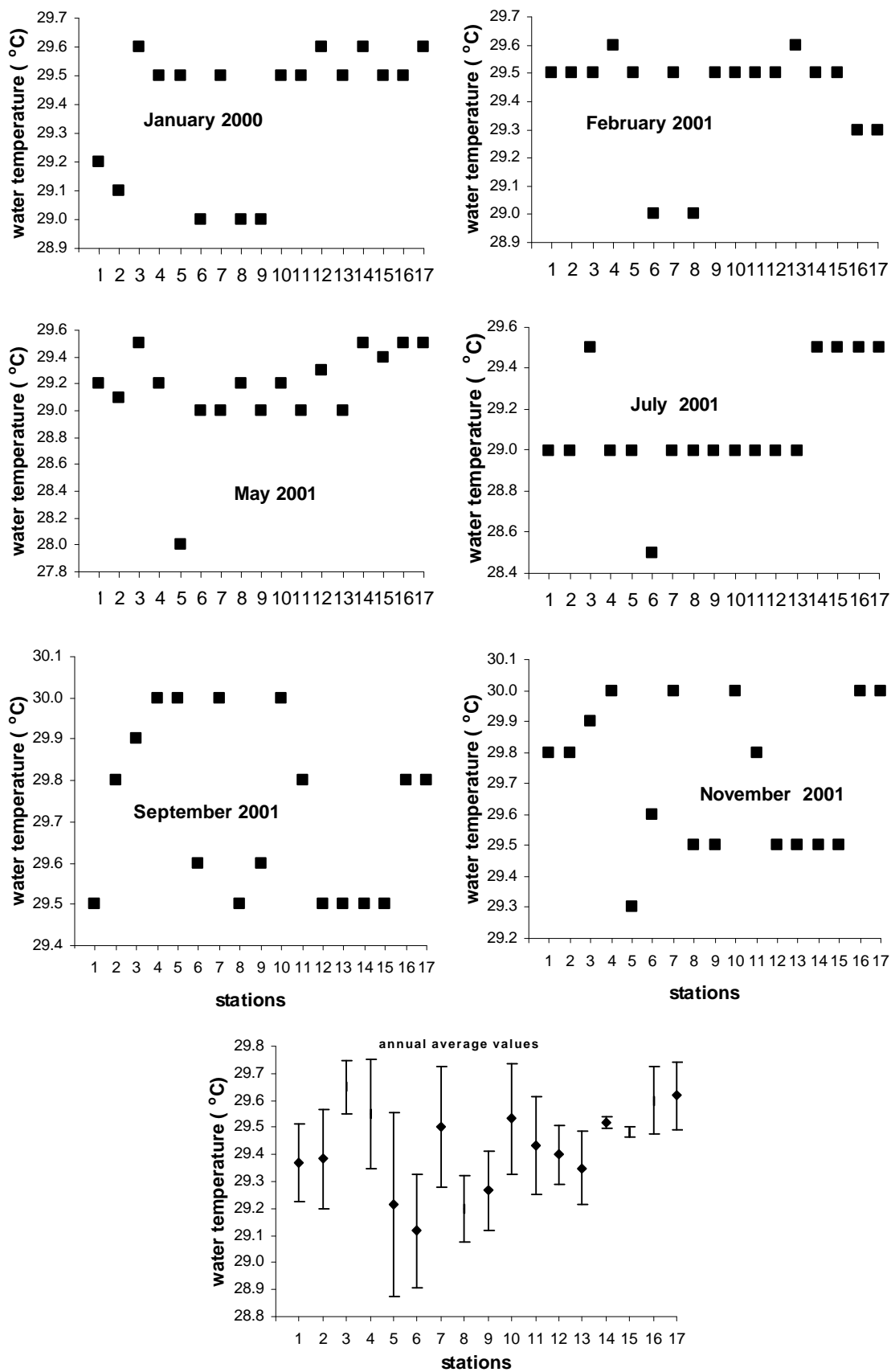




**Fig. 4.2.** Attenuation coefficients ( $m^{-1}$ ) at each sampling station and survey and its annual average in Lampung Bay, 16 = Kota Karang river mouth ; 17 = Way Lunik river mouth. Bars are standard deviations calculated from 6 data.



**Fig. 4.3.**  $Z_{mix}:Z_{eu}$  ratios at each sampling station and survey and its annual average in Lampung Bay, 16 = Kota Karang river mouth ; 17 = Way Lunik river mouth. Bars are standard deviations calculated from 6 data.



**Fig. 4.4.** Water temperature (°C) at each sampling station and survey and its annual average in Lampung Bay, 16 = Kota Karang river mouth ; 17 = Way Lunik river mouth. Bars are standard deviations calculated from 6 data.

There was no significant difference in water temperature neither with respect the spatial nor the temporal distribution, reflecting the relatively constant tropical temperature conditions throughout the year. Annual average water temperature ranged from 29.12 °C to 29.65 °C (Fig. 4.4.). There was no significant correlation with salinity (Pearson's  $r=0.13$ ), indicating a minor role of freshwater discharge on the water temperature pattern in the study area.

#### **4.1.2. Salinity and turbidity**

There were strong spatial gradients in both salinity and turbidity (Fig.4.5 and 4.6) in each temporal survey, which were due to the gradual impact of fresh water discharge. In keeping with this, there were significant differences in salinity and turbidity between sites (ANOVA,  $p<0.001$ ). A Post-Hoc LSD-Test (Least Significant Difference) showed that the spatial differences were due to stations of Kota Karang and Way Lunik river mouths, 4 and 15. Lowest salinity of 2.5 to 8.2 were recorded in the river mouths, while the highest prevailed at station 13, ranging from 32.9 to 34.3. Inversely with salinity pattern, the lowest turbidity prevailed at station 13, ranging from 0.2 to 0.45 NTU, while the highest prevailed at river mouths, ranging from 5.3 to 24.0 NTU.

There were significant differences in salinity between seasons. Temporal average of salinity ranged from 28.68 (January 2001) to 29.81 (November 2001), and that of turbidity from 1.32 NTU (February 2001) to 3.07 NTU (July 2001).

Correlation diagrams between salinity and turbidity (Fig 4.7 and 4.8) show a strong and inverse relationship ( $p<0.001$ ; Pearson's  $r = -0.85$ , and linear regression,  $R^2 = 0.73$ ). This high correlation underlines the prominent role of river discharge for the turbidity regime in Lampung Bay.

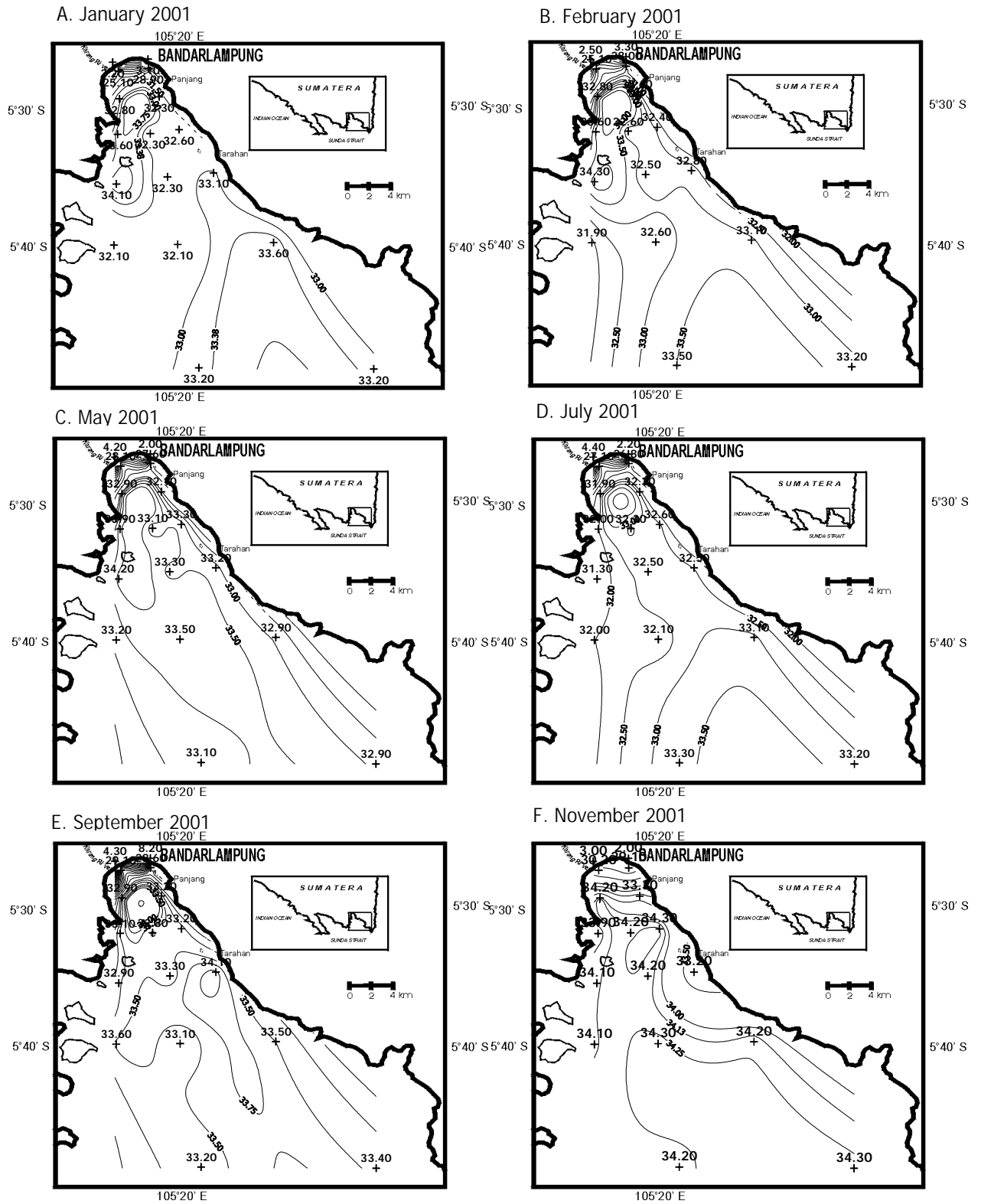
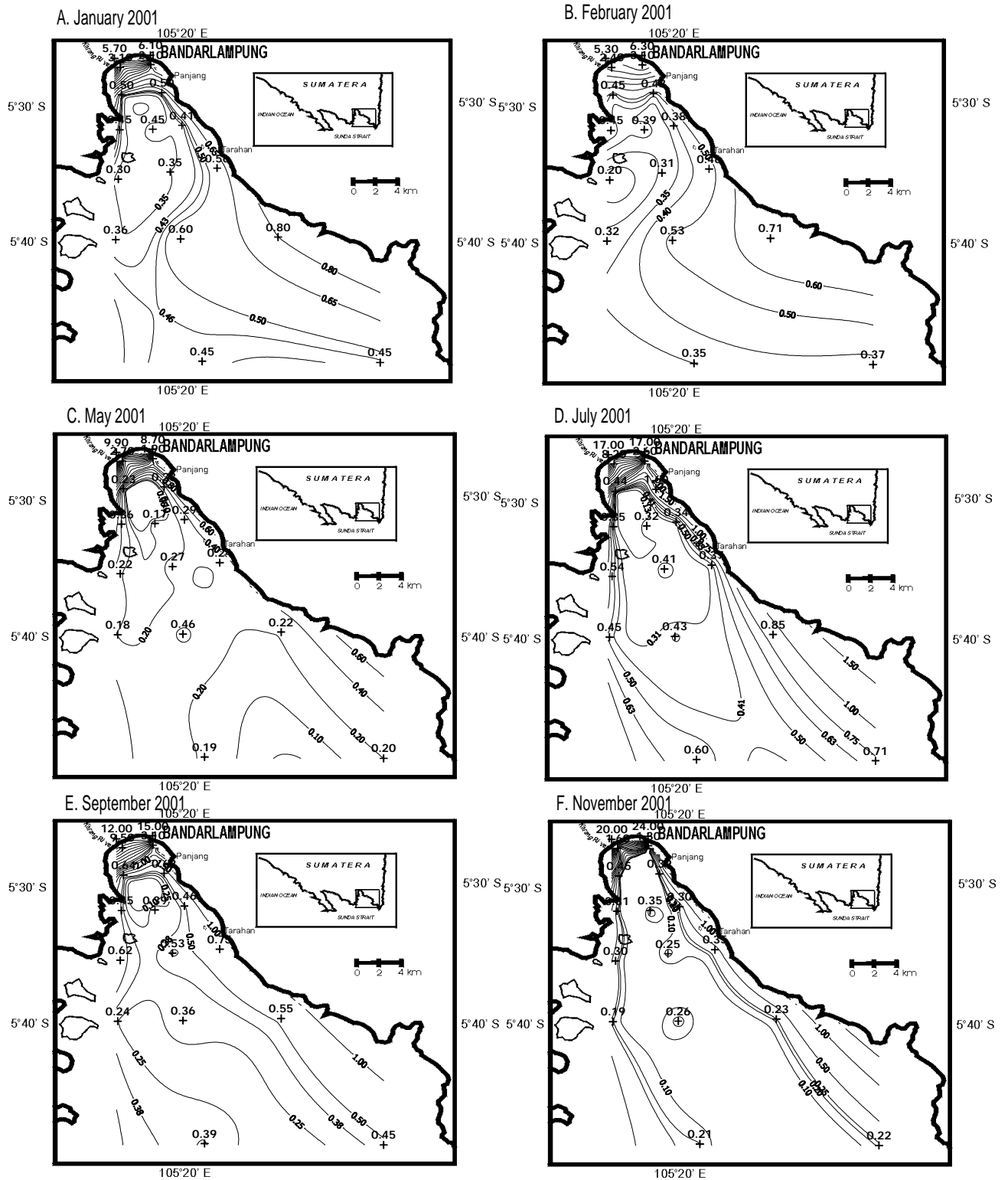
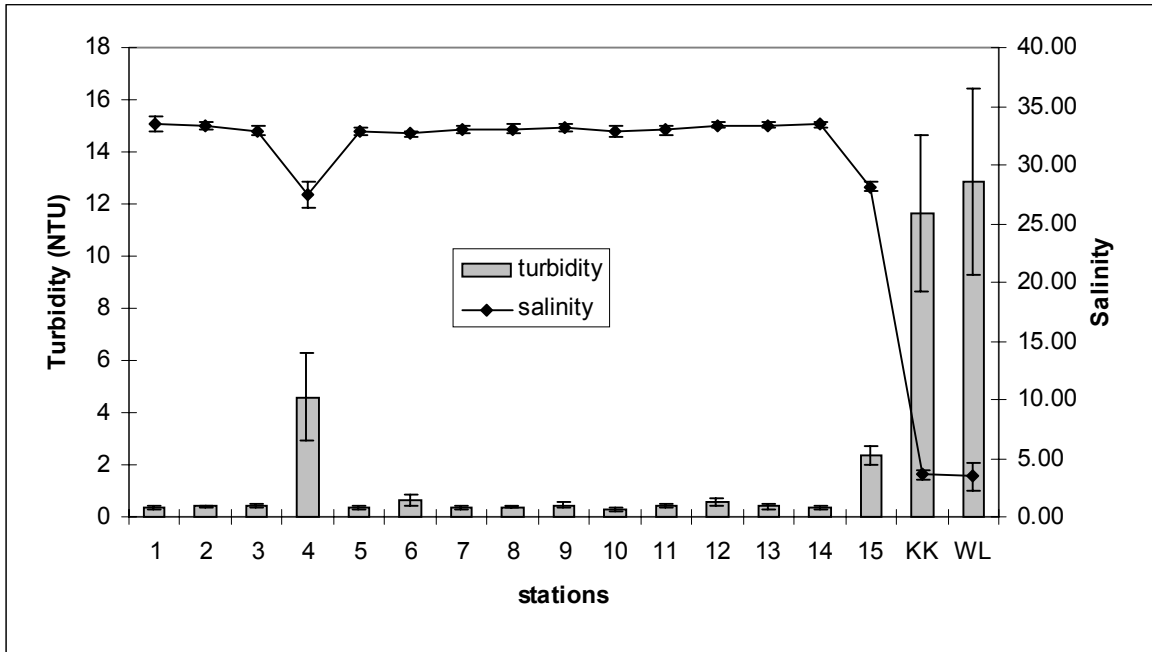


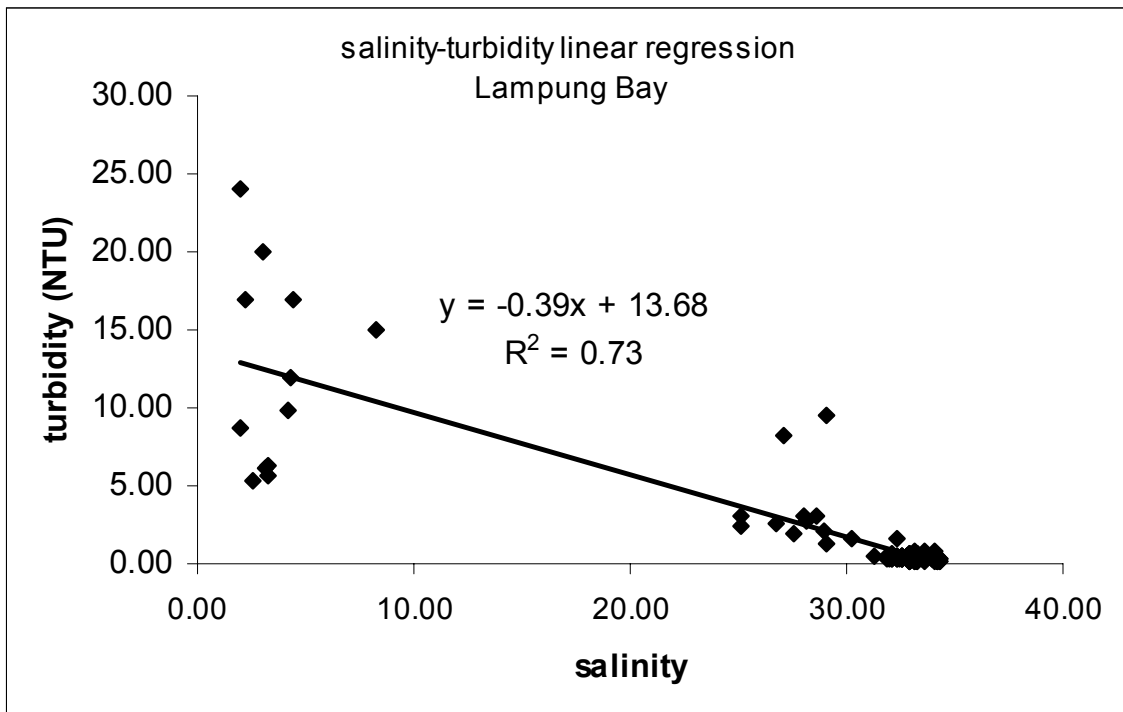
Fig. 4.5. Salinity contours in Lampung Bay. A: January 2001. B: February 2001. C: May 2001. D : July 2001. E : September 2001 and F: November 2001.



**Fig. 4.6.** Turbidity (NTU) contours in Lampung Bay. A: January 2001. B: February 2001. C: May 2001. D : July 2001. E : September 2001 and F: November 2001.



**Fig. 4.7.** Annual average salinity (lines) and turbidity (bars) in Lampung Bay. KK = Kota Karang river mouth ; WL = Way Lunik river mouth. Bars are standard deviations calculated from 6 data.



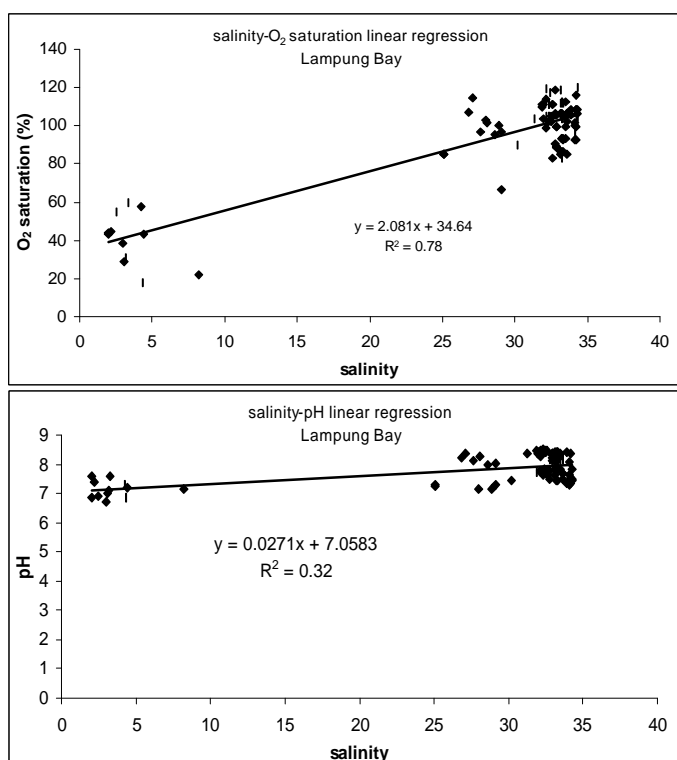
**Fig. 4.8.** Linear regression between salinity and Turbidity (NTU) in Lampung Bay.

### 4.1.3. Dissolved oxygen and pH

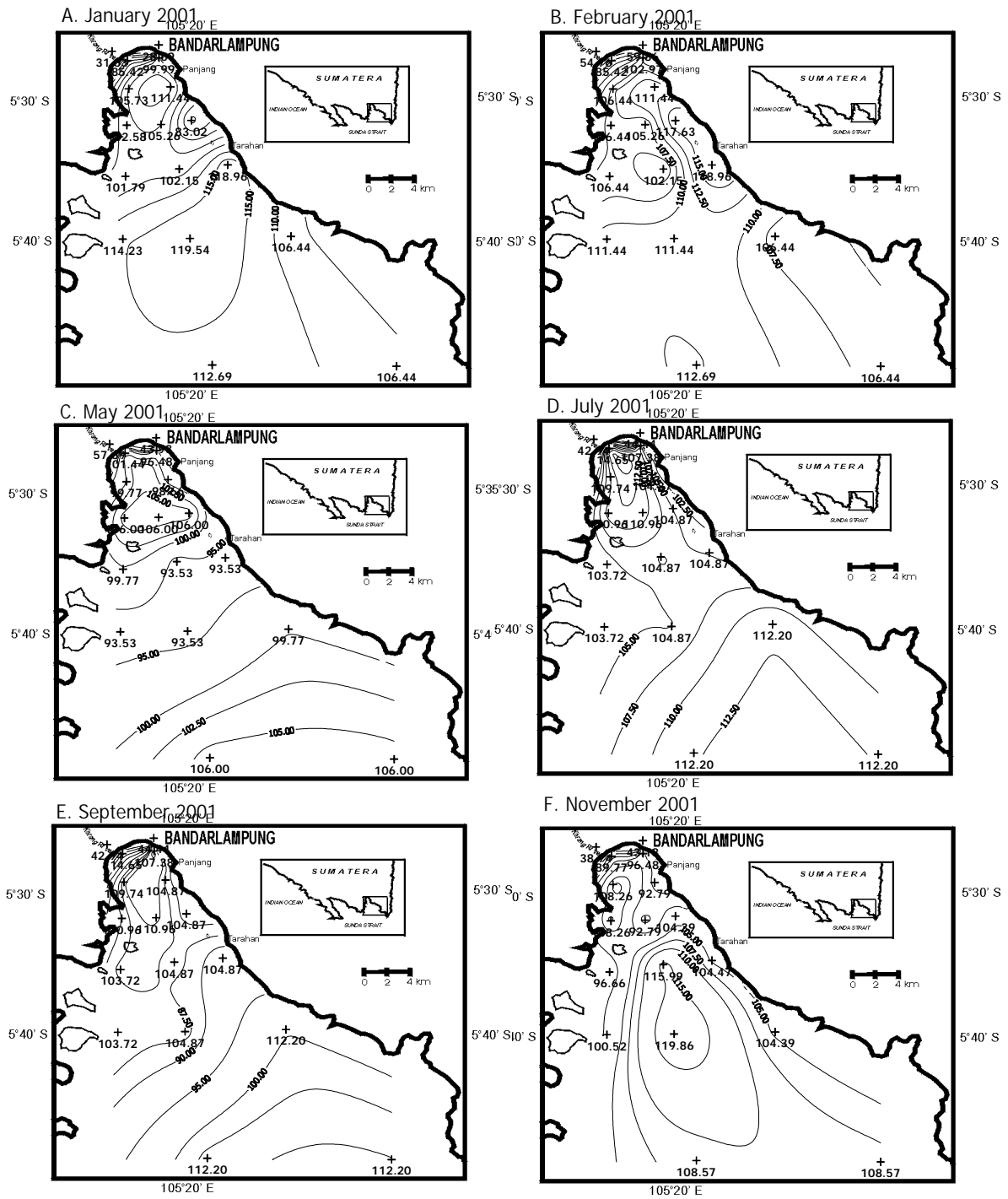
There was a significant spatial and temporal variation in oxygen saturation values in the area (ANOVA ;  $p < 0.01$ ). The distribution pattern of dissolved oxygen saturation for the temporal surveys are shown in Fig.4.10. Lowest temporal mean value was observed at Kota Karang river mouth (17.66%), while highest mean saturation value occurred at station 14 (112.69%). Absolute values were 0.89 mg/l O<sub>2</sub> and 7.14 mg/l O<sub>2</sub>, respectively. All river mouth stations exhibited extremely low oxygen saturation values, ranging from 17.66% - 59.86%, while the other stations were relatively high, exceeding >90%. The low values at the river mouth stations were in accordance with high attenuation coefficients, salinity and turbidity ( $p < 0.01$ ; Pearson's  $r = -0.83, 0.88$  and  $-0.79$ , respectively). High rates of oxygen consumption due to microbial degradation of particulate organic matter is supposed to be the main reason for the low oxygen condition in the river mouth areas. By contrast, the more offshore stations are likely to be influenced by the incoming waters from Sunda Strait, which are relatively high in dissolved oxygen (Wiryawan *et al.*, 1999). Strong sea current in the Sunda Strait promote a steady water exchange and high turbulent diffusion rate of oxygen from the air to the water. Linear regression analysis (Fig.3.50) showed a strong positive correlation ( $p < 0.001$ ) between salinity and dissolved oxygen content.

There were strong spatial and temporal variations in the pH values (ANOVA,  $p < 0.01$ ). Lowest pH always prevailed at the river mouth stations and at the surrounding sites (ranging from 6.72 to 7.61). The pH values gradually increased in the more saline waters, peaking at station 8 (ranging from 7.45 to 8.45). The pH was significantly correlated with salinity (Pearson's  $r = 0.56$ ,  $p < 0.001$ ). A low oxygen content and high decomposition processes in the river mouths might be the main cause for this low pH value in these sites.

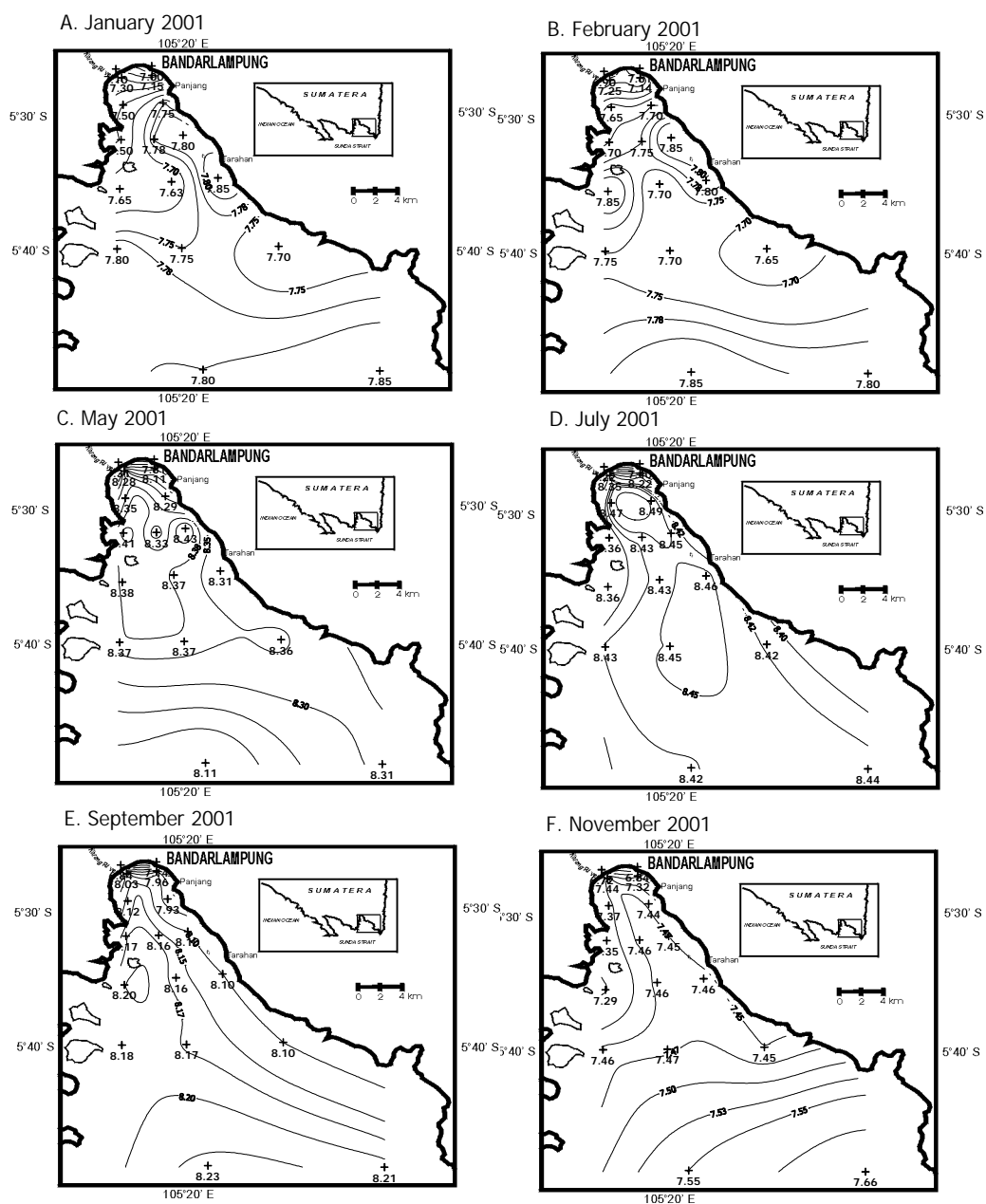
**Fig. 4.9.** Linear regression between salinity and dissolved oxygen saturation (upper graph) and pH (lower graph) in Lampung Bay.







**Fig. 4.10.** Oxygen saturation (%) contours in Lampung Bay. A: January 2001. B: February 2001. C: May 2001. D: July 2001. E: September 2001 and F: November 2001.



**Fig. 4.11.** pH contours in Lampung Bay. A: January 2001. B: February 2001. C: May 2001. D : July 2001. E : September 2001 and F: November 2001.

#### 4.1.4. Nutrient loads from the rivers

Nutrient loads from the 2 rivers in Lampung Bay were estimated with the same procedure for Jakarta Bay (see chapter Methods). In contrast to Jakarta Bay, Lampung Bay receives less fresh water discharge. However, Bandar Lampung as the biggest city in the area acts as a major source of nutrient enrichment in the bay's waters. The rivers, which flow through the city, transport the untreated organic waste water of the city directly into the bay. There are 6 major rivers, and the main two rivers are Kota Karang and Way Lunik. The first river flows through the west area of the city, which is mainly dominated by urban settlements, while Way Lunik passes human settlements and small industrial area, along the eastern border of the city.

Calculations of the monthly loads of nitrate, nitrite, ammonium, phosphate and silicate were performed for each river for the investigation periods (Table 4.1.).

From the 2 rivers observed (Table 4.1.), loads from the Way Lunik were higher than those of Kota Karang. This is both due to higher water discharge of Way Lunik river and higher nutrient concentrations in its water. Besides passing through the densed-urban area, this river also flows through an industrial area dealing with organic waste water. Annual loads of nitrate, nitrite, ammonium, DIN, phosphate and silicate in Way Lunik river accounted for  $203.5 \text{ t y}^{-1}$ ,  $34.5 \text{ t y}^{-1}$ ,  $1008.3 \text{ t y}^{-1}$ ,  $1246.3 \text{ t y}^{-1}$ ,  $260.6 \text{ t y}^{-1}$  and  $2757.1 \text{ t y}^{-1}$ , respectively. The second river, Kota Karang is slightly smaller than Way Lunik, with an average discharge of  $2.18 \text{ m}^3 \text{ s}^{-1}$ . Loads of nutrients from this river accounted for  $67.1 \text{ t y}^{-1}$ ,  $4.9 \text{ t y}^{-1}$ ,  $82.5 \text{ t y}^{-1}$ ,  $154.5 \text{ t y}^{-1}$ ,  $46.2 \text{ t y}^{-1}$  and  $1367.8 \text{ t y}^{-1}$  for nitrate, nitrite, ammonium, DIN, phosphate and silicate, respectively.

**Table 4.1.** Nutrient loads from the 2-river observed on each measurement period (ton month<sup>-1</sup>) and its annual load (ton year<sup>-1</sup>) in Lampung Bay.

<b>Kota Karang River</b>						
	NO <sub>3</sub> -N	NO <sub>2</sub> -N	NH <sub>4</sub> -N	DIN	PO <sub>4</sub> -P	SiO <sub>4</sub>
January	4.65	1.34	1.03	7.02	2.88	48.32
February	4.48	1.29	0.99	6.76	2.77	46.50
March	5.01	0.36	1.62	6.98	2.75	71.67
April	3.83	0.27	1.24	5.35	2.11	54.86
May	27.37	0.60	2.13	30.10	1.69	62.56
June	19.80	0.43	1.54	21.78	1.22	45.27
July	0.36	0.07	10.01	10.44	6.97	73.19
August	0.37	0.07	10.28	10.71	7.16	75.13
September	0.30	0.15	5.78	6.22	3.69	167.17
October	0.31	0.15	6.00	6.46	3.83	173.57
November	0.31	0.09	20.48	20.89	5.43	268.93
December	0.32	0.10	21.37	21.79	5.67	280.58
Annual load	67.10	4.92	82.48	154.50	46.18	1367.76
<b>Way Lunik River</b>						
	NO <sub>3</sub> -N	NO <sub>2</sub> -N	NH <sub>4</sub> -N	DIN	PO <sub>4</sub> -P	SiO <sub>4</sub>
January	7.95	7.57	20.14	35.67	15.04	118.13
February	7.39	7.04	18.73	33.16	13.98	109.82
March	31.45	7.94	25.61	64.99	15.96	119.58
April	29.04	7.33	23.65	60.03	14.74	110.45
May	62.54	1.34	58.44	122.32	24.21	74.36
June	59.01	1.26	55.15	115.43	22.85	70.17
July	1.25	0.41	54.79	56.45	23.95	103.08
August	1.28	0.42	56.22	57.92	24.58	105.76
September	1.70	0.33	98.37	100.39	40.35	303.33
October	1.84	0.36	106.58	108.78	43.72	328.67
November	0.04	0.22	238.33	238.60	10.30	638.19
December	0.04	0.24	252.27	252.55	10.90	675.50
Annual load	203.54	34.46	1008.29	1246.29	260.58	2757.04
Total annual loads from 2 rivers	270.64	39.37	1090.77	1400.79	306.76	4124.81

## 4.1.5. Dissolved inorganic nutrients

### 4.1.5.1. Phosphate ( $\text{PO}_4^{-3}\text{-P}$ )

There was a strong spatial gradient in dissolved inorganic phosphate concentrations (Anova,  $p < 0.001$ ), decreasing down the bay along with increasing salinity (Fig. 4.12). High values always prevailed in the river mouths, ranging from 4.44 to 43.25  $\mu\text{M PO}_4\text{-P}$ . In the river plume areas, phosphate concentration slightly decreased (ranging from 0.29 to 5.49  $\mu\text{M PO}_4\text{-P}$ ) and finally declined to minimum levels in the more offshore waters (ranging from 0.01 to 0.77  $\mu\text{M PO}_4\text{-P}$ ). Phosphate minima found at station 1 in July 2001 (0.009  $\mu\text{M PO}_4\text{-P}$ ), while the maxima measured at Way Lunik river mouth (43.239  $\mu\text{M PO}_4\text{-P}$ ). The phosphate pattern was in accordance with that of salinity and turbidity, showing a strong correlation (salinity-phosphate  $r = -0.73$  ; turbidity-phosphate  $r = 0.70$ ).

Seasonal variation of phosphate concentrations was observed. The lowest average prevailed in November 2001 (1.23  $\mu\text{M PO}_4\text{-P}$ ) and the highest was in September 2001 (3.793  $\mu\text{M PO}_4\text{-P}$ ).

### 4.1.5.2. Nitrate [ $\text{NO}_3^-$ -N]

There were significant differences in nitrate concentrations between sites and seasons (ANOVA,  $p < 0.001$ ). Highest concentrations were observed in the river mouths. Spatial gradient shows highest values in the river mouths (ranging from 0.68 to 45.30  $\mu\text{M}$ ). In the river plume waters (stations 4 and 15), nitrate concentration decreased, ranging from 0.886 to 9.530  $\mu\text{M NO}_3\text{-N}$  and then decreased further in the more offshore waters. (Fig.4.13). Nitrate minima was measured at station 6 (0.001  $\mu\text{M NO}_3\text{-N}$ ) in November 2001 and the maxima prevailed at Way Lunik river mouth (109.618  $\mu\text{M NO}_3\text{-N}$ ) in May 2001.

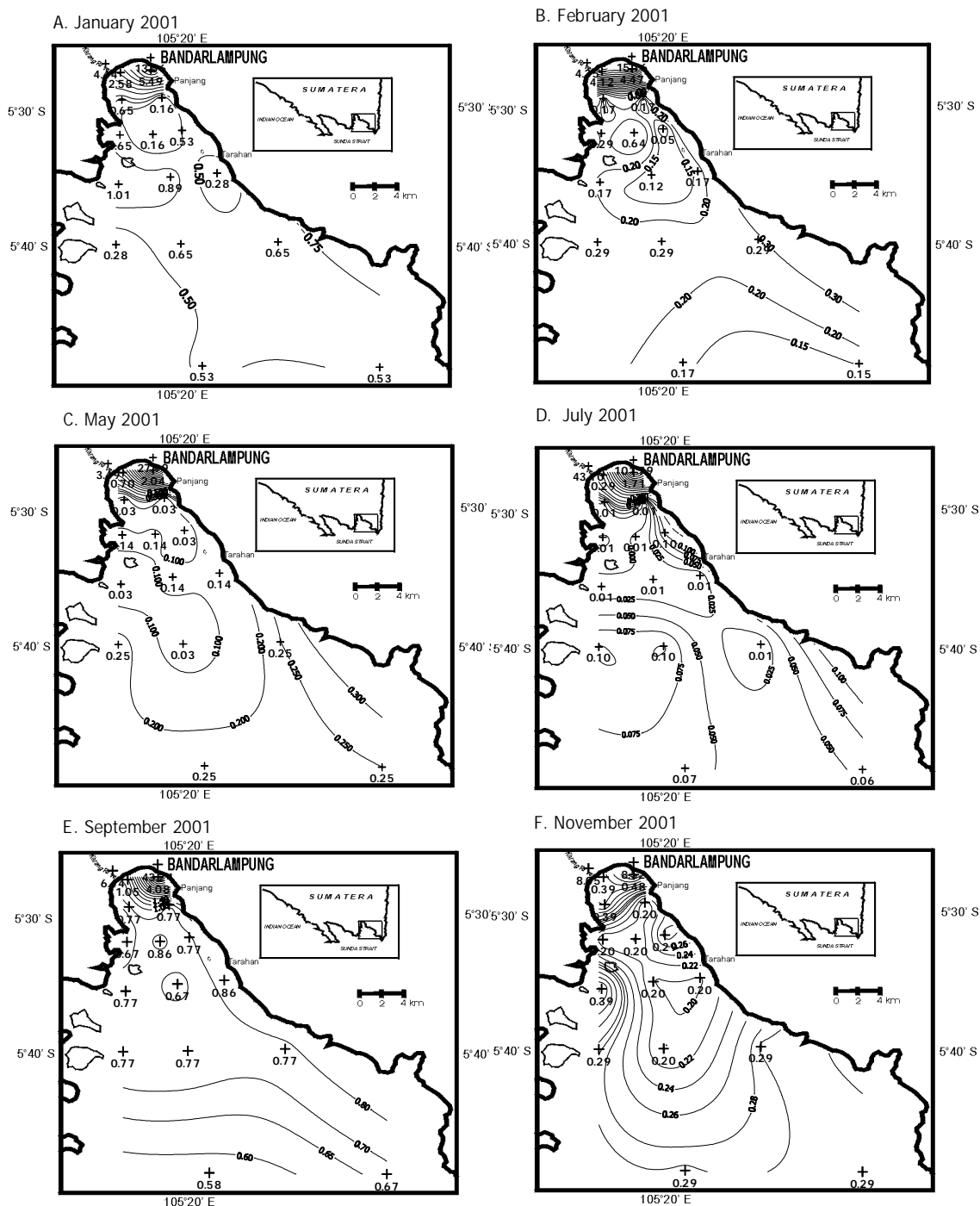
The temporal variations of nitrate concentrations showed a maximum temporal mean in May 2001 (14.21  $\mu\text{M NO}_3\text{-N}$ ) and a minimum in November 2001 (0.36  $\mu\text{M NO}_3\text{-N}$ ). This high average value of nitrate in May 2001 was mostly due to the high concentrations in the river mouths and at the east shore stations (stations 9 and 12), which may be a result of increased inputs from the agricultural areas along the east-coast of the bay through the small scattered irrigation canals. Correlation between nitrate with both salinity and turbidity showed a strong inverse relationship, underlining the role of freshwater input for the nitrate distribution in the bay ( $p < 0.01$  ; Pearson's  $r = -0.51$  and  $r = 0.39$ , respectively).

### 4.1.5.3. Nitrite [ $\text{NO}_2^-$ -N]

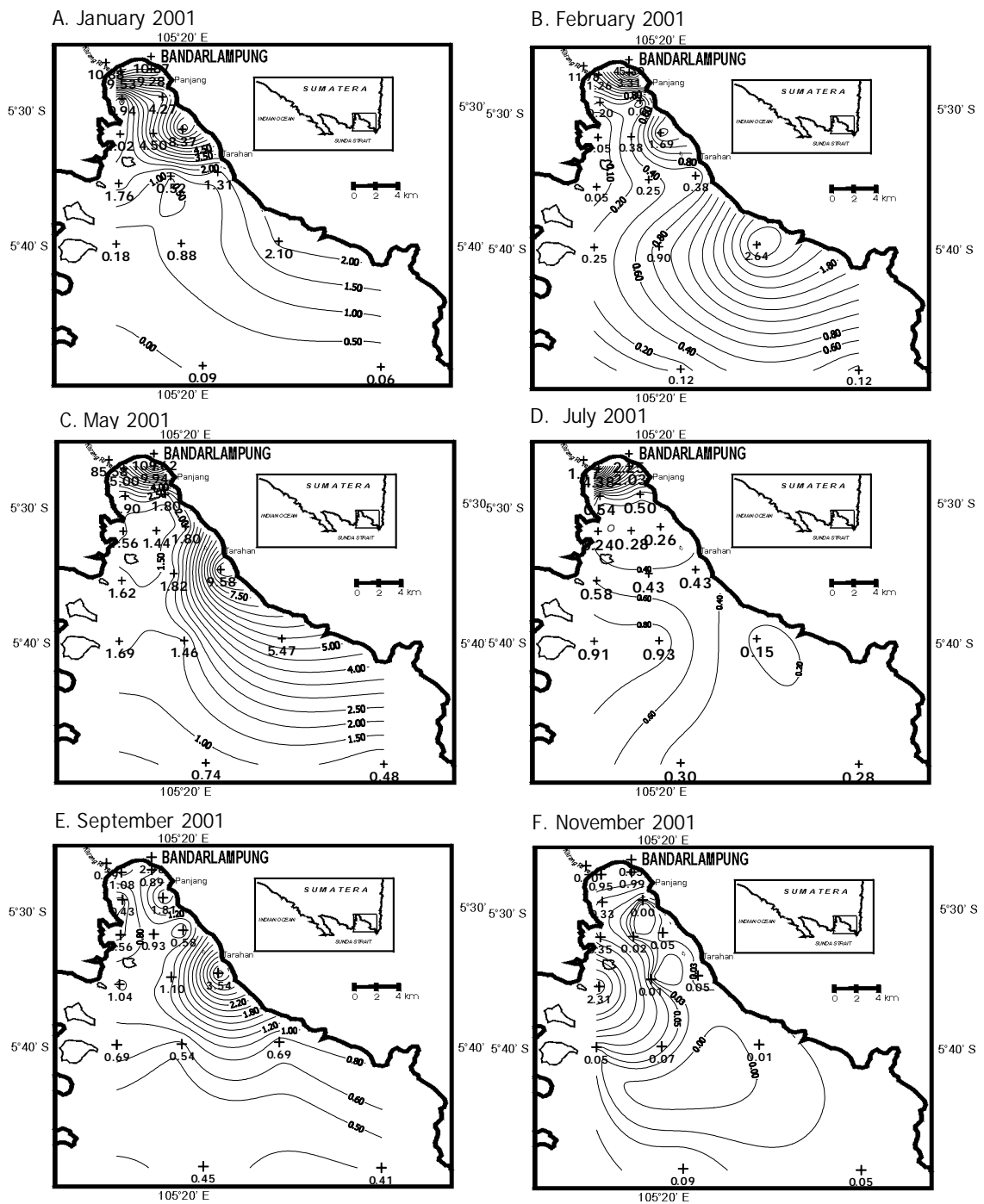
The distribution pattern of nitrite concentrations closely followed that of nitrate, with maximum concentration in the river mouths (ranging from 0.28 to 13.96  $\mu\text{M}$ ) and surrounding areas (stations 4 and 15) (ranging from 0.12 to 3.25  $\mu\text{M}$ ) (Fig. 4.14). In the more saline waters, nitrite decreased, ranging from 0.051 to 0.271  $\mu\text{M NO}_2\text{-N}$ . Nitrite concentration was strongly inversely correlated with salinity (Pearson's  $r = -0.55$ ,  $p < 0.001$ ).

Seasonal variations were not significant, with highest average values in January 2001 (1.52  $\mu\text{M NO}_2\text{-N}$ ) and as for nitrate, a minimum in November 2001 (0.11  $\mu\text{M NO}_2\text{-N}$ ).

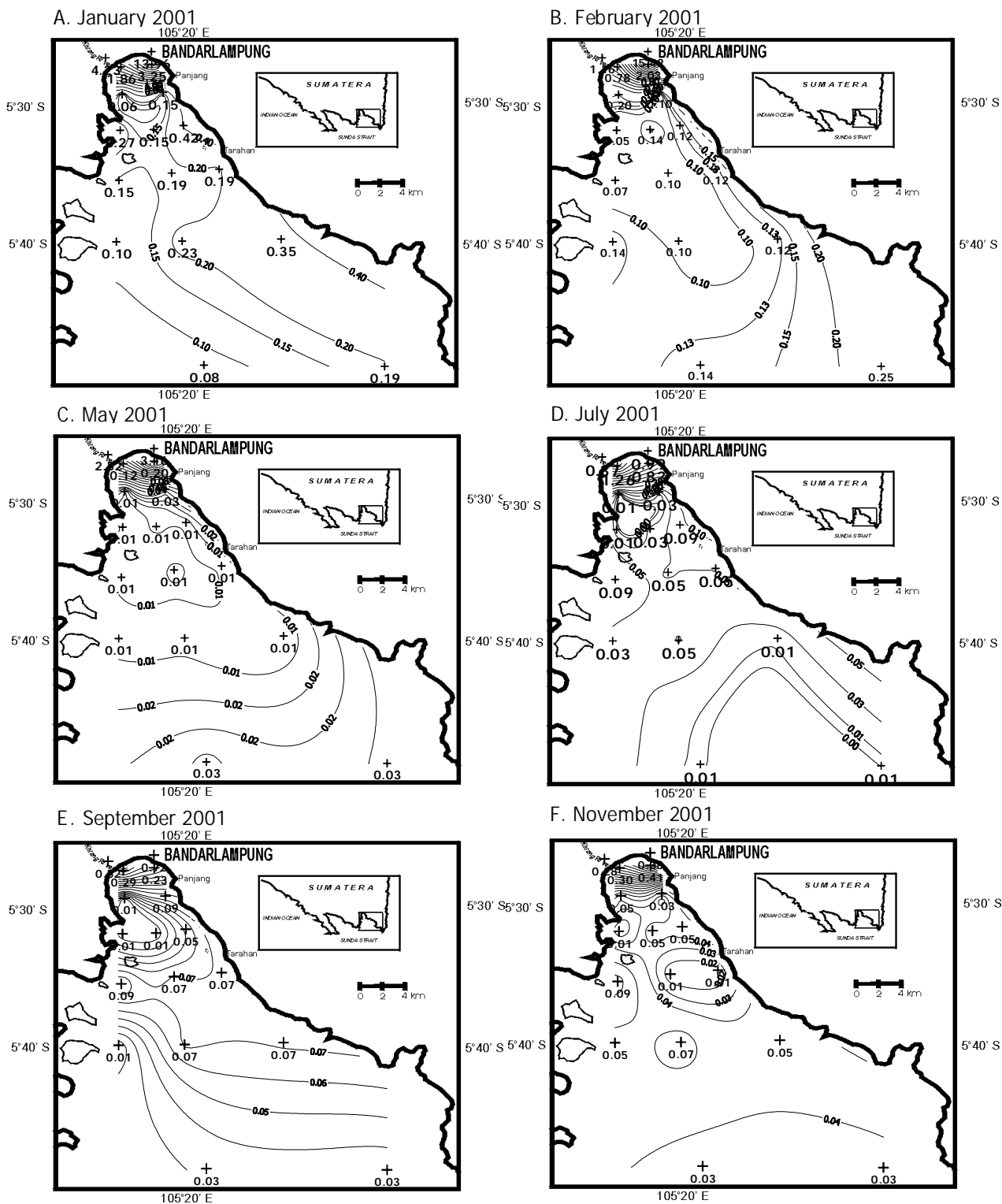
This is commensurate with the temporal variation of nitrite concentration in the rivers, showing a strong riverine influence on the bay's nitrite concentration. In keeping with this, there was a strong inverse correlation of nitrite concentrations with salinity.



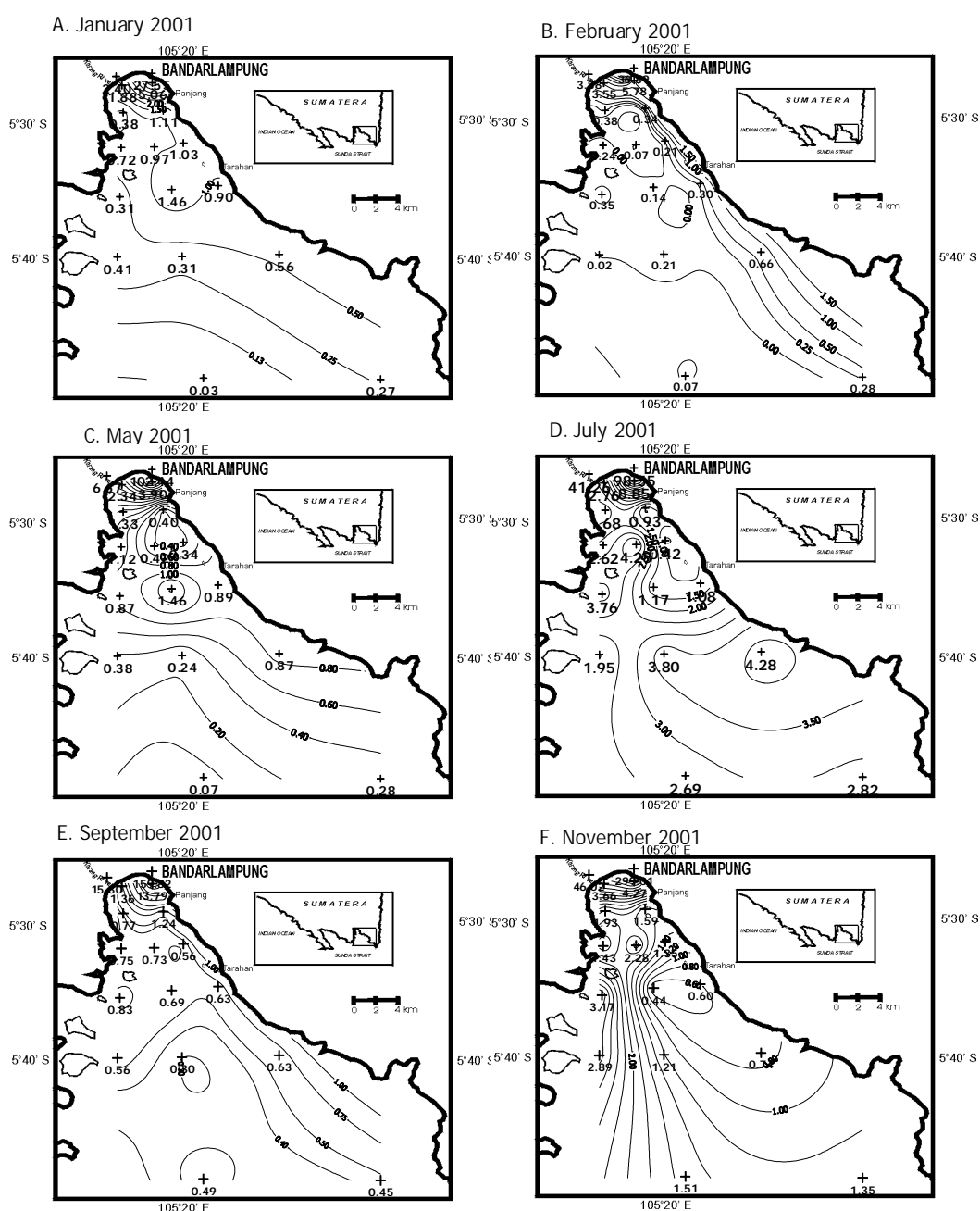
**Fig. 4.12.** Phosphate ( $\mu\text{M PO}_4\text{-P}$ ) contours in Lampung Bay. A: January 2001. B: February 2001. C: May 2001. D: July 2001. E: September 2001 and F: November 2001.



**Fig. 4.13.** Nitrate ( $\mu\text{M NO}_3\text{-N}$ ) contours in Lampung Bay. A: January 2001. B: February 2001. C: May 2001. D: July 2001. E: September 2001 and F: November 2001.



**Fig. 4.14.** Nitrite ( $\mu\text{M NO}_2\text{-N}$ ) contours in Lampung Bay. A: January 2001. B: February 2001. C: May 2001. D: July 2001. E: September 2001 and F: November 2001.



**Fig. 4.15.** Ammonium ( $\mu\text{M NH}_4\text{-N}$ ) contours in Lampung Bay. A: January 2001. B: February 2001. C: May 2001. D: July 2001. E: September 2001 and F: November 2001.

#### 4.1.5.4. Ammonium ( $\text{NH}_4^+\text{-N}$ )

Spatial pattern of ammonium concentrations are shown in Fig.4.15. There were significant differences in ammonium concentrations both between sites (ANOVA;  $p < 0.001$ ) and seasons (ANOVA,  $p < 0.05$ ). Ammonium levels were extremely high in the river mouths (2.40 to 299.01  $\mu\text{M NH}_4\text{-N}$ ), but steeply decreased in the river plume areas (stations 4 and 15), ranging from 1.36 to 13.80  $\mu\text{M NH}_4\text{-N}$ . This steep gradient might be due to the rapid uptake by phytoplankton as well as dilution by the low ammonium sea water. In the more offshore waters (stations 5,7,10,11,12,13 and 14), ammonium concentrations were always low ( $< 1.00 \mu\text{M NH}_4\text{-N}$ ). A strong inverse correlation ( $p < 0.001$ ; Pearson's  $r = -0.60$ ) was observed between salinity and ammonium throughout



the research period, indicating that freshwater discharge was the main source of ammonium in the area.

The seasonal distribution revealed an elevated temporal average value in November 2001 (21.97  $\mu\text{M NH}_4\text{-N}$ ), which is in keeping with increased river discharge.

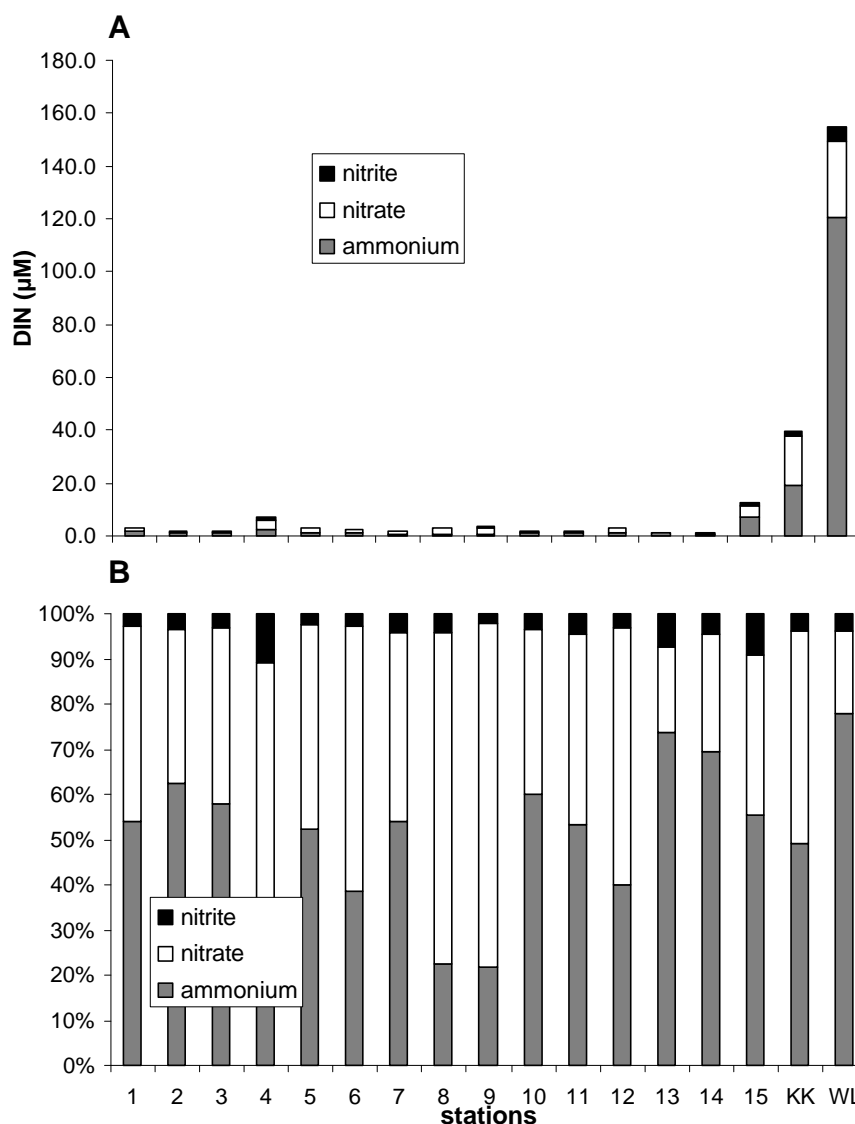
#### 4.1.5.5. Dissolved inorganic nitrogen (DIN)

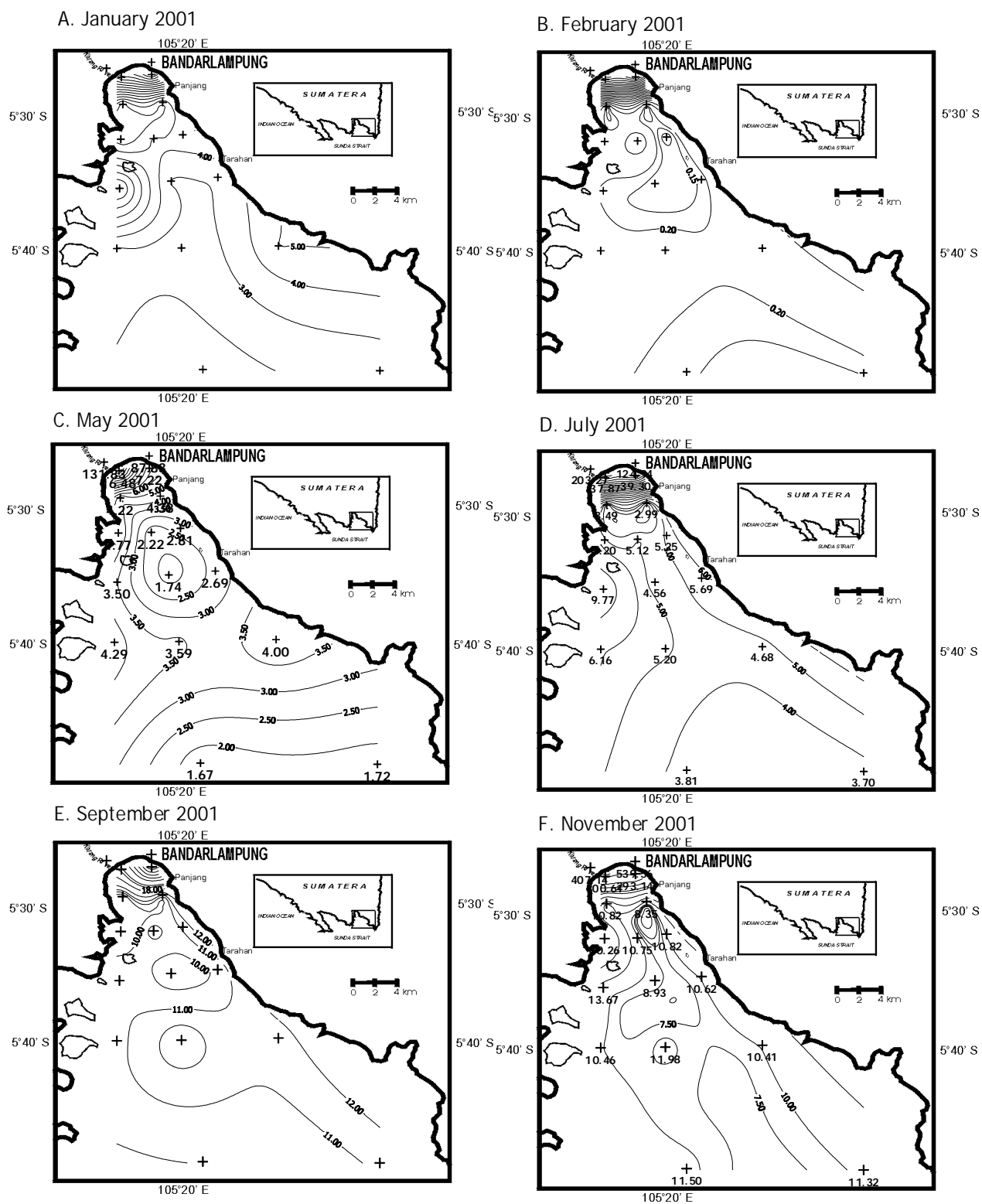
The distribution of DIN as the sum of the dissolved inorganic nitrogen species was almost equally dominated by the nitrate and ammonium at most of the stations, with exceptional situation in the Way Lunik river, where ammonium showed the dominant form of the DIN, and at stations 8 and 9, where nitrate formed more than 70% of the DIN (Fig. 4.16).

**Fig. 4.16.**

Mean total DIN concentrations composed of nitrite, nitrate and ammonium (A), and percent contribution of each nitrogen species (B) in Lampung Bay.

KK: Kota Karang river mouth  
 WL: Way Lunik river mouth



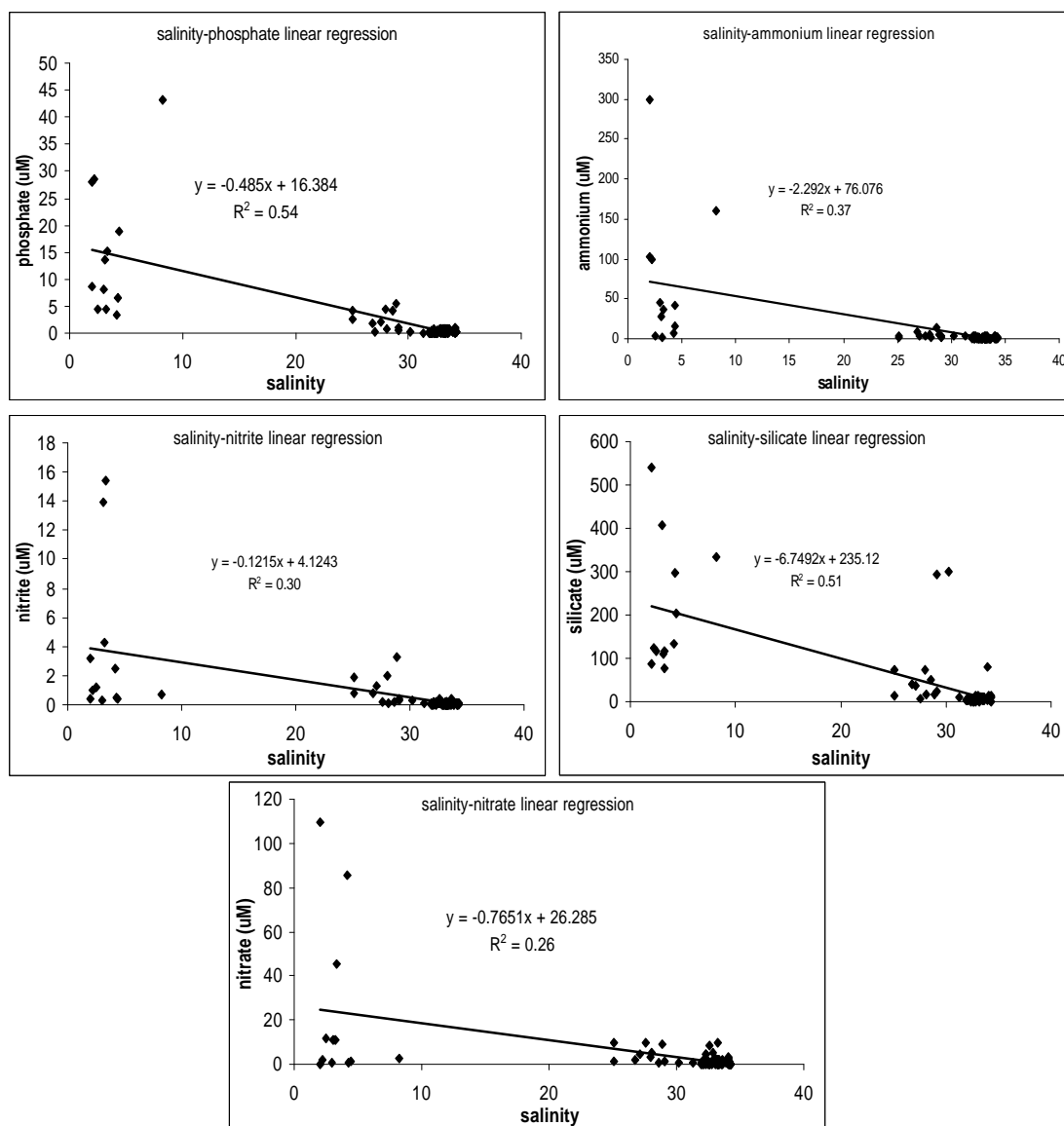


**Fig. 4.17.** Silicate ( $\mu\text{M Si}$ ) contours in Lampung Bay. A: January 2001. B: February 2001. C: May 2001. D: July 2001. E: September 2001 and F: November 2001.

#### 4.1.5.6. Silicate [ $\text{SiO}_4$ ]

Silicate concentrations varied significantly both with respect to the spatial and temporal scales (ANOVA,  $p < 0.001$ ). As for ammonium, silicate also showed a high values in the river mouths, stations 4 and 15 and the inshore stations, and rapidly decreased in the more offshore waters (Fig 4.17). In the river mouths, silicate concentrations ranged from 76.178 to 539.563  $\mu\text{M Si}$ . Also, in the river plume, high silicate levels still prevailed, ranging from 7.23 to 300.62  $\mu\text{M Si}$ , while in the more offshore waters, they dropped down to 0.92 - 13.01  $\mu\text{M Si}$ .

Highest averages prevailed in November 2001 (102.97  $\mu\text{M Si}$ ), while they were lowest in July 2001 (15.46  $\mu\text{M Si}$ ), which is in accordance with the relative amounts of river run off. During September and November 2001, high silicate levels reached far into the bay, indicating the strong impact of river discharge during that period, which was obvious from the relatively low salinity prevailing during that time in the area. The dominant role of freshwater for the silicate concentrations in the bay is supported by a strong and inverse correlation of this nutrient species with salinity ( $p < 0.001$ ; Pearson's  $r = -0.71$ ).

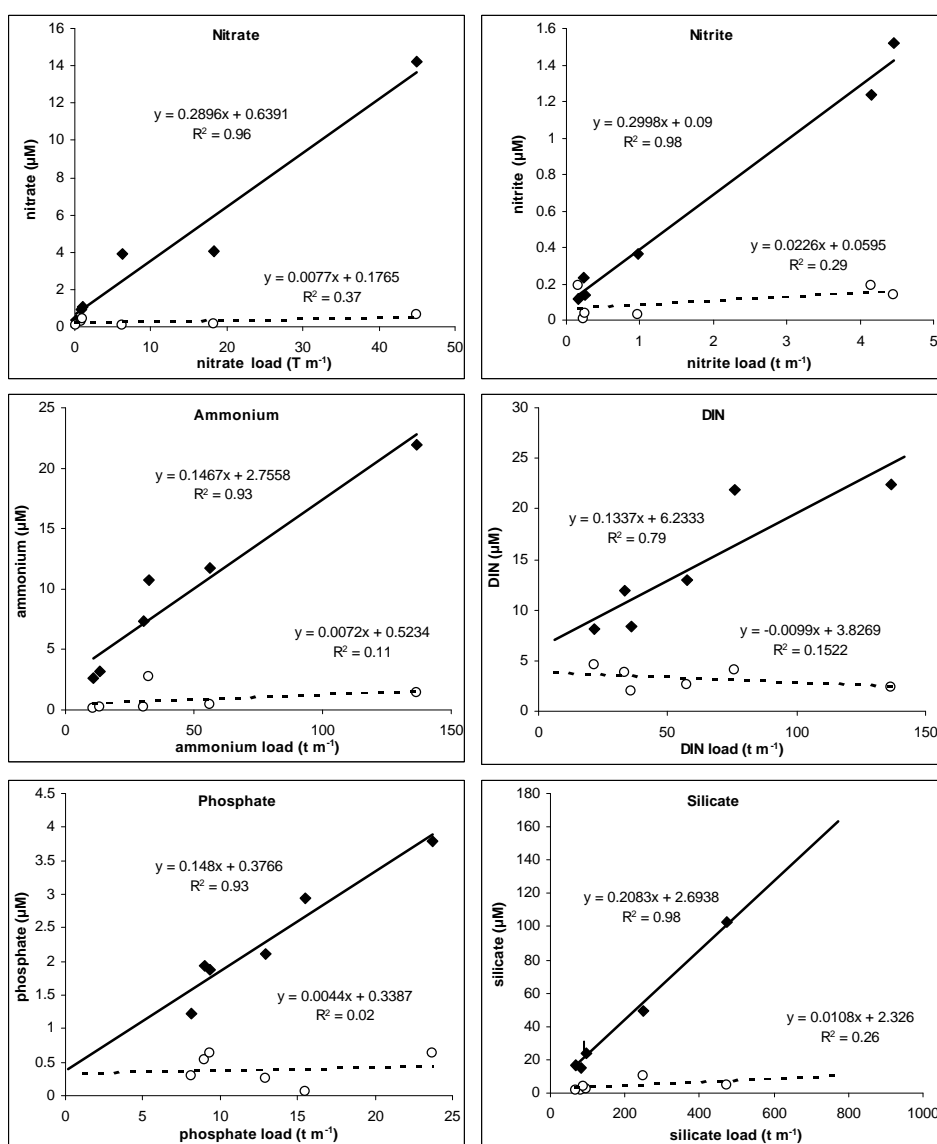


**Fig. 4.18.** Linear regressions between salinity and nutrients (ammonium, phosphate, silicate, nitrite and nitrate) in Lampung Bay.

In order to observe the nutrient mixing process in the bay waters, a set of linear regression analysis between salinity and each nutrient species ( $n = 102$ ) was performed, using the data from all of the seasonal surveys as a basis (Fig. 4.18). Results showed that salinity and nutrients were moderately correlated ( $R^2$  of 0.54, 0.37, 0.30, 0.51 and 0.26 for phosphate, ammonium, nitrite, silicate and nitrate, respectively), indicating the overall importance of freshwater inflow for the nutrient distribution in the bay.

#### 4.1.5.7. Correlation between nutrient load and nutrient concentration in the bay

In order to assess the importance of riverine nutrient discharge for the nutrient in the bay, a more detailed linear regression analysis between the riverine nutrient loads and both the average of nutrient concentrations of the inshore stations and the offshore stations was performed (Fig.4.19.). In that figure, linear regression between each nutrient load and inshore nutrient concentrations (stations 4 and 15) are drawn in solid lines, while



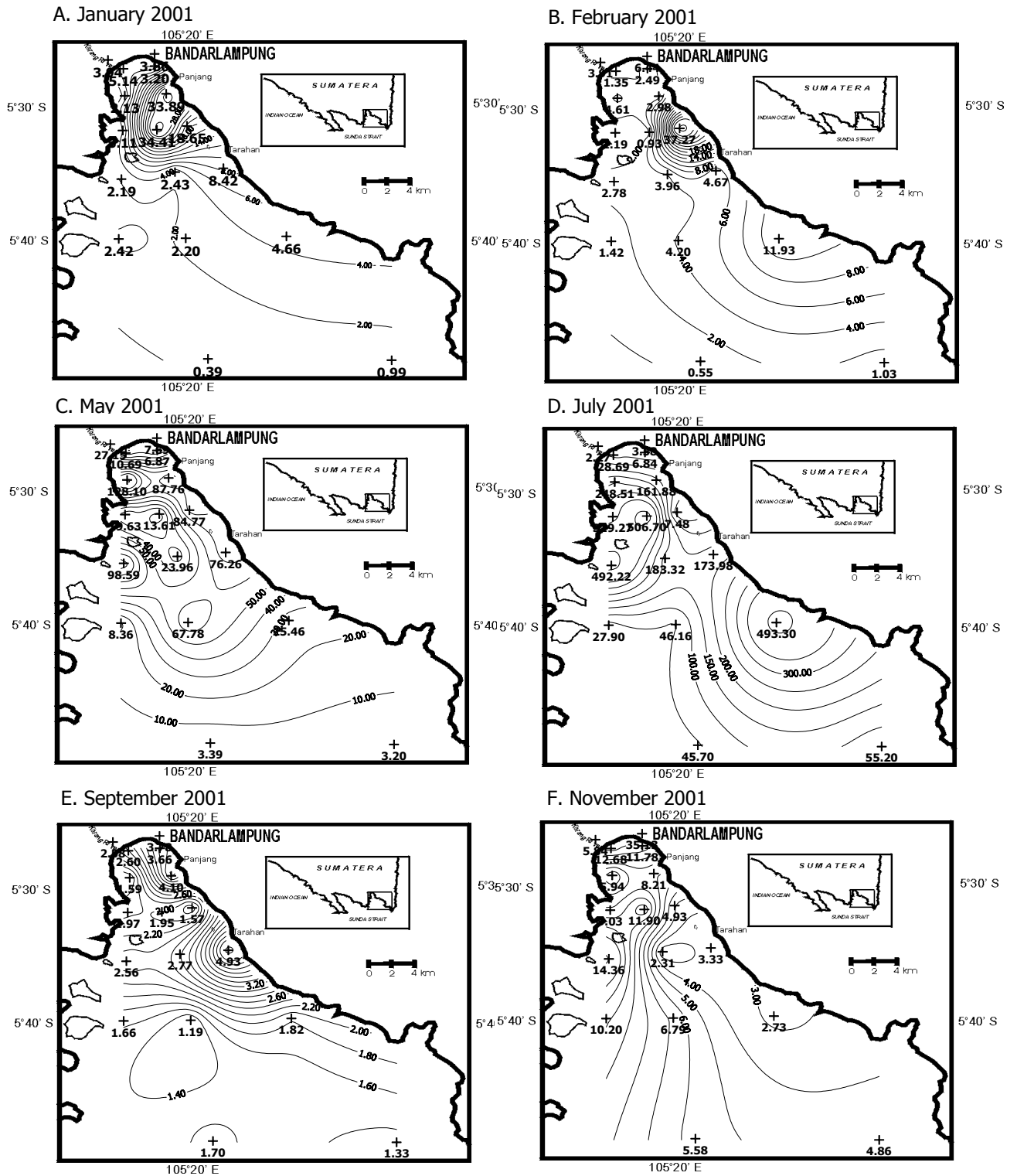
**Fig. 4.19.** Linear regression between riverine nutrient loads and ambient average nutrient concentrations in the bay. Regression between nutrient load and average inshore nutrient concentration are indicated by solid line, while regression with offshore averages are drawn in dotted lines.

with the offshore stations (stations 10,11,12) average are drawn in dotted lines. By comparing these 2 linear regressions, the relative role of nutrient loading from the incoming rivers on the variation of nutrient concentrations in the bay's waters can be observed. Linear regression between nutrient loads and inshore-waters values shows a strong correlation for all the nutrient species. By contrast, correlation with offshore values resulted in low correlation, showing that the influences of riverine nutrient loads only occurred in the limited area close to the river mouths and did not reach the offshore part of the bay. Hence, the temporal variation of those nutrients in the bay is more subject to other nutrient sources in the area, including internal transformation processes, biological uptake and additional external influences.

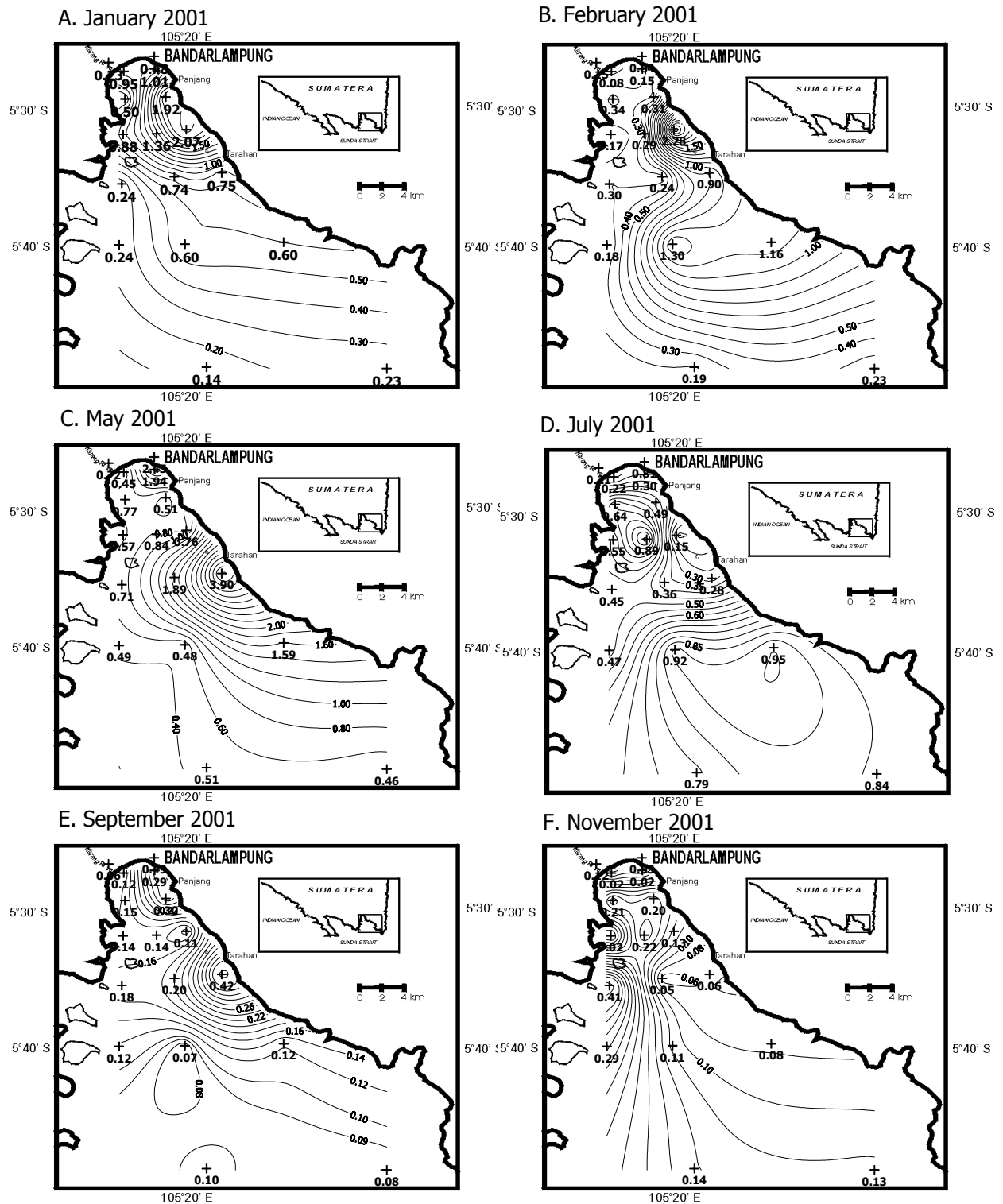
#### **4.1.5.8. Molar ratio of dissolved inorganic nitrogen to phosphate (DIN:P) and to Silicate (DIN:Si).**

Contours of molar DIN:P ratios during the study periods are shown in Fig. 4.20. There were significant temporal and spatial differences in this ratio (ANOVA,  $p < 0.05$ ). In general, low ratios ( $< 15$ ) prevailed at river mouths, stations 4 and 15, indicating a potential nitrogen limitation for phytoplankton. At these sites (stations river mouths, 4 and 15), phosphate were high throughout the study period, resulting in low DIN:PO<sub>4</sub> ratios. In the more offshore waters, this ratio increased above the Redfield's ratio, indicating potential phosphate limitation. Annual mean values of the N/P ratio ranged from 7.62 at Kota Karang river mouth to 102.12 at station 1. The minimum temporal mean prevailed in September 2001 (2.46), while maximum was observed in July 2001 (164.88). This high mean value in July 2001 was mostly caused by low phosphate concentration, while nitrogen showed a rather stable values during this period. Pearson's correlation analysis showed a weak correlation between N/P ratios and salinity ( $p > 0.05$  ; -0.11), indicating a minor influence of river inflow on these ratios.

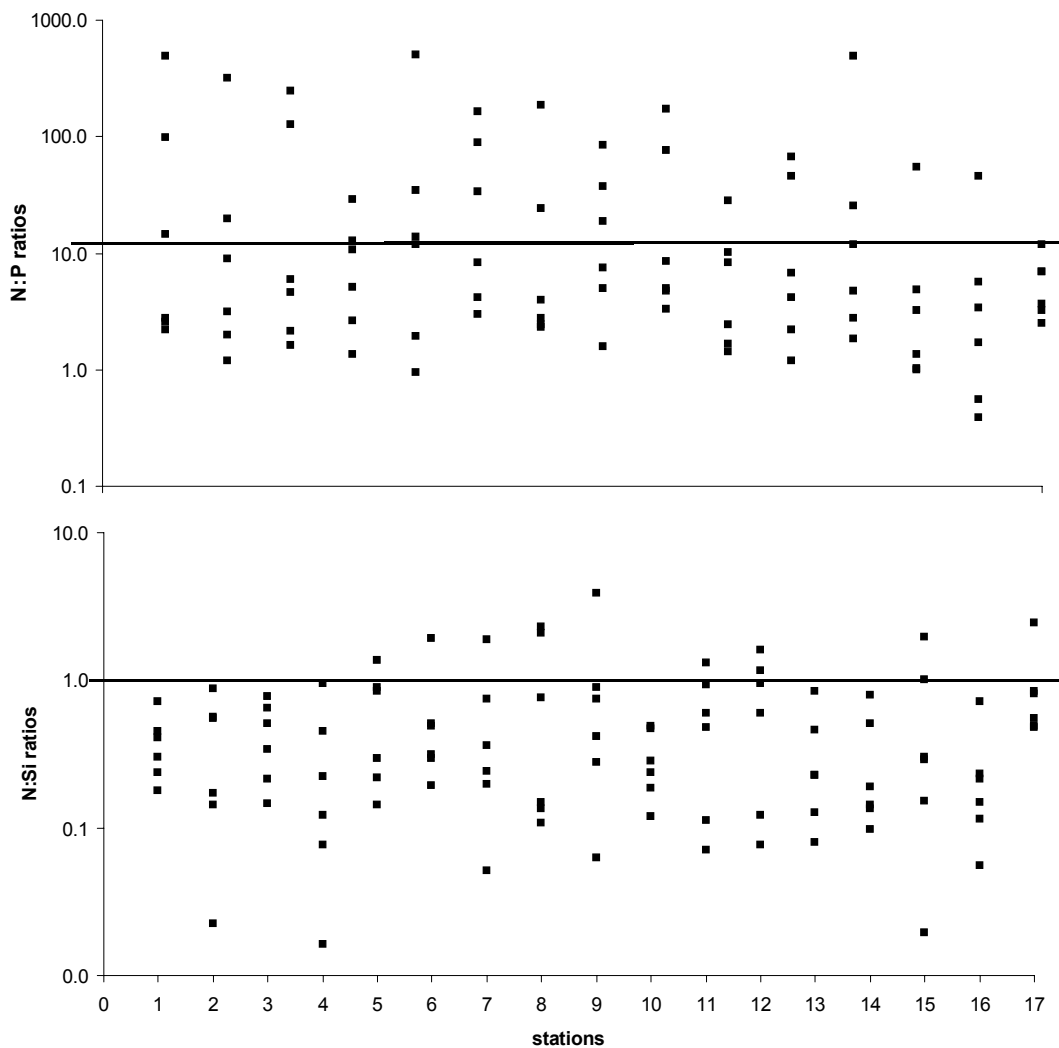
As for the DIN:P ratio, the ratios of DIN to silicate was significantly different between sites and temporal surveys (ANOVA,  $p < 0.05$ ). In general, they were low at almost all stations ( $< 1.00$ ), pointing out that silicate is not a potentially limiting nutrient (Fig 4.22). The values remained low across the seasons, especially during the high rainfall periods, where mean ratios of 0.16 to 0.18 prevailed. Maximum annual average was 1.05 at station 9, while the lowest encountered at Kota Karang river mouth (0.25). The latter was due to the high silicate content in the river water. The freshwater inflow seems to constitute a continuous supply of silicate to the bay.



**Fig. 4.20.** DIN : P ratio contours in Lampung Bay. A: January 2001. B: February 2001. C: May 2001. D : July 2001. E : September 2001 and F: November 2001.



**Fig. 4.21.** DIN:Si ratio contours in Lampung Bay. A: January 2001. B: February 2001. C: May 2001. D: July 2001. E: September 2001 and F: November 2001.

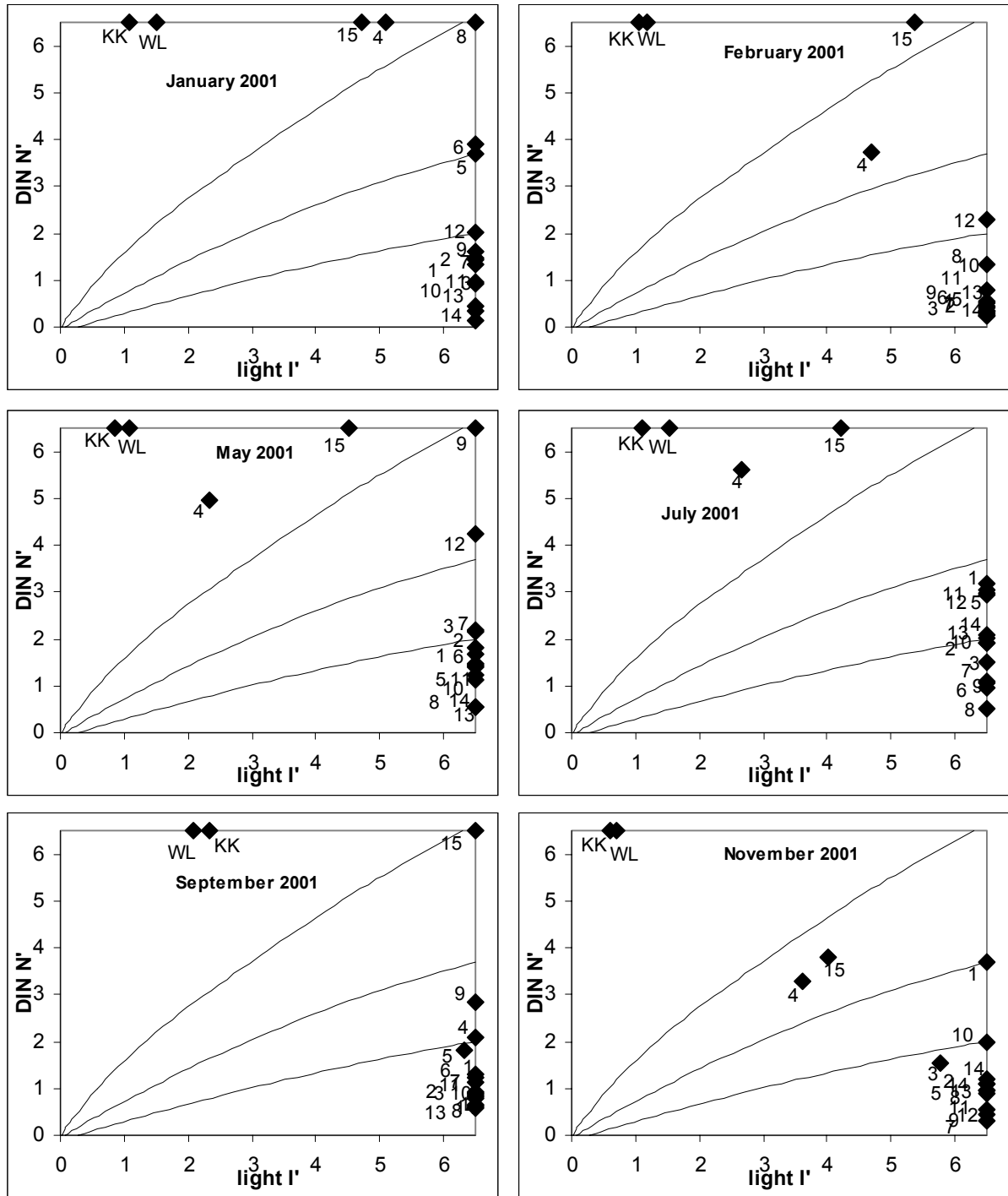


**Fig. 4.22.** Molar ratios of DIN:P (upper graph) and DIN:Si (lower graph) at each station in Lampung Bay. Horizontal lines indicate where DIN:PO<sub>4</sub> is 15 (upper graph) and DIN:Si is 1 (lower graph). 16 and 17 are station of Kota Karang and Way Lunik river mouths, respectively.

#### 4.1.6. Phytoplankton growth rate sensitivity to light and nutrients

Based on procedure developed by Cloern (1999), nutrient (DIN) and light resources were compared at each station and measurement aimed to observe to occurrence of the potential light or nutrient resource limitation. In general, most of the measurements showed that phytoplankton growth in Lampung Bay were limited by nutrient rather than light availability. Fig. 4.23. shows only few of measurements (i.e. river mouth stations and its plume area) were located in the upper-left corner of the resource-limitation map, indicating strong light limitation. Meanwhile, other stations were clustered in the lower-right of diagram, implying persistent nutrient limitation. In spatial scale, river mouth stations were always strongly limited by light, while other stations were strongly limited by nutrient resource. In seasonal scale, no significant change was observed, showing a relatively minor influence of seasons on the light and nutrient behaviour in the study area.





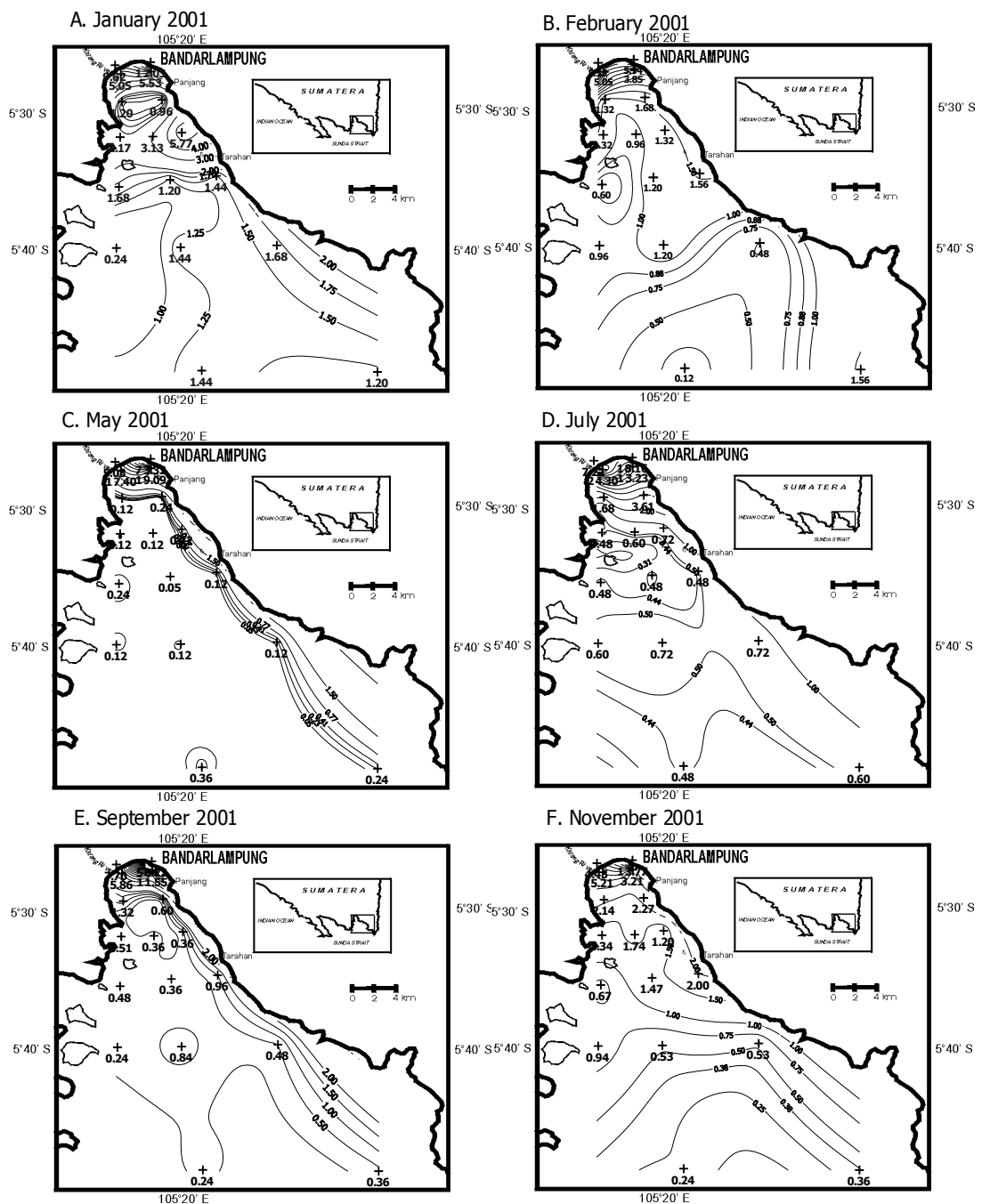
**Fig.4.23.** The light and nutrient resources for phytoplankton growth in Lampung Bay. Dark diamonds show positions of light and nutrient measurements on the resource limitation map. Numbers indicate sampling stations. (calculation was performed according to the procedure of Cloern, 1999, see methods). KK=Kota Karang river mouth ; WL = Way Lunik river mouth.

#### 4.1.7. Chlorophyll *a*, phytoplankton community and pigments

Fig.4.24. demonstrates the chlorophyll *a* distribution for each seasonal survey in Lampung Bay. There are distinct spatial gradients (ANOVA,  $p < 0.001$ ). Spatial variation

accounted for 58% of the variance. Chlorophyll *a* levels were generally high at 2 river mouth stations and the surrounding sites, ranging from 4.45 to 73.32  $\mu\text{g Chl } a \text{ l}^{-1}$  and then steeply declined in the more saline waters (ranging from 0.12 to 1.68  $\mu\text{g Chl } a \text{ l}^{-1}$ ).

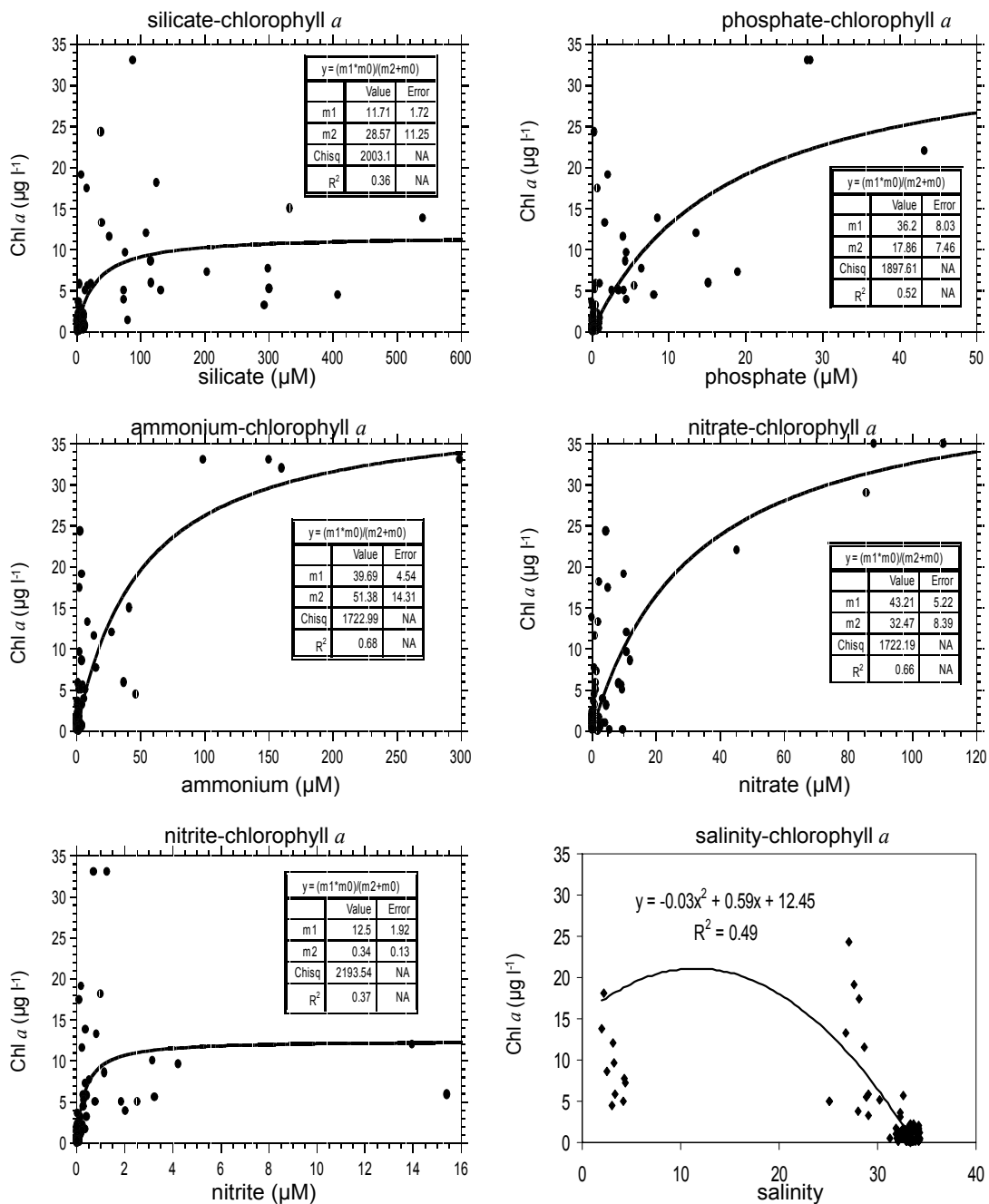
In general, besides of high chlorophyll *a* concentrations at the river mouths (ranging from 5.05 to 5.77  $\mu\text{g Chl } a \text{ l}^{-1}$ ), high concentrations were also observed at the neighboring stations (stations 4 and 15), ranging from 0.24 to 2.16  $\mu\text{g Chl } a \text{ l}^{-1}$ , indicating a high influence of the river inflows on phytoplankton biomass.



**Fig. 4.24.** Chlorophyll *a* contours ( $\mu\text{g Chl } a \text{ l}^{-1}$ ) in Lampung Bay. A: January 2001. B: February 2001. C: May 2001. D: July 2001. E: September 2001 and F: November 2001.

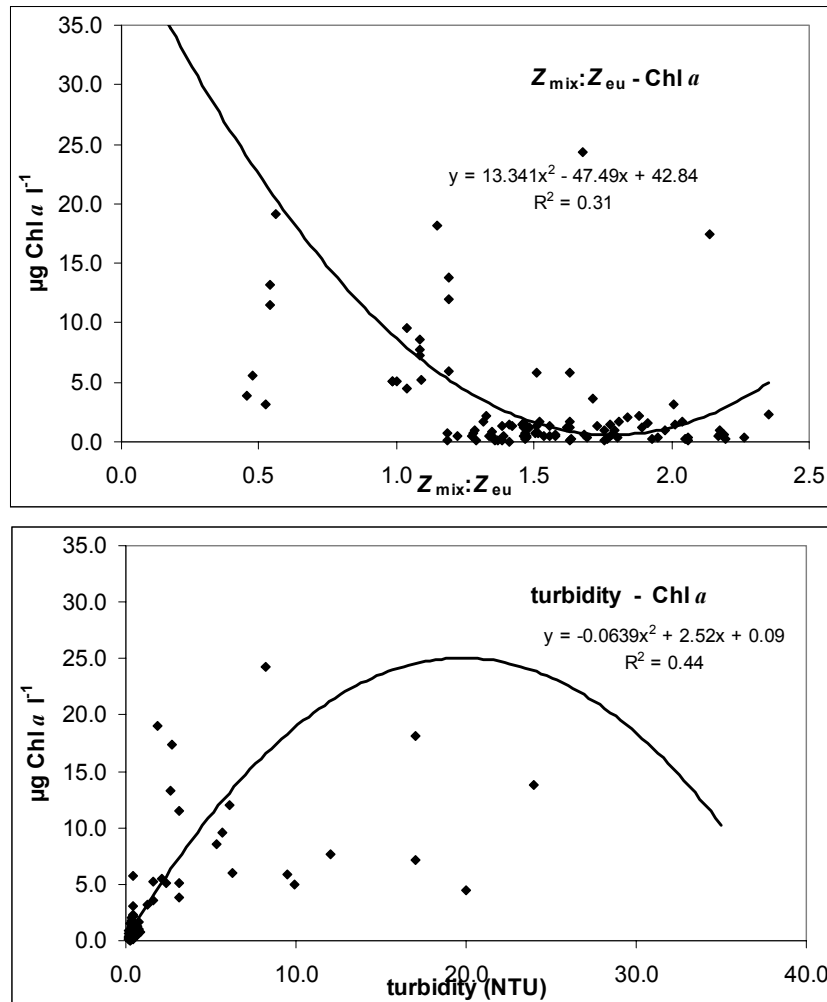
During January 2001, high concentrations were also observed in the east coast of the bay, where a group of urban settlement exist. During February 2001 survey, besides at river mouths, the maximum was found at both stations 4 and 15, reaching  $5.05 \mu\text{g Chl } a \text{ l}^{-1}$  and  $3.85 \mu\text{g Chl } a \text{ l}^{-1}$ , respectively. During other temporal surveys, high chlorophyll *a* always prevailed at stations 4 and 15, ranging from  $5.21$  to  $24.30 \mu\text{g Chl } a \text{ l}^{-1}$  and from  $3.21$  to  $19.09 \mu\text{g Chl } a \text{ l}^{-1}$ , respectively.

Seasonal variation of chlorophyll *a* displayed a low average value in February 2001 and high values in May 2001 and September 2001, which accounted for  $2.22 \mu\text{g Chl } a \text{ l}^{-1}$ ,  $6.91 \mu\text{g Chl } a \text{ l}^{-1}$  and  $5.32 \mu\text{g Chl } a \text{ l}^{-1}$ , respectively. Relationship between nutrients,



**Fig.4.25.** Hyperbolic relationships between silicate, phosphate, ammonium, nitrate, nitrite, salinity to chlorophyll *a* in Lampung Bay.  $n = 102$ .

salinity,  $Z_{\text{mix}}:Z_{\text{eu}}$  and turbidity to chlorophyll  $a$ , showed significant ( $p < 0.001$ ) correlation between silicate, phosphate, ammonium, nitrate, nitrite and to chlorophyll  $a$  (Fig 4.25). ( $R^2 = 0.68, 0.52, 0.36, 0.66$  and  $0.37$ , respectively). Salinity was significantly exponentially correlated with chlorophyll  $a$  ( $R^2 = 0.49$ ), indicating an important influence of freshwater inflow on phytoplankton biomass.



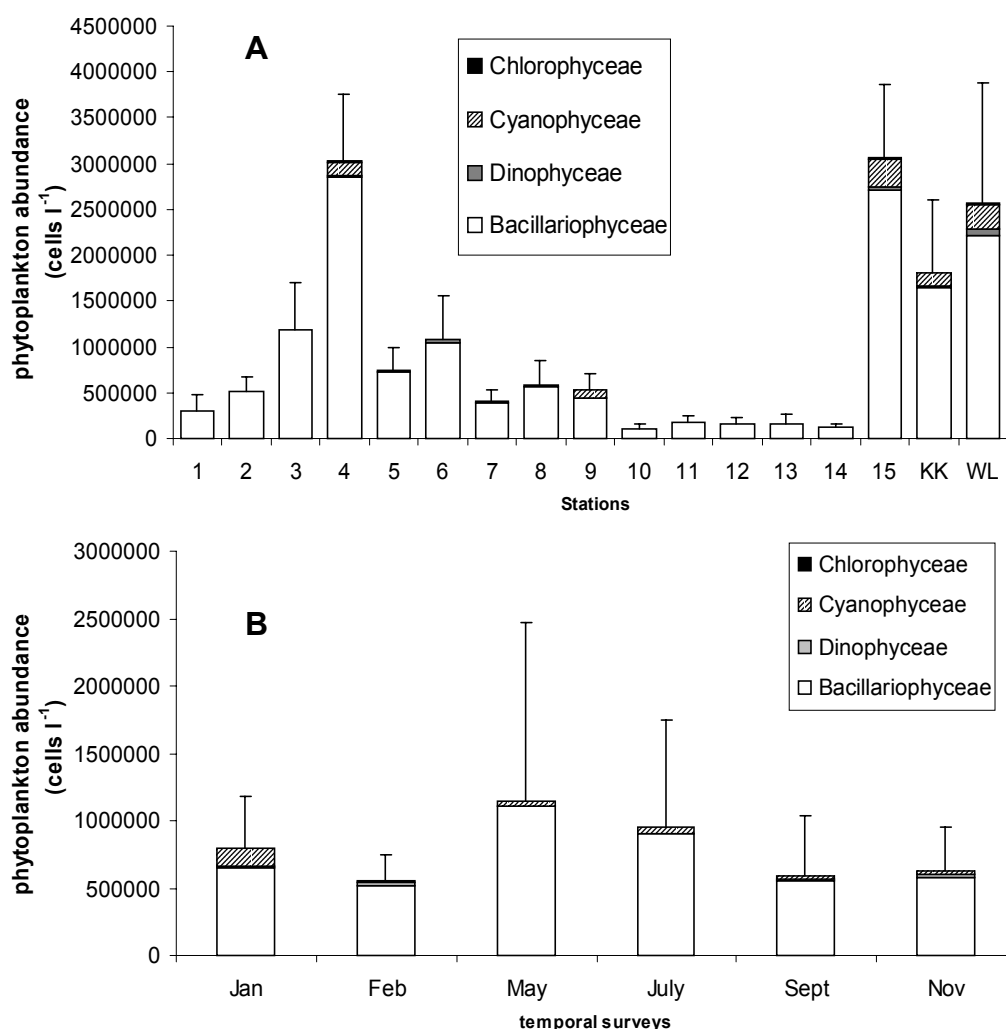
**Fig.4.26.** Exponential relationships between  $Z_{\text{mix}}:Z_{\text{eu}}$  and turbidity to chlorophyll  $a$  in Lampung Bay.

There were significant differences in phytoplankton cell abundance between the sampling sites and different seasons (ANOVA,  $p < 0.01$ ). In the river mouths and its surroundings, phytoplankton abundance was higher (around  $2.5 \times 10^6$  cells  $\text{l}^{-1}$ ) than in the more offshore waters (around  $0.5 \times 10^6$  cells  $\text{l}^{-1}$ ). Positive significant ( $p < 0.01$ ) correlations between silicate, ammonium, nitrate, nitrite and phosphate to phytoplankton abundance were found, suggesting a causal relationship between the increased nutrient supply and phytoplankton development. As expected, phytoplankton abundance was positively correlated with chlorophyll  $a$  ( $p < 0.001$ ; Pearson's  $r = 0.69$ ), indicating a low variation of phytoplankton species composition at all stations, which mostly dominated by diatoms. Phytoplankton abundance is significantly correlated with salinity, turbidity and Secchi depth (Pearson's  $r = -0.42, 0.33$  and  $-0.63$ , respectively). Seasonal variation of

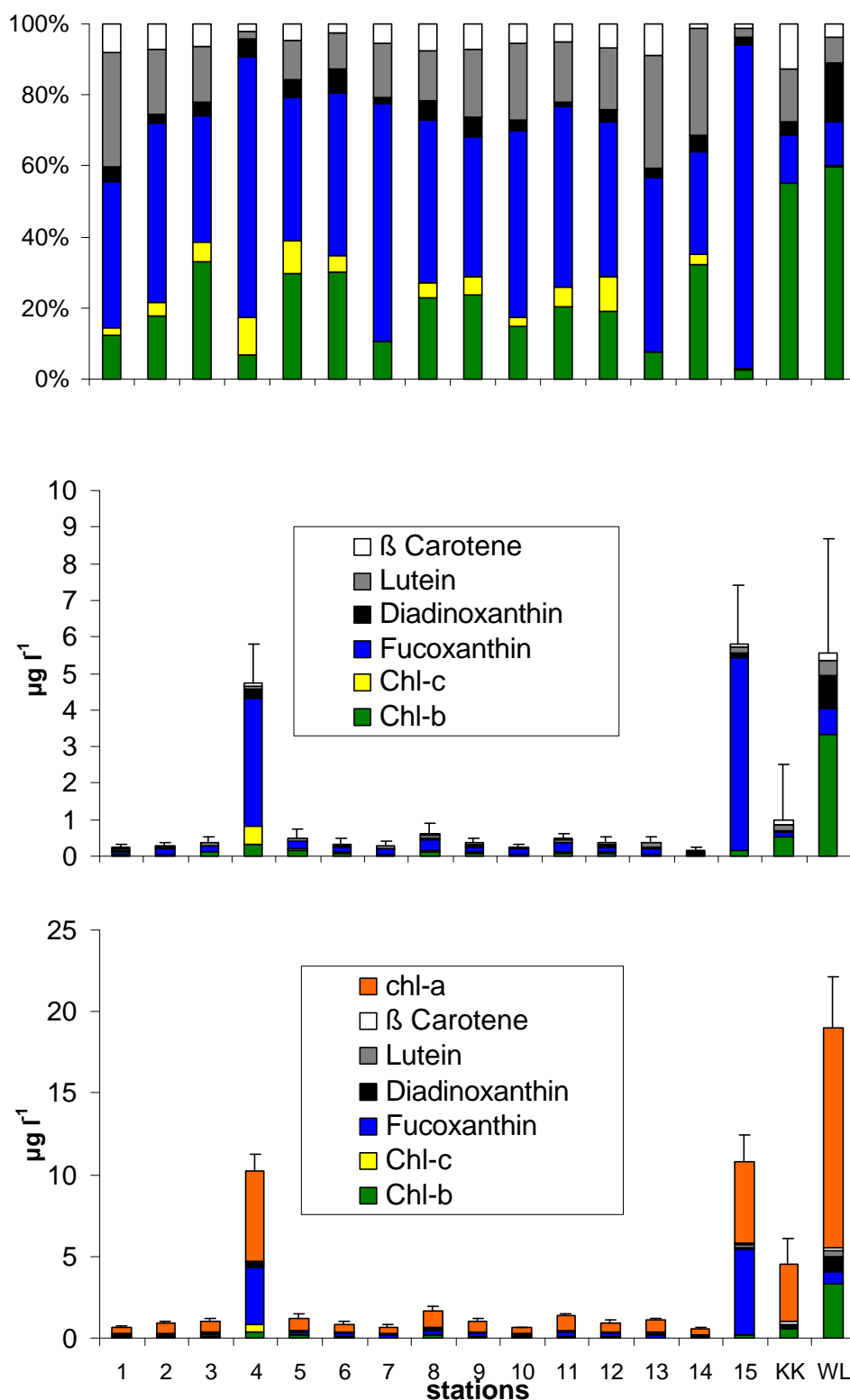
phytoplankton abundance showed high levels during May and July 2001 and low levels during February and September 2001.

The typical phytoplankton community in Lampung Bay was dominated by diatoms (*Chaetoceros danicus*, *C. cf. debilis* and *Pseudonitzschia* spp). Dinoflagellates and cyanophyceae only accounted for less than 15%, with highest abundances in the river mouths and surrounding areas (stations 4 and 15) (Fig.4.27). Typical species among the dinoflagellates were *Ceratium furca*, *C. tripos* spp, and *Dinophysis* spp, while cyanophyceae were mostly made up by *Trichodesmium* spp. This cyanobacteria species usually occurred along the shrimp pond areas, along the west and east coast of the bay.

In addition to microscopic identification, phytoplankton groups were determined through algal pigment analysis using HPLC. In Lampung Bay, the pigment observed were chlorophyll *a*, *b*, *c*, peridinin, fucoxanthin, diadinoxanthin, lutein, zeaxanthin and  $\beta$  carotene. Some of the pigments can be used as biomarker for the following species : dinoflagellates (peridinin and chlorophyll *c*), diatoms (fucoxanthin, diadinoxanthin and



**Fig. 4.27.** Average phytoplankton abundance (cells  $l^{-1}$ ) in Lampung Bay. (A) comparison between stations and (B) between temporal surveys. WL = Way Lunik river mouth, KK = Kota Karang river mouth. Bars are standard deviations.



**Fig. 4.28.** Pigments composition in Lampung Bay. Comparison in percentage (upper graph), comparison without chl *a* (middle graph) and comparison includes Chl *a* (lower graph). Bars are standard deviations. KK = Kota Karang river mouth ; WL = Way Lunik river mouth.

chlorophyll *c*), chlorophyceae (lutein and chlorophyll *b*) and cyanophyceae (zeaxanthin).

In keeping with phytoplankton distribution, high pigment concentrations prevailed at river mouths and at the surrounding sites (stations 4 and 15), while at other stations, pigment

were low. Fucoxanthin and diadinoxanthin dominated the phytoplankton pigments, indicating the dominance of diatoms at all stations, except in the river mouths (Fig.4.28). In the river mouths, chlorophyll *b* was the dominant pigment. This could be due to the high abundance of the green algae *Scenedesmus* spp. at this site. Dinoflagellates were found almost at all sites in rather low abundance, which was indicated by their biomarker chlorophyll *c*. These results show that diatoms were the main group of phytoplankton in the study area. Other groups : dinoflagellates, chlorophyceae and cyanophyceae also occurred, but they were in limited numbers.

#### 4.1.8. Planktonic primary production

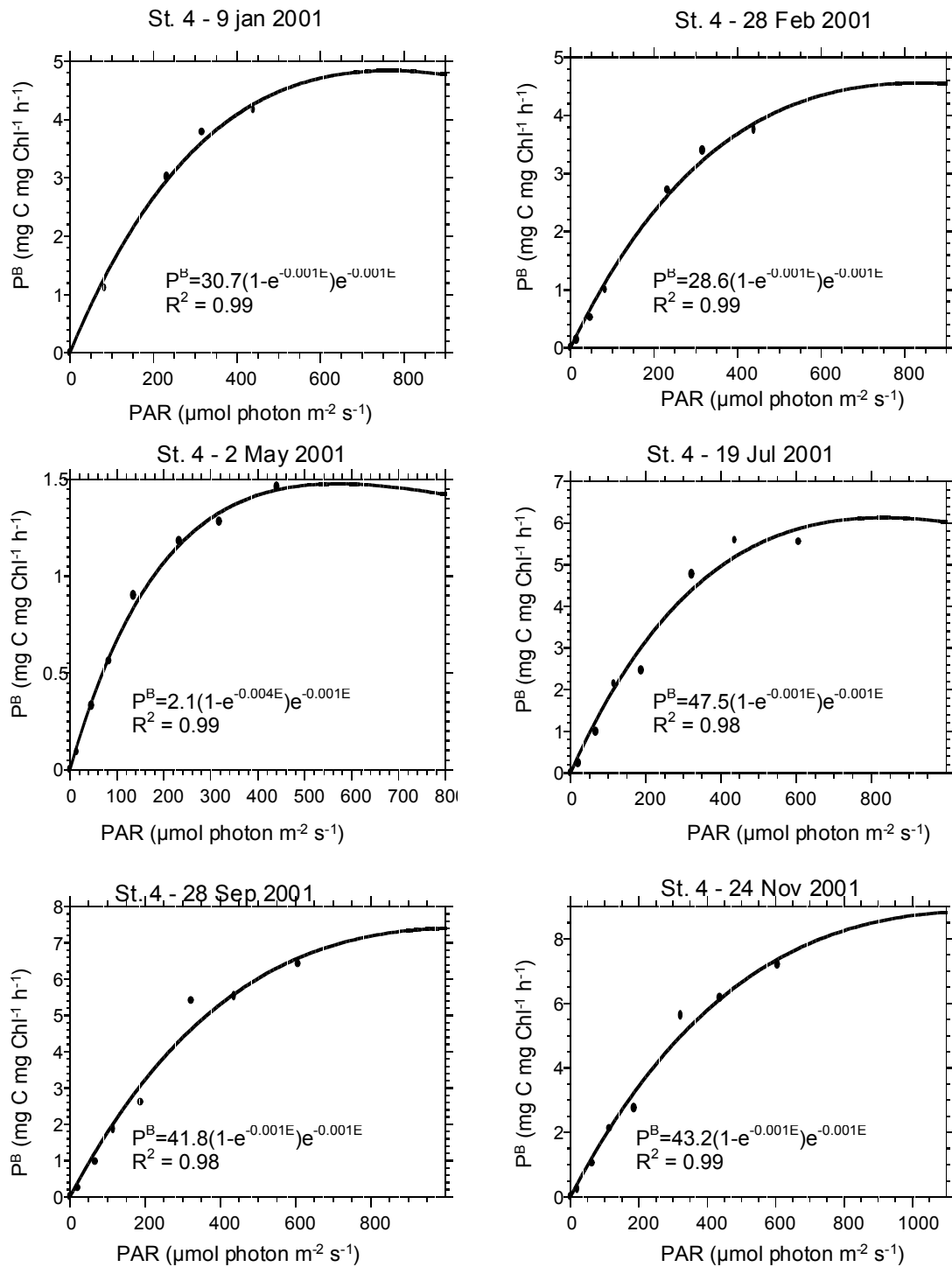
Fig. 4.29.A-C. illustrate P-E curves obtained from seasonal incubation measurements of primary production at three stations representing different nutrient conditions in Lampung Bay. Station 4 is situated in the vicinity of the Kota Karang river mouth and also nearby a traditional fish processing settlements, hence representing high nutrient waters. Station 7 is in the middle of the bay, while station 11 is situated at the outer part of the bay.

The chlorophyll-specific maximum photosynthetic rate ( $P_{max}^B$ ) ranged from 1.48 to 8.84, 1.51 to 6.08 and 0.78 to 8.30 mg C mg Chl<sup>-1</sup> h<sup>-1</sup> for stations 4,7 and 11, respectively (Fig. 4.30.A). The high nutrient site, station 4, was always high in  $P_{max}^B$ , while station 11 exhibited generally low values, with an exception in July 2001.

The slope of the P versus E is assigned as photosynthetic efficiency ( $\alpha^B$ ) (Fig. 4.30.B). In general, it ranged from 0.003 to 0.025 mg C mg Chl<sup>-1</sup> h<sup>-1</sup> ( $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$ ).  $\alpha^B$  values observed at all stations varied and there was no characteristic pattern related to the ambient water conditions. This parameter was not significantly correlated to any PE curve parameter, except to  $P_{max}^B$  ( $p < 0.001$  ; Pearson's  $r = 0.83$ ). This significant correlation underlines the dependence of  $P_{max}^B$  on the photosynthetic efficiency of the phytoplankton communities in Lampung Bay.

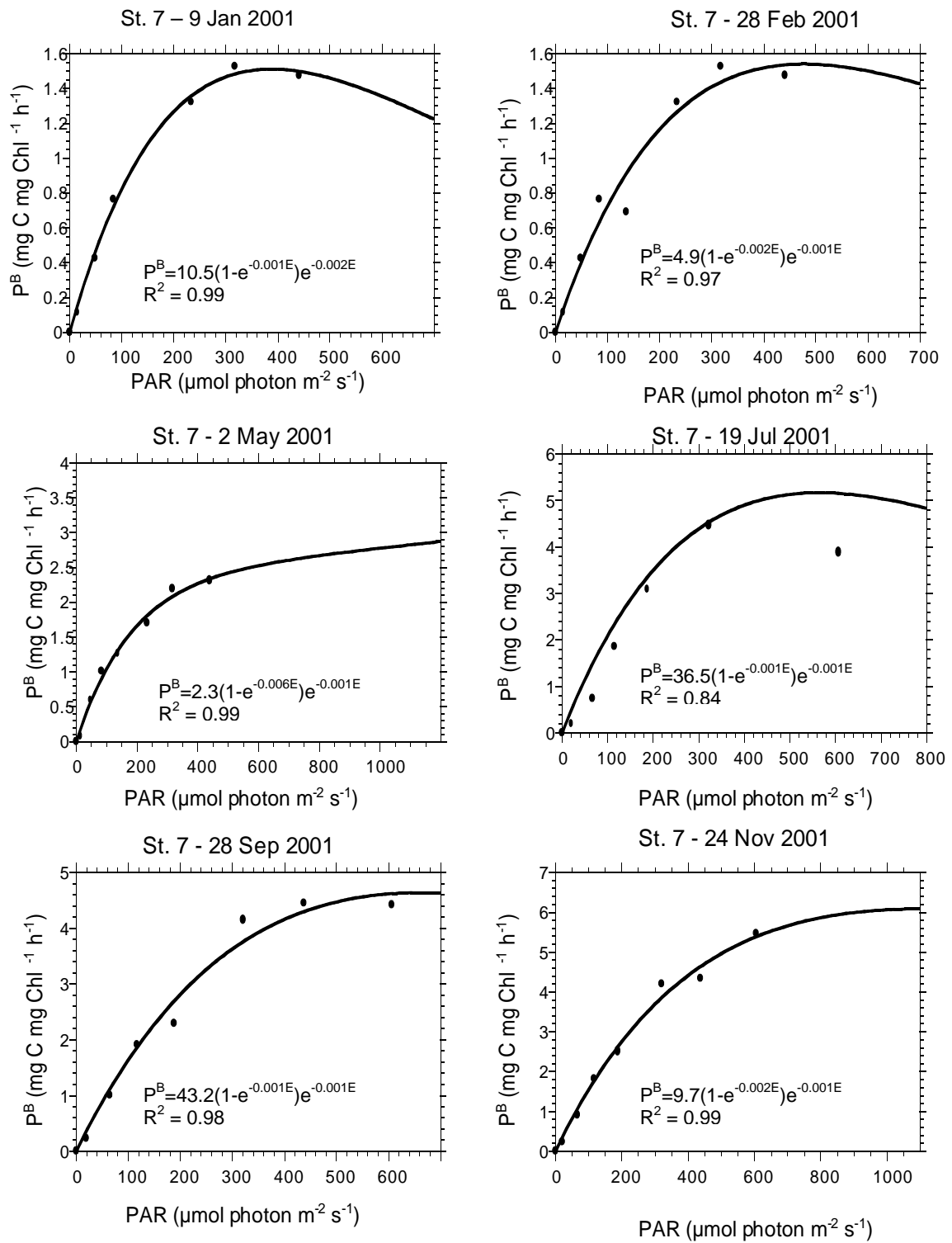
Light saturation values ( $E_k$ ) were relatively high throughout the year (Fig. 4.30.C), indicating species acclimation to strong light condition. No significant difference between sites and seasons was observed, indicating that the phytoplankton communities were generally adapted relatively similar in light levels.  $E_k$  values ranged from 93.6 to 488  $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$ . With exception in January and February 2001,  $E_k$  values of the phytoplankton community at station 4 were higher than the others, ranging from 173.9 to 435.2  $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$ . At station 7, it ranged from 142.4 to 352.0  $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$ , while at station 11, it ranged from 93.6 to 488.6  $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$ .

Integrated to the P-E previously described above, daily water column primary production exhibited a clear spatial pattern (Fig. 4.30.D). Highest production was observed at station 4 whereas in the middle of the bay (station 7) and even more at the seaward border (station 11) primary production levels were much lower. A t-test revealed that daily production at station 4 was significantly higher than at the other two stations ( $p < 0.001$ ), while station 7 and 11 were not significantly different. Maximum daily production accounted for 686 mg C m<sup>-2</sup> d<sup>-1</sup> (station 4, July 2001), while minimum level was only 36 mg C m<sup>-2</sup> d<sup>-1</sup> (station 11, September 2001).

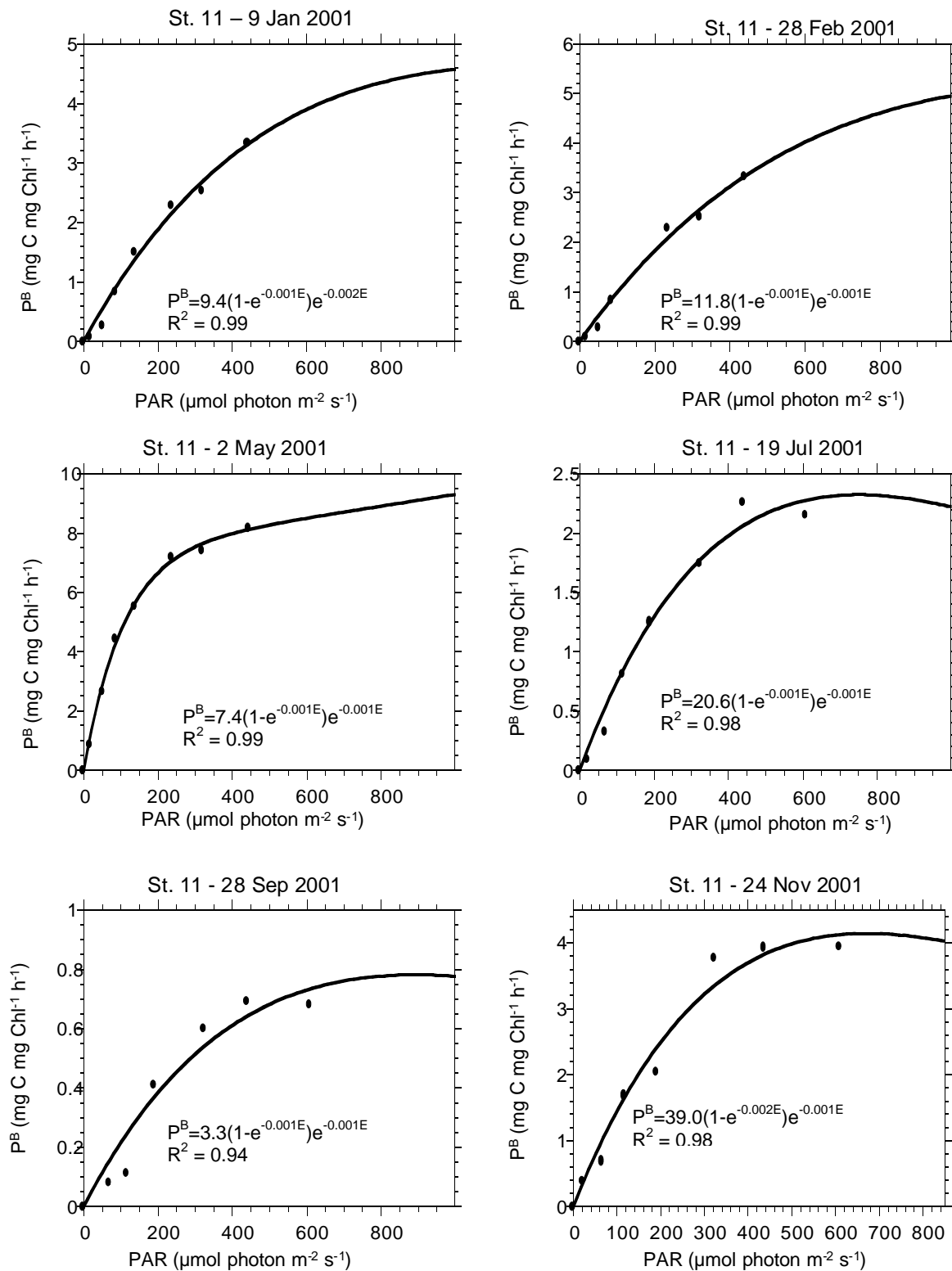


**Fig.4.29.A.** P-E curves of phytoplankton primary production at station 4 in Lampung Bay, during 6 different temporal surveys (note different scales).

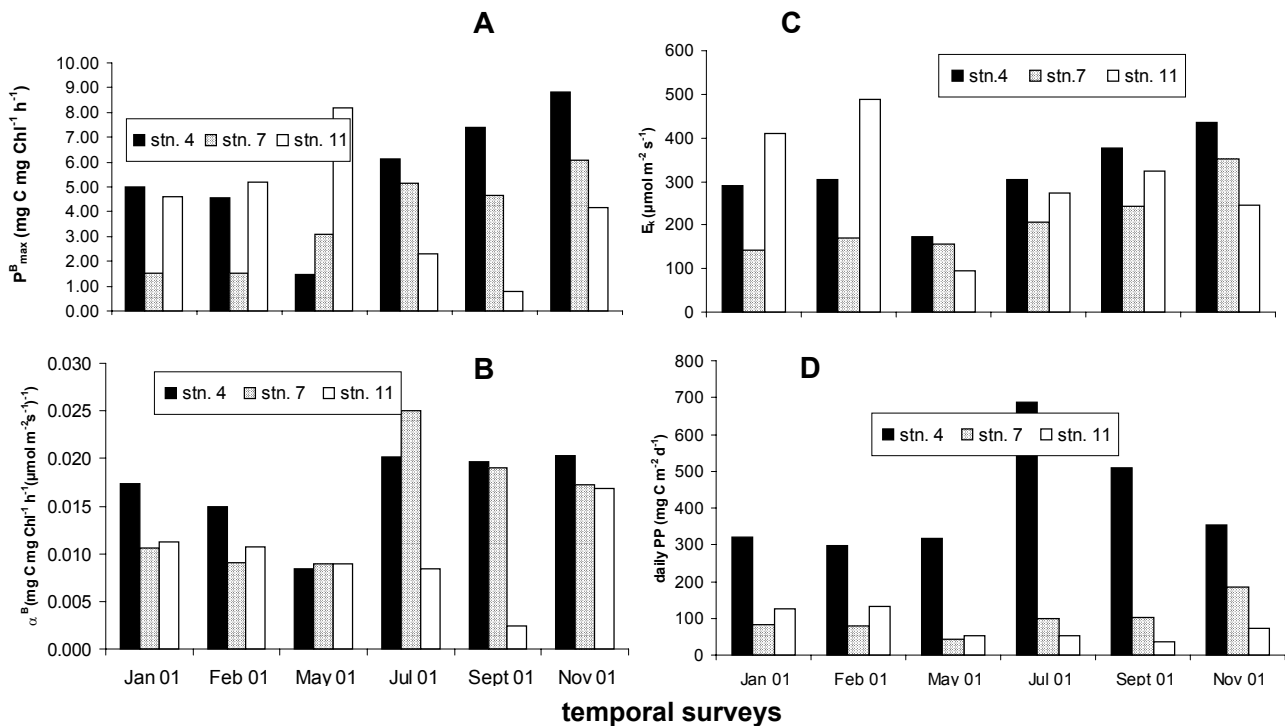




**Fig.4.29.B.** P-E curves of phytoplankton primary production at station 7 in Lampung Bay, during 6 different temporal surveys (note different scales).



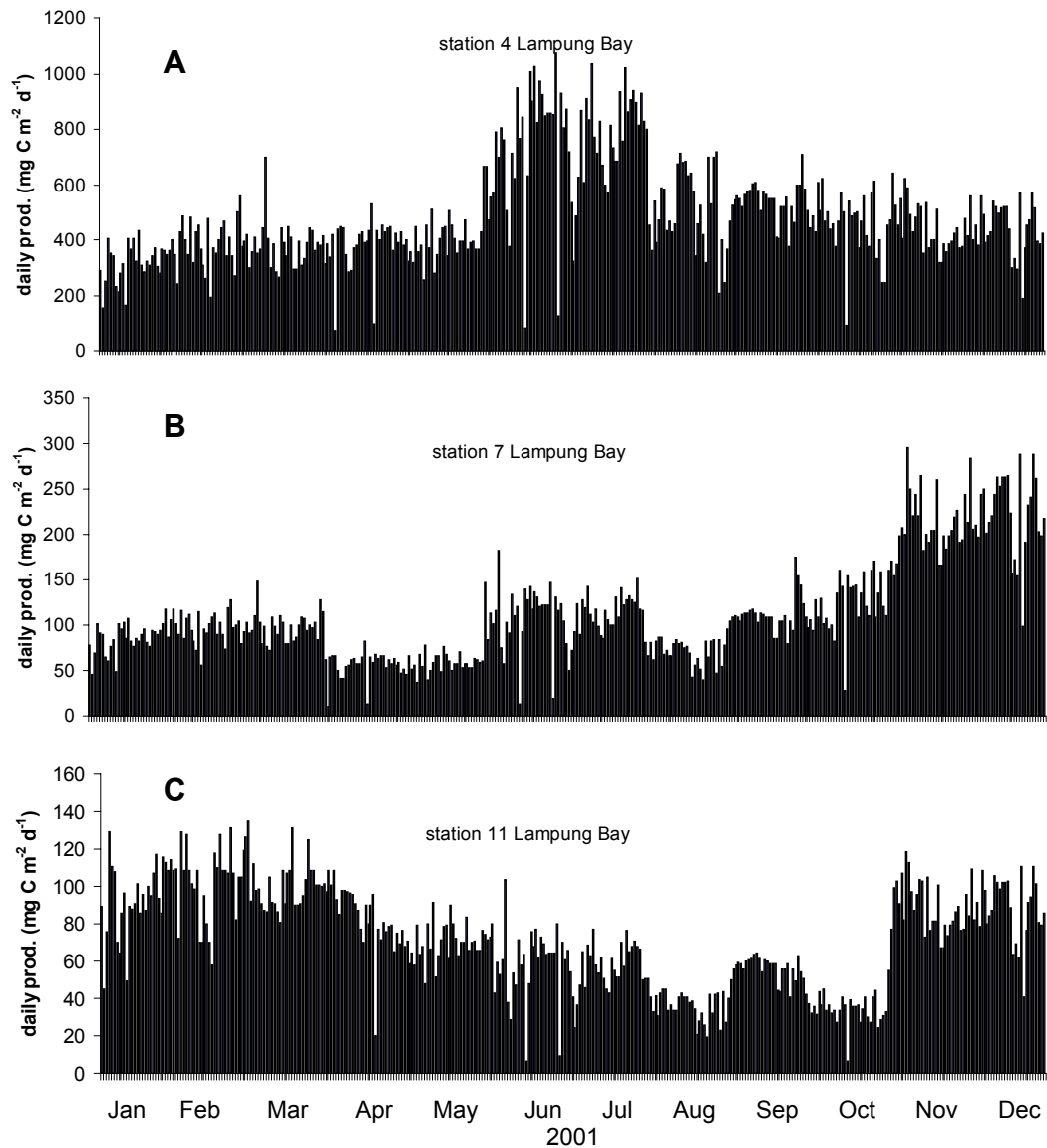
**Fig.4.29.C.** P-E curves of phytoplankton primary production at station 11 in Lampung Bay, during 6 different temporal surveys (note different scales).



**Fig. 4.30.** Annual cycle of P versus E parameters and daily primary production in Lampung Bay. (A) maximal rate of Chl-specific photosynthesis ( $P_{max}^B$ ); (B) slope ( $\alpha_B$ ); (C) light saturation parameter ( $E_k$ ) and (D) daily production (PP).

The daily production pattern is consistent with the pattern of the dissolved inorganic nutrient concentrations, chlorophyll *a*, phytoplankton abundance and the attenuation coefficient ( $p < 0.01$ ; Pearson's  $r = 0.62, 0.87, 0.92$  and  $0.88$ , respectively). Seasonal variation in daily primary production showed high values during the rainy seasons (January, February 2001, September and November 2001), and low values during the dry season (in May 2001 and July 2001), with one exception for station 4, which exhibited maximum production in July 2001. This may be due to the steady nutrient supply to this site from the Kota Karang river and from the coastal fish processing activities in its direct vicinity, which produces a significant amount of organic sewage all the year around.

Fig.4.31 shows an estimation of annual primary production for Lampung Bay at the three different nutrient state sites. In the vicinity of the Kota Karang river (station 4), annual primary production accounted for  $196.68 \text{ g C m}^{-2} \text{y}^{-1}$ , whereas in the middle (station 7) and offshore part of the bay (station 11), it was considerably lower ( $40.12 \text{ g C m}^{-2} \text{y}^{-1}$  and  $30.78 \text{ g C m}^{-2} \text{y}^{-1}$  for stations 7 and 11, respectively). The average of these three sites which are held to be representative for the different nutrification levels in the bay, accounted for  $89.20 \text{ g C m}^{-2} \text{y}^{-1}$ . Hence, regards to the trophic classification of coastal ecosystems (Nixon, 1995), Lampung Bay can be classified as oligotrophic in its offshore waters (below  $100 \text{ g C m}^{-2} \text{y}^{-1}$ ), while the coastal area subjected to the river inflow and fishermen village was to be classified as mesotrophic (between  $101\text{-}300 \text{ g C m}^{-2} \text{y}^{-1}$ ).



**Fig. 4.31.** Annual phytoplankton primary production estimates in Lampung Bay 2001. (A) station 4 ; (B) station 7 and (C) station 11.

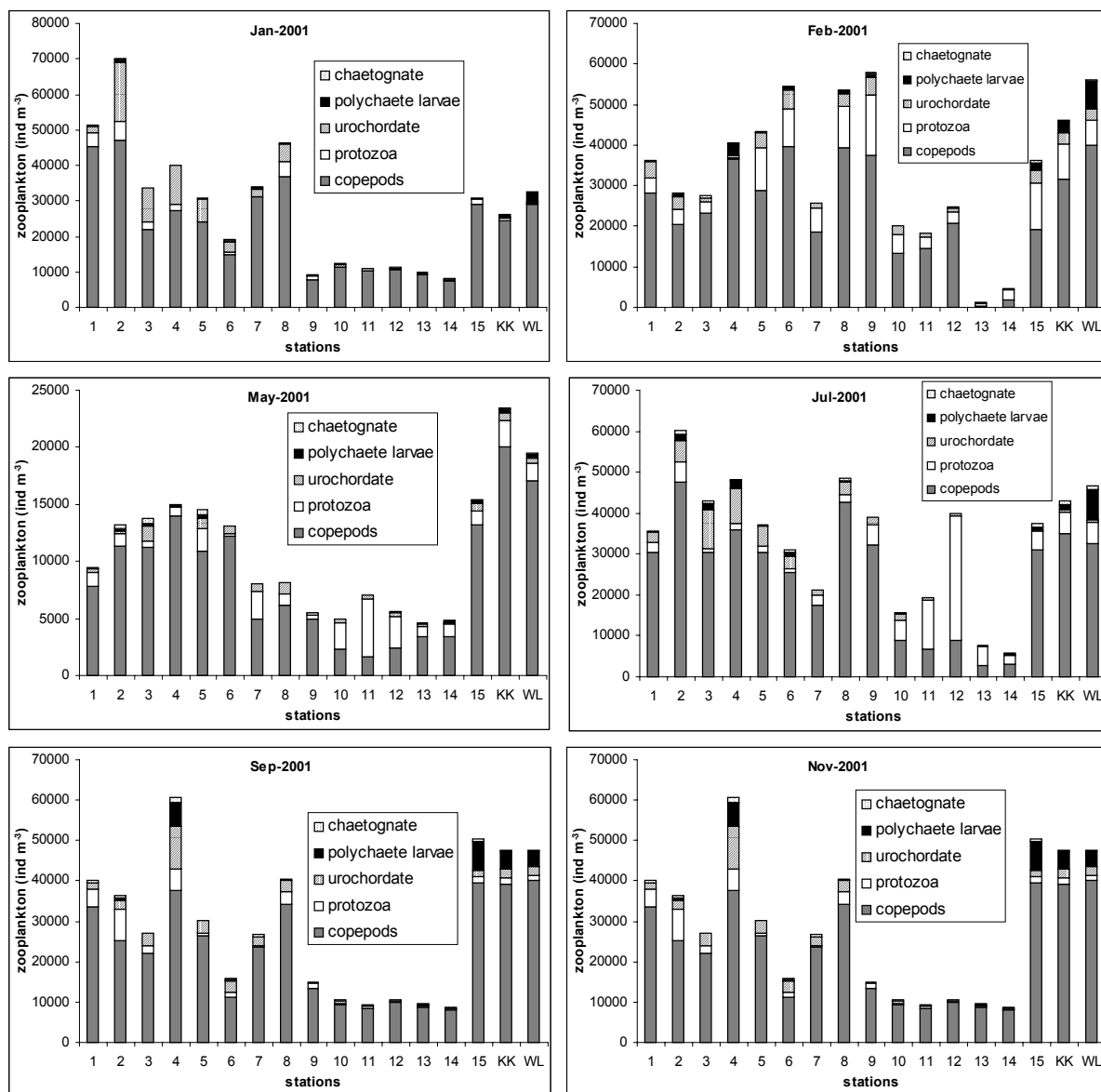
#### 4.1.9. Zooplankton community

In general, the zooplankton communities in Lampung Bay were dominated by marine copepods and followed by protozoa. Other groups such as gastropod larvae, polychaete larvae and urochordates played only a minor role.

Zooplankton was most abundant in the river mouths and at the surrounding stations (stations 4 and 15) amounting to more than 50000 ind m<sup>-3</sup>, while rather low abundances were found at the centre and at the outer borders of the bay (ranging from 5000 ind m<sup>-3</sup> to 30000 ind m<sup>-3</sup>). This pattern coincides with the pattern of phytoplankton biomass and

and cell abundance ( $p < 0.001$ ,  $R = 0.72$ ), indicating a strong link between predators (zooplankton) and preys (phytoplankton). This is supported by the fact that the most dominant genus of zooplankton were marine copepods such as *Acartia spp.* and *Paracalanus spp.*, which are well known as intensive phytoplankton grazers in marine and coastal environments.

The occurrence of gastropods and polychaete larvae indicates the presence of their adult organisms. In general, the larvae were more abundant in the river mouths and at the surrounding stations. Polychaetes are often associated with muddy sediment and tolerate to oxygen poor conditions (Nybakken, 1988). In keeping with this, polychaete larvae were most abundant in the more-turbid and low oxygen waters, which may also be a main habitat for the adults in the bay. At these sites, the relative abundance of copepods decreased.



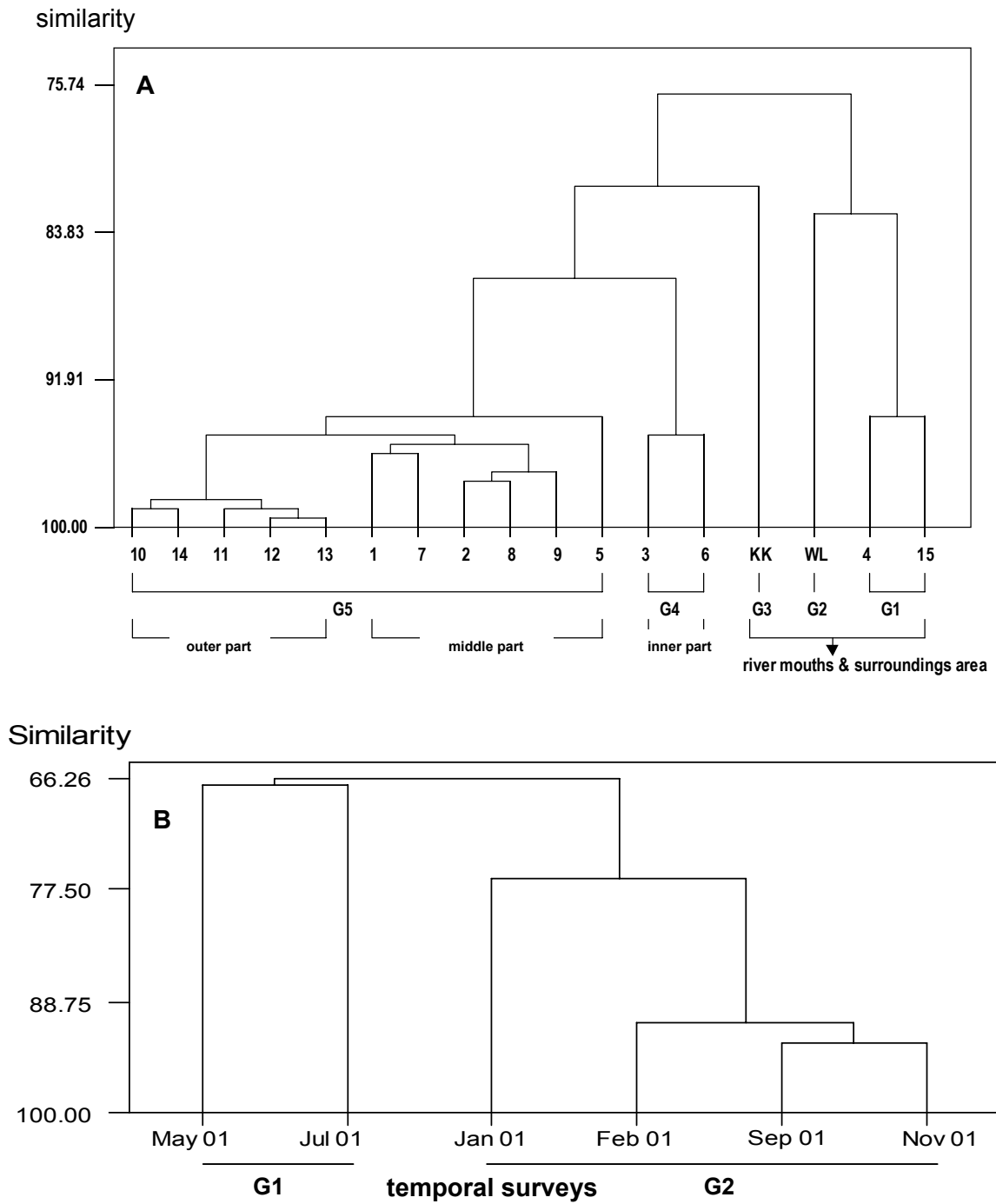
**Fig.4.32.** Zooplankton groups at each sampling station and temporal survey in Lampung Bay. KK = Kota Karang river mouth and WL = Way Lunik river mouth.

#### 4.1.10. Cluster and Principal Component Analysis

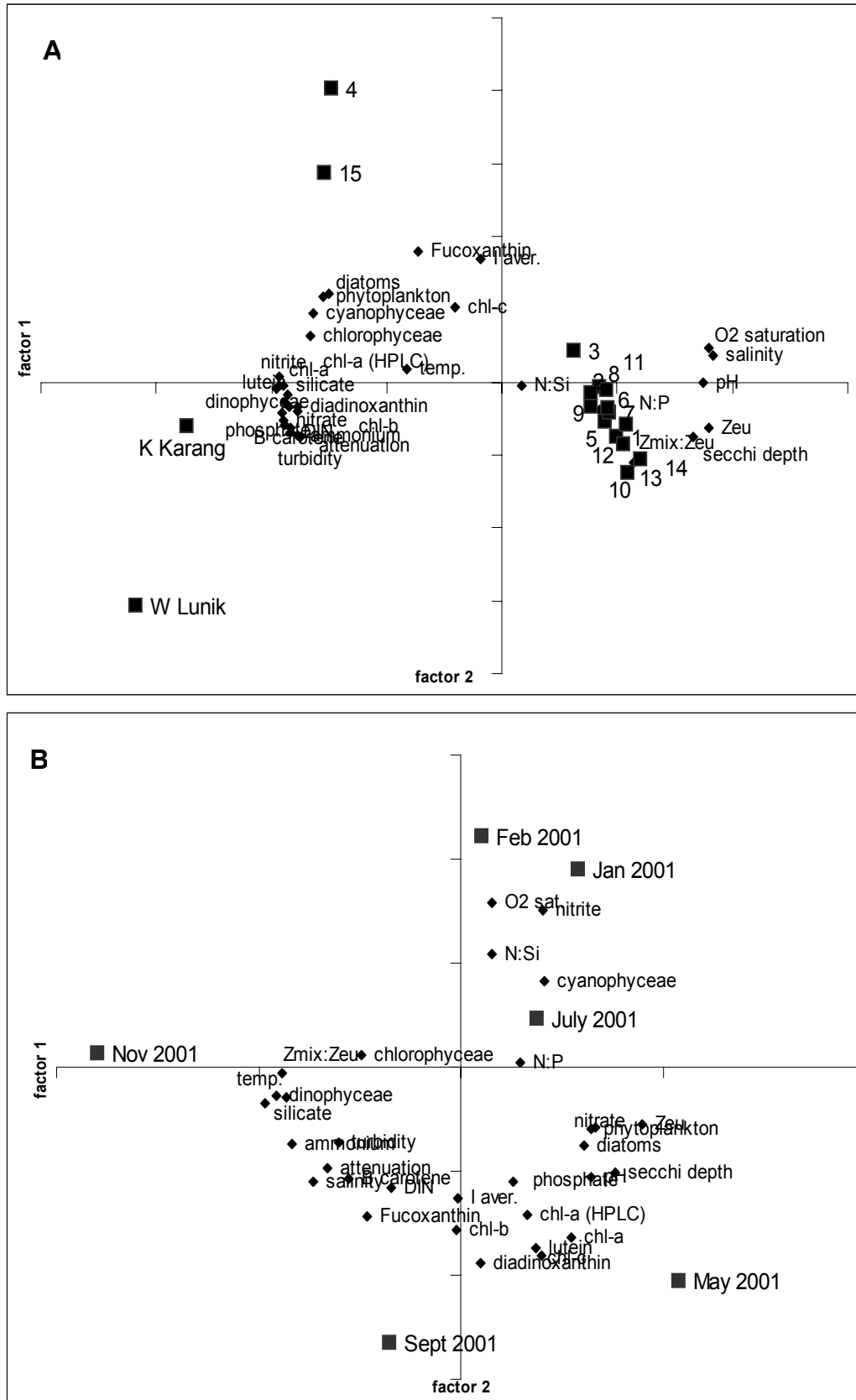
A grouping process based on 32 variables measured on each station for the whole study period has been performed complemented by a biplot PCA. Fig. 4.33. and 4.34. illustrate the cluster-dendrogram and biplot PCA diagram, respectively. Cluster analysis at the 93% similarity level, resulted in 5 distinct spatial groups of stations in Lampung Bay, those are : (1) station 4 and 5 ; (2) Way Lunik river mouth ; (3) Kota Karang river mouth; (4) stations 3 and 6 ; and (5) stations 1,7,2,8,9,5,10,11,12,13 and 14. Cluster 5 can subdivided into 2 subgroups : (5-1) stations 1,7,2,8,9 and 5 ; and (5-2) stations 10, 14, 11, 12 and 13. This grouping results reflects a clear spatial grouping in the bay, which consisted of the river mouth and surrounding area (groups 1, 2 and 3), the all inshore waters (group 4), middle part of the bay (subgroup 5-1) and finally outer part of the bay (subgroup 5-2). Through biplot of PCA diagram (Fig. 4.36.), it can be seen that groups 1 and 2 were strongly characterized by high nutrients, high turbidity, high phytoplankton biomass, high phytoplankton pigments, low N:P ratio, low  $Z_{mix}:Z_{eu}$ , low secchi depth, low oxygen saturation, low pH, low  $Z_{eu}$  and low salinity. The other groups differed typically exhibited low nutrients, low turbidity, low phytoplankton biomass, low phytoplankton pigments, high salinity, high  $Z_{mix}:Z_{eu}$ , high oxygen content, High N:P ratio and high Secchi depth.

The temporal cluster analysis resulted in the occurrence of 2 distinct seasonal groups. In the first cluster, the survey of January 2001, February 2001, September 2001 and November 2001 were grouped together, while the second group encompassed the surveys in May 2001 and July 2001. In more detail, the first group can be divided into 3 sub-groups : (1) January 2001 ; (2) February 2001 and (3) September 2001 and November 2001. This temporal grouping is consistent with the seasonal pattern, with the first group represents the rainy period and the second group represents the dry period. The Biplot PCA showed that surveys in January and February were close one to another characterized by high values in nitrite and oxygen content, while the surveys in September and November 2001 showed high levels of ammonium, silicate, and turbidity. Surveys in May and July 2001 were characterized by high phosphate and phytoplankton biomass.

The PCA diagram (Fig.4.34-B) also shows a strong positive correlation between the parameters oxygen saturation, salinity, pH,  $Z_{eu}$ ,  $Z_{mix}:Z_{eu}$  and secchi depth, and inverse correlation between those parameters and phytoplankton biomass, turbidity and nutrients. There was also a strong correlation between chlorophyll *a* with both salinity and turbidity, indicating an importance role of fresh water inflow on phytoplankton biomass.



**Fig. 4.33.** Dendrogram of spatial clusters (A) and temporal clusters (B) based on 32 variables in Lampung Bay. KK = Kota Karang river mouth, WL = Way Lunik river mouth. G1 = Group 1 ; G2 = Group2, etc.

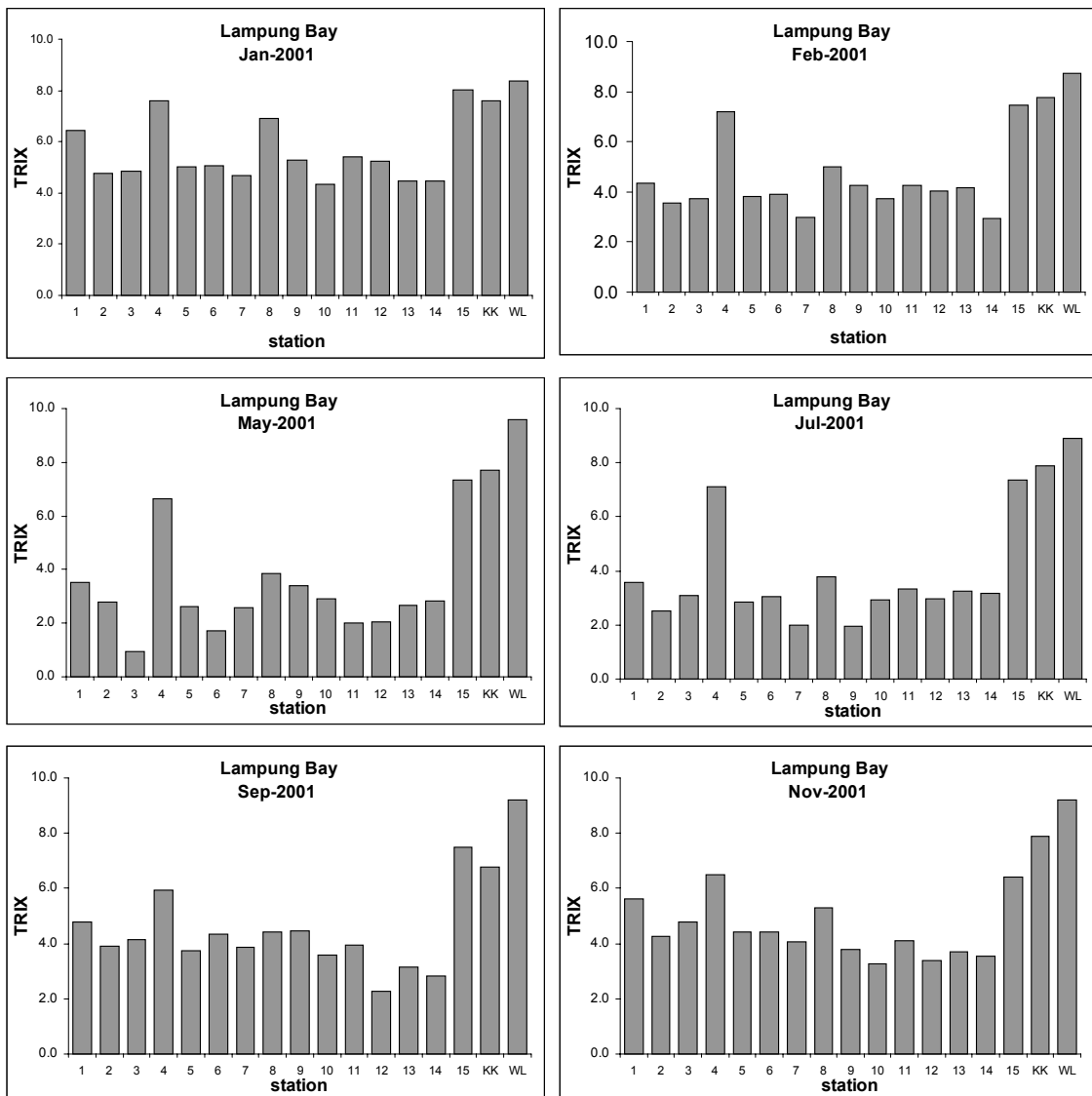


**Fig. 4.34.** Principal component analysis of the total environmental variables (32 variables) calculated based on stations as object (A) and time of samplings as object (B) in Lampung Bay.



### 4.1.11. Trophic state of Lampung Bay

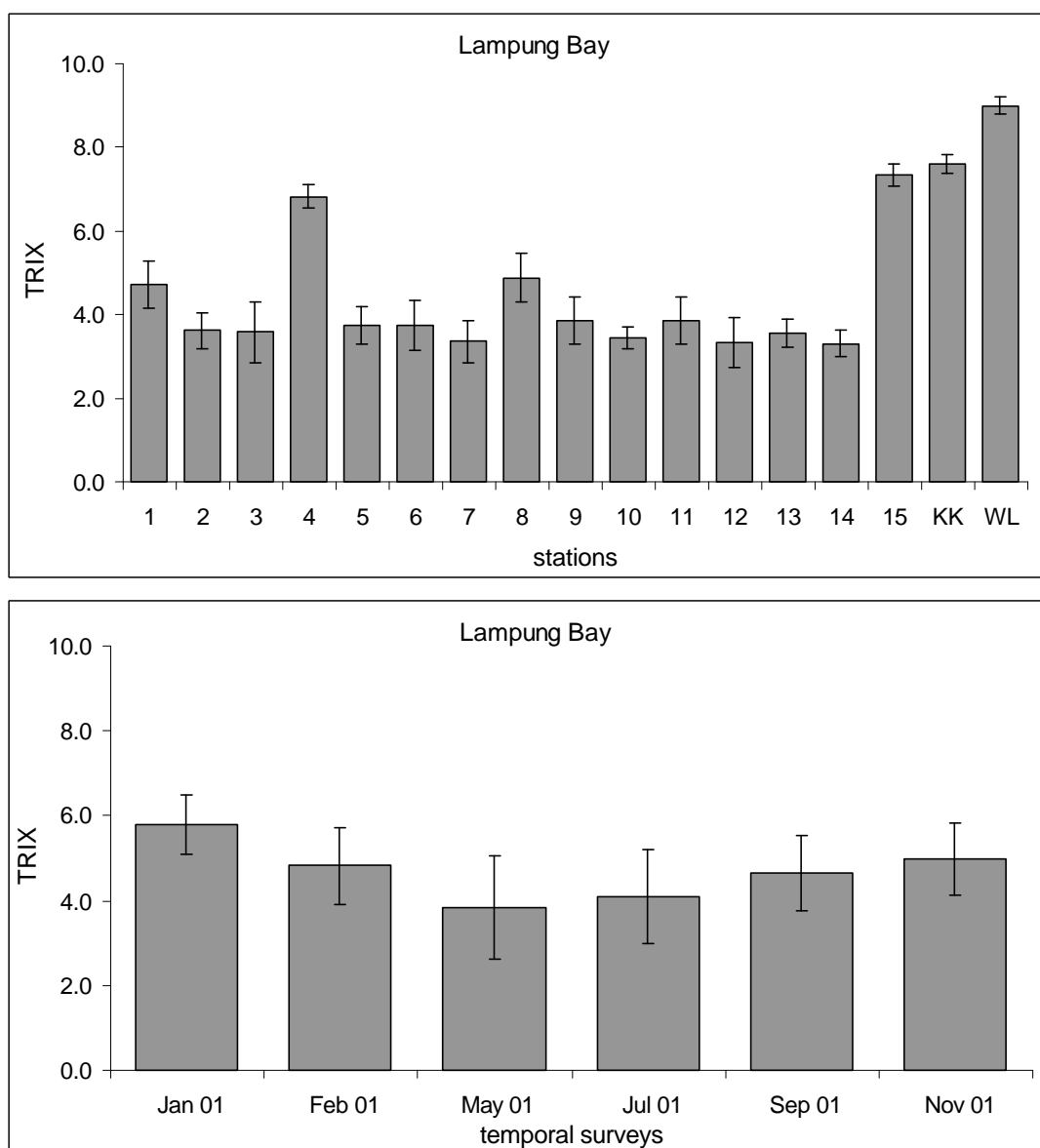
The calculation of the trophic index (TRIX) was performed by taking into account the complete data set from the all bays stations. This allows for an objective comparison between different bay systems. Fig.4.35 shows distribution of TRIX values for each station throughout the year, while Fig.4.36. shows the average of TRIX values for the stations (upper graph) and the average for each temporal survey (lower graph). In general, all river mouth stations and their surrounding stations (stations 4 and 15) were high in TRIX values, exceeding a level of 6.0. By contrast, at the more offshore stations, the TRIX decreased down below 5.0. At all river mouth stations, it ranged from 6.8 to 9.6 for then slightly reduced at stations 4 and 15, ranging from 5.9 to 8.0. At other stations, it ranged from 1.9 to 6.4. The lowest TRIX (1.9) prevailed at the west coast of the inner bay (station 3) during May 2001 . This station is not subjected to the direct influence of river run off or intense human activities. The highest TRIX (9.6) prevailed at Way Lunik river mouth during the July 2001 measurement (TRIX = 9.6).



**Fig. 4.35.** TRIX for each temporal survey in Lampung Bay. KK = Kota Karang river mouth, WL = Way Lunik river mouth.

Lowest average of TRIX (of about 4) was found during the dry season in May and July 2001, while highest levels were found during the rainy season, especially in January 2001, where accounted for 5.79.

In general, the calculation of the trophic index in Lampung Bay revealed that according to combination criteria of Caiaffa (1999) and Nixon (1995), the limited area of river mouths and surrounding waters has to be classified as hyper-eutrophic because of their high nutrient levels and elevated phytoplankton biomass (TRIX > 6.0). On the contrary, the middle and outer parts of the bay have to be rated as eutrophic and mesotrophic (TRIX = 4.0 - 6.0 and 2.0 - 4.0, respectively).



**Fig.4.36.** Average TRIX values in spatial (upper graph) and temporal (lower graph) scales in Lampung Bay. KK= Kota Karang river mouth; WL = Way Lunik river mouth. Bars are standard deviations.

## 4.2. Discussion on Lampung Bay

The combined results show that there are five different areas with distinct ecological properties in Lampung Bay, which are : (1) river mouths (2) the area subjected to direct riverine influence (river plumes) (3) the inner part of the bay which is not subjected to riverine inflows (4) the middle part of the bay and (5) the outer part of the bay. In the following, a brief characterisation of the abiotic and biotic features of these different regimes is discussed.

### 4.2.1. Parameters related to underwater irradiance

Although slightly deeper than Jakarta Bay, the water column of Lampung Bay (average depth 17.3 m) is homogeneously mixed (Wiryawan *et al.*, 1999), except in the limited area of river mouths, where a local stratification may occur due to salinity differences. Comparison between light and nutrient resources showed that, only river mouths and surrounding sites were limited by light, while at other sites, light was not a limiting element for phytoplankton growth. However, based on the light availability for phytoplankton growth, which is expressed as the  $Z_{mix}:Z_{eu}$  ratio, the inner part of the bay is generally better than the offshore waters, mainly due to the low water depth.

In the river mouths,  $Z_{mix}:Z_{eu}$  ratios were high ( $>1$ ) due to high turbidity, but in their river plumes, this ratio decreased (around 1) due to the decrease of turbidity, resulting in low  $Z_{mix}:Z_{eu}$  ratios. This ratio increased again in the middle and outer parts of the bay ( $>1.5$ ), which is caused by significant increase of the mixed water column. Thus, from the light availability for phytoplankton growth, the river plume waters are the optimum site compared to other sites in the bay.

### 4.2.2. Nutrients and their loads from rivers

Estimates on the total annual loads of nutrients from all the 6 rivers entering the bay are 5002.8 t DIN  $y^{-1}$ , 1095.56 t  $PO_4\text{-P}$   $y^{-1}$  and 14731.5  $SiO_4$  t  $y^{-1}$ . However, those rivers are not the only source of nutrients for the bay. Other sources of nutrients are scattered along the coast, such as a trading harbour, an industrial area, agricultural rice fields and shrimp pond areas, altogether contributing to the nutrient dynamics of the bay. Both of the rivers observed exhibit similar patterns in nutrient loads, showing that ammonium and nitrate as the most important nutrients discharged by the city. It is supposed that source of ammonium is mostly from domestic sewage emissions downstream. This domestic sewage contains high amounts of organic material which are directly entering the small streams and canals because sewage plant are lacking. Decomposition of those organic materials will result in oxygen exhaustion and ammonium formation, especially during the dry season with low water exchange. Fishermen settlement in the vicinity of Kota Karang river mouth also contribute some amount of organic waste, which in turns being decomposed, producing ammonium in the water. By contrast, nitrate is likely to be a results of fertiliser leakage from the agricultural activities along the river banks.

Nutrient concentration spatial distribution in the bay was high in the river mouths and surrounding areas, then decreased in the inner, middle and outer parts of the bay. In the riverine-marine transitional zone, nutrient concentrations sharply decreased in a factor of about 5 to 10. This sharp decrease might be caused by dilution with lower nutrient water

and due to the rapid uptake by phytoplankton. Correlation analysis between riverine nutrient loads with ambient nutrient concentrations in the bay showed that the nutrient concentration in the whole bay waters was not only regulated by the nutrient loads from the 2 rivers observed. The strong influence occurred only in the limited area close to the incoming rivers and in the inner part of the bay. In the middle part of the bay, nutrient concentrations might be also governed by other sources of nutrients scattered along the bay's coastline, such as shrimp pond and rice field culture activities. By contrast, in the outer part of the bay, where human activities along its shoreline much reduce, the influence of water masses coming from the Sunda Strait might occurred. During the dry period, the water masses from the Java Sea, which are high in nutrients, flow through the Sunda Strait into the Indian Ocean, and part of them enter Lampung Bay, resulting in higher nutrient concentrations in Lampung Bay waters. Inversely, during the rainy period, the water masses with low nutrient concentrations from the Indian Ocean deriving the Lampung Bay waters (Hendiarti *et al.*, 2002). This monsoonal pattern seems to play an important role in the seasonal variability of the middle and outer parts of Lampung Bay as can be traced from the seasonal variation of the nutrient concentration of these areas. It is important to note that on a seasonal scale, an inverse phenomena occurred in the river mouths and surrounding sites and in the inner part of the bay. These sites exhibit elevated values during the rainy season, especially for ammonium and phosphate concentrations which is as consequences of higher river discharge and associated nutrient loads at this period of the year.

It can be concluded that the spatial and temporal variability of nutrient concentrations in Lampung Bay is governed by the riverine inputs and influence of the Sunda Strait water masses. The inner part of the bay is likely more regulated by the influence of the incoming rivers, while the middle and outer parts of the bay are likely much influenced by the Sunda Strait water masses. These altogether form the nutrient dynamics in the Lampung Bay.

### 4.2.3. Phytoplankton biomass and community

High values of phytoplankton biomass occurred in the river mouths and surrounding areas, while in the more offshore waters, the chlorophyll *a* remained low. In the inner part of the bay which is not subjected to riverine influence, chlorophyll *a* decreased by a factor of 2, while in the middle and outer part of the bay it rapidly decreased by a factor of around 15. This clear spatial pattern shows that the phytoplankton biomass is regulated by the availability of both nutrients and light.

Seasonal phytoplankton biomass dynamics showed a high mean chlorophyll *a* level during the dry season. This was mostly due to elevated concentrations in the middle and outer parts of the bay and is hence supposed to be a result of advection of nutrient rich water from the Sunda Strait as mentioned previously. However, during the dry season, the areas exposed to the riverine influence were lower in phytoplankton biomass, which is concomitant with the lower nutrient loads from the rivers.

As for Jakarta Bay, phytoplankton community in Lampung Bay was dominated by diatoms (mainly *Chaetoceros danicus*, *C. cf. decipiens* and *Pseudonitzschia* spp). The other groups were dinoflagellates, and cyanophyceae. Cyanophyceae and dinoflagellates more abundant especially along the river mouths and surrounding

areas, while at other sites, these 2 groups were relatively low. In this bay, dinoflagellates mainly consists of *Ceratium furca*, and *Dinophysis* cf. *caudata*, while cyanophyceae mostly consists of *Trichodesmium* spp. This cyanophyceae species, usually occurs along the shrimp pond area, which scattered exist along the west and east coast of the bay. In 1995 and 1996, a bloom of *Trichodesmium* spp. occurred along the east coast of Lampung Bay and Sunda Strait (Wiryanawan *et al.*, 1999). The most abundant species *Chaetoceros danicus* and *C. cf. decipiens* were almost found at all sites of the bay, but they slightly decreased in the river mouths, when dinoflagellates and cyanophyceae slightly increased. The increase of dinoflagellates and cyanophyceae in the river mouths might be related to relatively more calm waters (due to salinity stratification) and decrease of DIN:P ratio. This is in keeping with the classical theory of phytoplankton stated by Margalef (1978), explaining the occurrence of dinoflagellates in the more calm-stratified water. Especially in the offshore waters, the dominant species are the small and chained species such as *Chaetoceros* spp. As a conclusion, the phytoplankton biomass dynamics in the study area is likely governed by the dynamics of nutrient concentrations.

#### 4.2.4. Planktonic primary production

Estimates on annual primary production in Lampung Bay ranged from 31 g C m<sup>-2</sup> y<sup>-1</sup> (station 11 - offshore part) to 197 g C m<sup>-2</sup> y<sup>-1</sup> (station 4 – inner part). There were 2 studies previously done in the inshore part of this area, resulting in estimates of 70 g C m<sup>-2</sup> y<sup>-1</sup> (Tambaru, 2000) and 152 g C m<sup>-2</sup> y<sup>-1</sup> (Sunarto, 2001), which are comparable with primary production estimates of the inner part of the bay (this study). Compared with the mean estimates of 45 estuarine systems all over the world (190 g C m<sup>-2</sup> y<sup>-1</sup>) reviewed by Boynton *et al.* (1982), the primary production values of Lampung Bay was in the range. Compared to those of Jakarta Bay, the production estimates in Lampung Bay were lower, which is in conformity with the lower values of chlorophyll *a* as well as nutrients in Lampung Bay than Jakarta Bay.

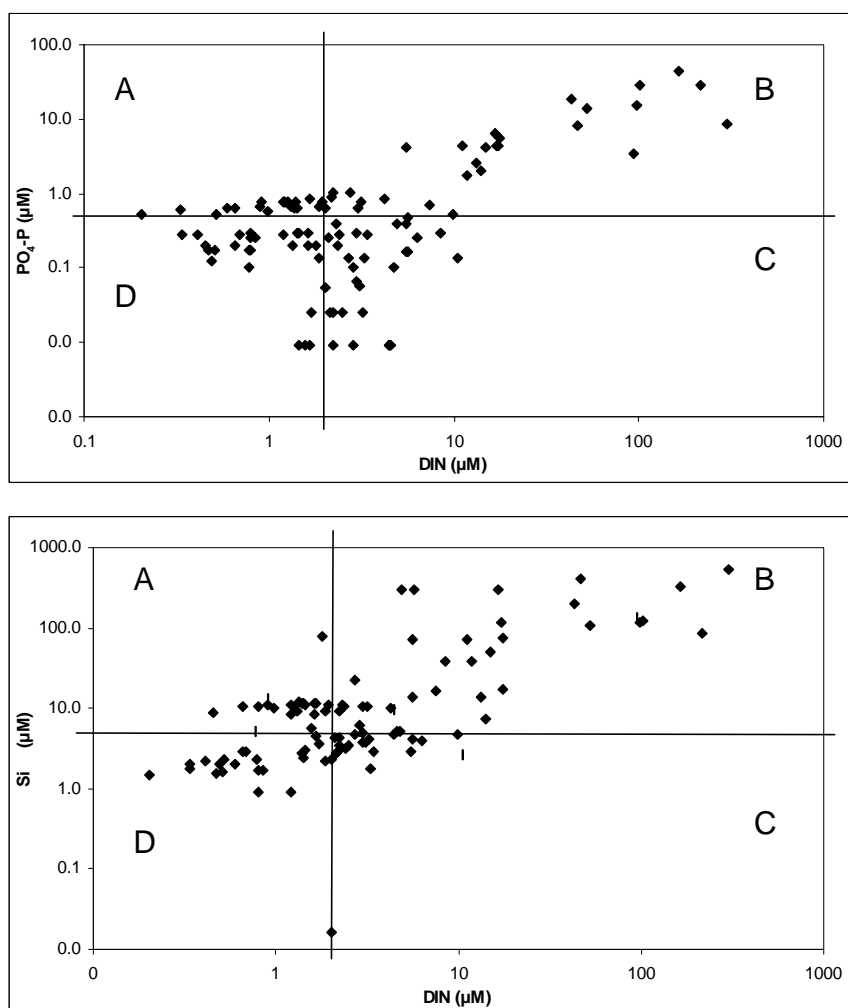
The results of  $P_{\max}^B$  exhibited a clear trend, which were higher in the high nutrient site compared to that of low nutrient site, showing the important role of nutrients in the variability of  $P_{\max}^B$ . Compared to those of Jakarta Bay,  $P_{\max}^B$  of Lampung Bay values were slightly lower, showing a clear difference between those 2 different nutrient level phytoplankton assemblages. Since the phytoplankton communities in the area were dominated by the diatoms for the whole year, the species-specific effect on the variability of  $P_{\max}^B$  is considered low.

The  $E_k$  values (ranged from 93.6 to 488  $\mu$  mol photons m<sup>-2</sup> s<sup>-1</sup>) were relatively high throughout the study period, showing a high acclimatisation on high light intensity. This values were comparable with the  $E_k$  values of Hurun Bay (Indonesia) phytoplankton assemblage previously done by Tambaru (2000).  $E_k$  values of this study are higher than that of the Wadden Sea (Tillmann *et al.*, 2000) and most of other temperate estuaries (Fisher *et al.*, 1982 ; Pennock and Sharp, 1986 and Cole *et al.*, 1991). This high series of  $E_k$  values in Lampung Bay showed that the phytoplankton assemblage in the area were adapted to strong light intensities. Comparison with Jakarta Bay, the Lampung Bay's results on  $E_k$  values were comparable, since the 2 bays are located in the similar latitude experienced with relatively similar in solar insolation.

It can be concluded that, the phytoplankton primary production in Lampung Bay is regulated by both nutrient and light resources.

#### 4.2.5. Nutrient limitation on phytoplankton growth

To estimate which nutrient acts as a limiting element, a combination of techniques molar ratio of ambient nutrient concentrations and comparison to threshold values were used. In Lampung Bay, DIN:P ratios showed low values in the river mouths and surrounding sites (< 15), and slightly increased in the inshore, middle and outer parts of the bay. In the river mouths and surrounding sites, the low DIN:P ratios were mainly caused by the increase of phosphate instead of the decrease of N. The relatively high DIN:P ratios in the middle



**Fig.4.37.** Plot of DIN and PO<sub>4</sub> (above) and DIN and silicate (below) against assumed nutrient thresholds values. The D area on each graph defines the region for which nutrient concentrations are below published half-saturation constants for nutrient uptake of natural phytoplankton populations, while the B area indicates the region where ambient nutrient concentrations are above the threshold.

and outer parts of the bay were mainly caused by depletion of phosphate (below minimum threshold for P,  $< 0.5 \mu\text{M}$ ) instead of the increase of DIN.

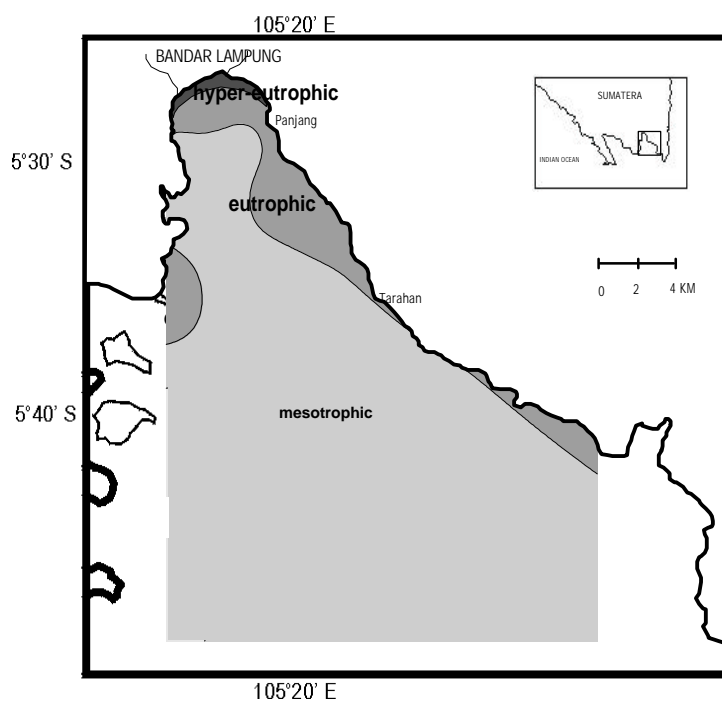
The DIN:Si ratio was low at all sites of the bay and no specific trend could be observed. Around 88% of the values were  $< 1$ , indicating no potential limitation of silicate throughout the bay. Compared to the silicate threshold for phytoplankton growth ( $> 5 \mu\text{M Si}$ ), most of the stations showed values above this threshold. The freshwater inflow from rivers seems to be a continuous source of silicate for the bay.

Fig.4.37. shows a plot of ambient nutrient concentrations in Lampung Bay, which is divided into 4 regions, which are characterised by different levels of the half saturation constants of nutrient uptake. Almost from all seasonal surveys, stations of river mouths, and surrounding sites (stations 4 and 15) always located above their threshold values. In total, 26% measurements located above the 3 thresholds of silicate, DIN and phosphate. Meanwhile, 12% measurements located below the thresholds of all those 3 nutrients. The rest of the measurements were partially limited either by phosphate, DIN or silicate (57%, 63 % and 46 %, respectively).

Hence it can be concluded that silicate is not a potential limiting nutrient, meanwhile, N and P likely the potential limiting nutrient for phytoplankton growth in Lampung Bay. In the river mouth and inshore waters, phytoplankton was likely limited by N, while in the more offshore waters, it was likely limited by both N and P.

#### **4.2.6. Trophic state**

Spatial grouping process based on trophic states resulted in 3 distinct trophic states (according to a combined classification of Caiffaa, 1999 and Nixon, 1995) : hypertrophic, eutrophic and mesotrophic (Fig.4.38.). The hypertrophic area prevailed in a very narrow area of the river mouths. The eutrophic state prevailed in the river plume areas and in the inner layer of the bay. In the middle and outer layers of the bay, the level decreased to mesotrophic. Comparison to those of Jakarta Bay, the trophic levels in Lampung Bay are generally lower. It could be seen through the bigger proportion of the mesotrophic area in Lampung Bay than in Jakarta Bay, showing a lower degree of anthropogenic eutrophication in Lampung Bay. Most of the areas of the bay were classified as mesotrophic, showing a good balance of local hydrodynamic factors in reducing the eutrophication effects. With relatively high water residence time (around 15 days ; Koropitan, pers.comm), Lampung Bay actually faces disadvantages in the accumulation of materials derived from human activities in its coastal area. This is especially true in the coming period where the increase of region's population is expected, causing an apparent increase of nutrient enrichment from the land.



**Fig.4.38.** Projection map of the spatial trophic states of Lampung Bay calculated based on TRIX and trophic classification according to Caiiffa ( 1999) and Nixon (1995).



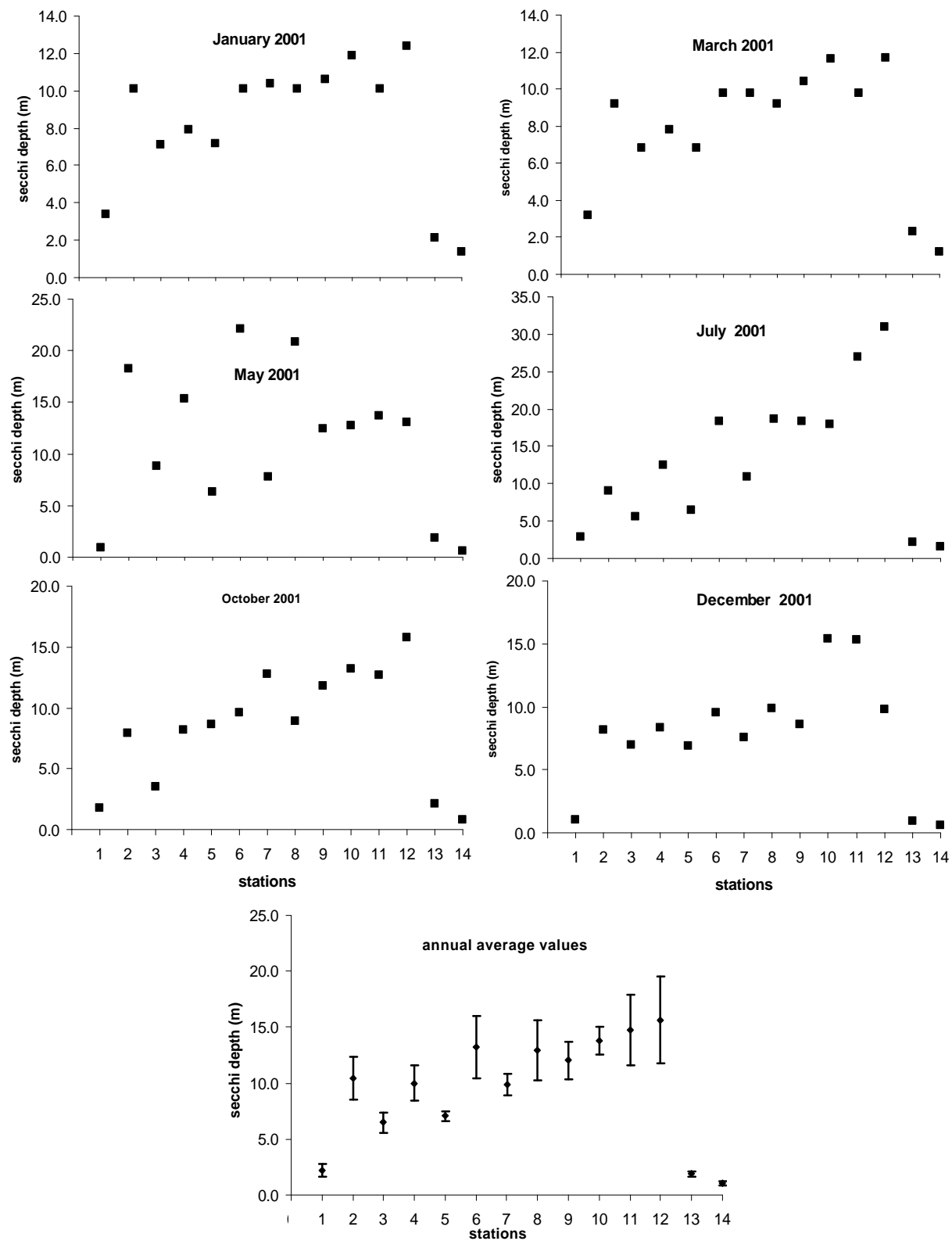
## 5. Results and discussion : Semangka Bay

### 5.1. Results

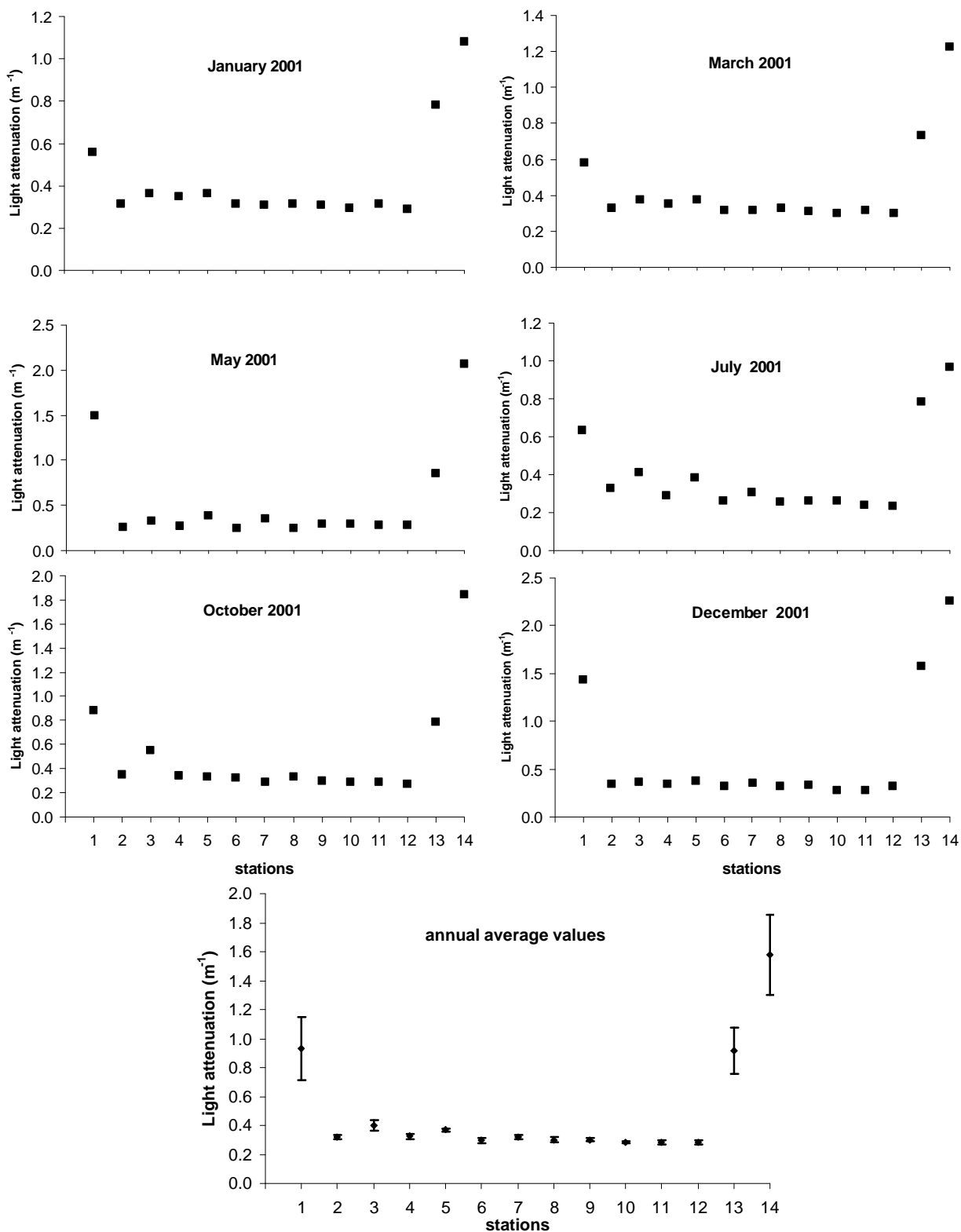
#### 5.1.1. Secchi depth, light-attenuation, $Z_{\text{mix}}:Z_{\text{eu}}$ ratio and water temperature

Fig. 5.1. shows Secchi depth values at Semangka Bay's stations for each of the temporal surveys and the annual average values. Secchi depth was significantly different between sites and seasons (ANOVA,  $p < 0.001$ ). The lowest values always prevailed at Semangka river mouth (ranging from 0.6 to 1.6 m), while the highest values were always measured at stations 10, 11 and 12 (ranging from 9.8 to 31.0 m). May and July 2001 surveys resulted in higher mean Secchi depth values than other temporal surveys. Vertical light-attenuation coefficients ( $\text{m}^{-1}$ ) ranged from  $0.23 \text{ m}^{-1}$  (station 12) to  $2.26 \text{ m}^{-1}$  (Semangka river mouth). The annual average of this variable varied between  $0.28 \text{ m}^{-1}$  (station 12) to  $1.58 \text{ m}^{-1}$  (Semangka river mouth) (Fig.5.2). In keeping with the Secchi depth distribution, there were significant differences in the light attenuation coefficient between sites and seasons (ANOVA,  $p < 0.05$ ). Stations at river mouth, river plume (1) and town-harbour waters (13) exhibited high attenuation coefficients, while at the other stations, the light attenuation was low. Secchi disk readings were significantly and positively correlated with salinity, but inversely with turbidity ( $p < 0.001$ ; Pearson's  $r = 0.43$  and  $-0.33$ , respectively), indicating a prominent input of river discharge on this parameter. As a consequence, the attenuation coefficient too, was significantly related to turbidity and salinity ( $p < 0.001$ ; Pearson's  $r = 0.61$  and  $-0.75$ , respectively).

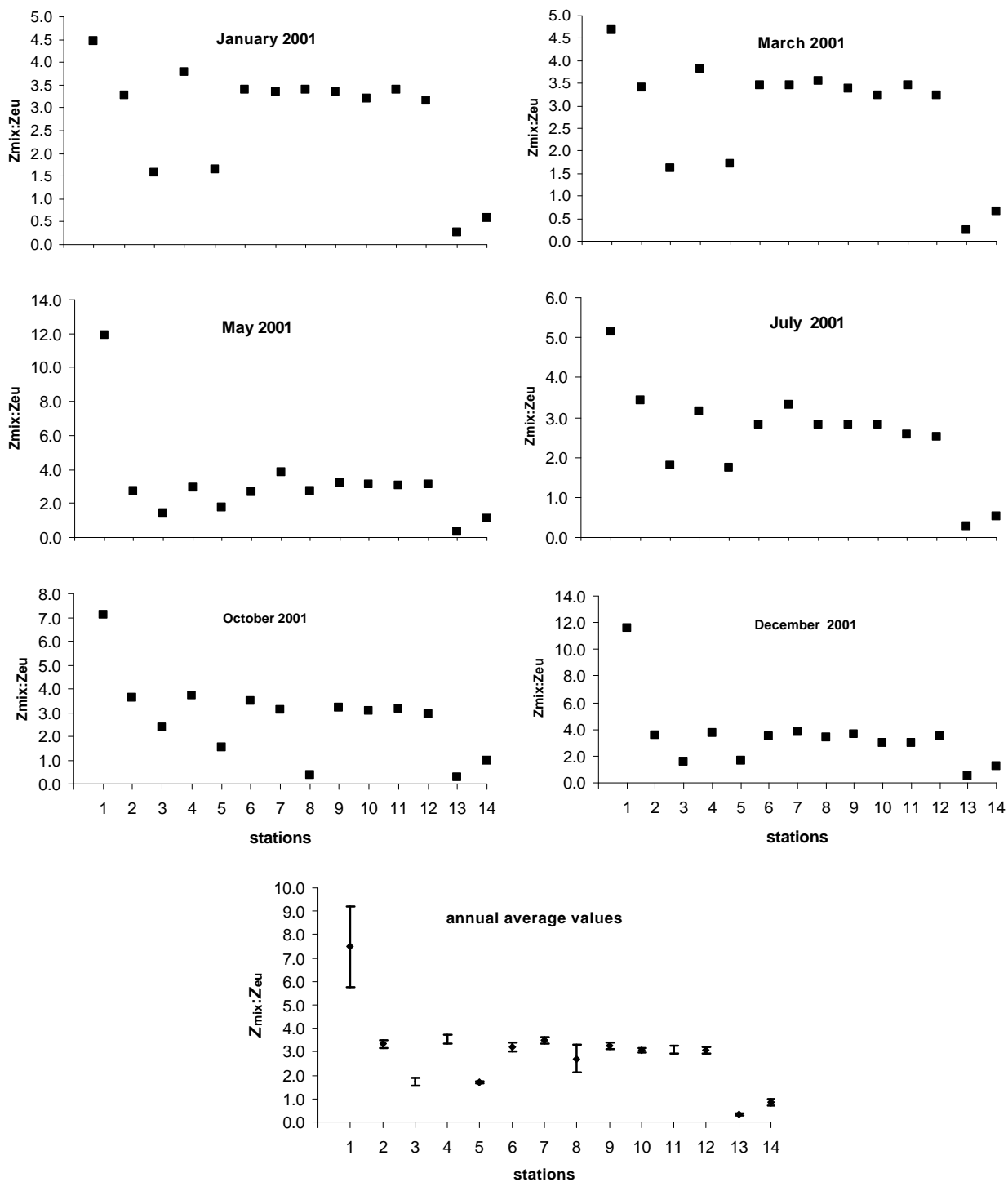
CTD profiles and other measurements done in the area (Hendiarti, pers.comm.) showed that the water column was homogeneously mixed down to a depth of about 60 m. There was a significant spatial variation in the  $Z_{\text{mix}}:Z_{\text{eu}}$  ratio (ANOVA,  $p < 0.001$ ), but a non-significant temporal variation. In general, the river mouth and all inshore stations (stations 3, and 13) exhibited low  $Z_{\text{mix}}:Z_{\text{eu}}$  ratios, while the more offshore stations were characterised by high values (Fig.5.3) in spite of a better water transparency. An exceptional situation occurred at station 1, which is located in the plume of the Semangka River. At this site, high  $Z_{\text{mix}}:Z_{\text{eu}}$  ratios were observed (ranging from 4.46 to 11.94), due to high turbidity levels. The lowest mean of  $Z_{\text{mix}}:Z_{\text{eu}}$  prevailed at the harbour site (station 13), where the water depth was very shallow. In general  $Z_{\text{mix}}:Z_{\text{eu}}$  ratios were not significantly correlated with light attenuation, underlining the importance of vertical mixing depth for this parameter.



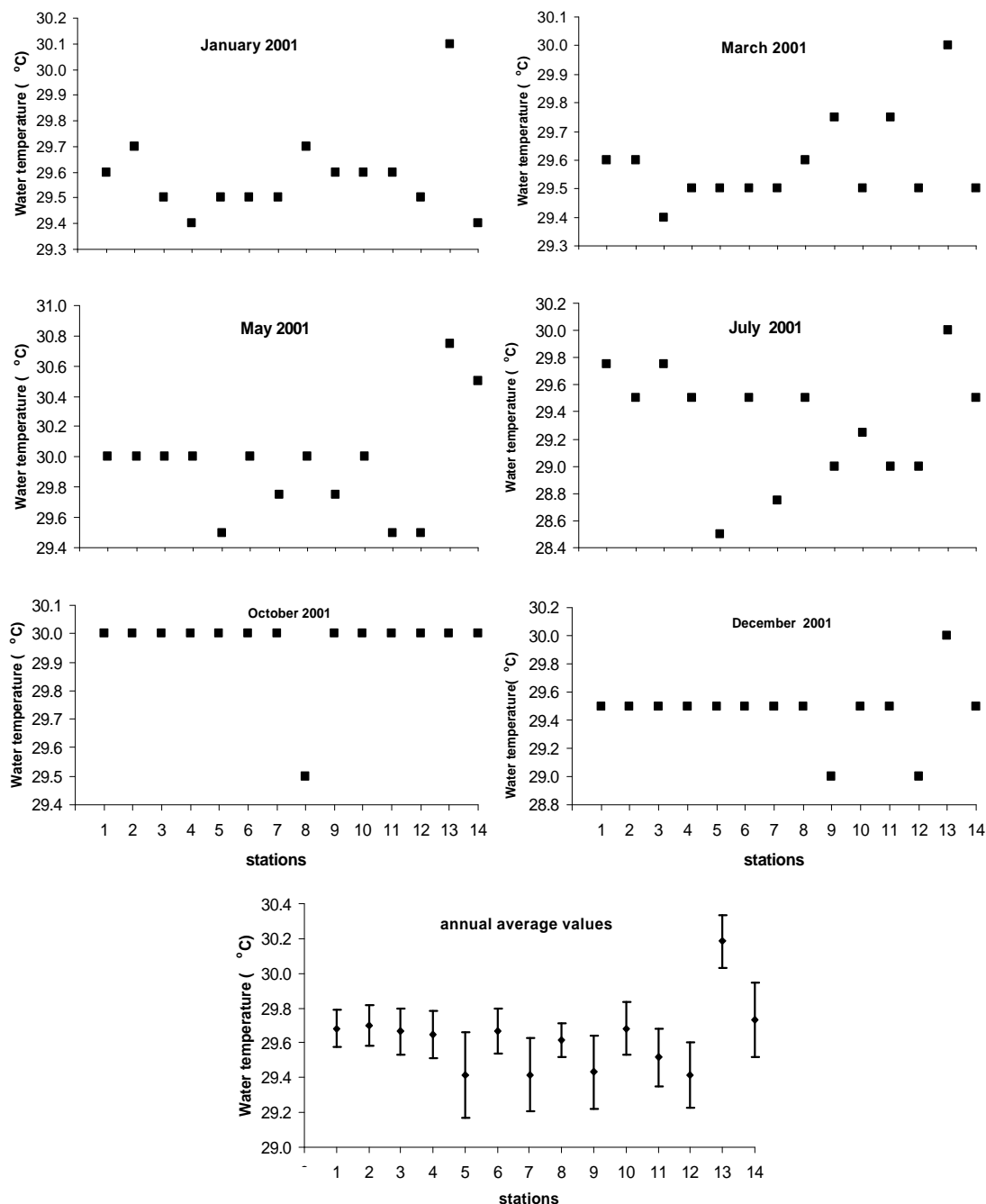
**Fig. 5.1.** Secchi depth (m) at each sampling station and temporal survey in Semangka Bay. 14 = Semangka river mouth Bars are standard deviations calculated from 6 data.



**Fig. 5.2.** Attenuation coefficients ( $m^{-1}$ ) at each sampling station and temporal survey in Semangka Bay, 14 = Semangka river mouth Bars are standard deviations calculated from 6 data.



**Fig.5.3.**  $Z_{mix}:Z_{eu}$  ratios at each sampling station and temporal survey in Semangka Bay, 14 = Semangka river mouth. Bars are standard deviations calculated from 6 data.



**Fig. 5.4.** Water temperature (°C) at each sampling stations and temporal survey in Semangka Bay, 14 = Semangka river mouth. Bars are standard deviations calculated from 6 data.

Significant spatial and temporal variations in water temperature were observed in Semangka Bay (ANOVA ;  $p < 0.01$ ). The lowest annual average in water temperature prevailed at station 5 (29.4 °C), which is characterized by a rather deep water column (35 m), while the highest was observed at the shallow water of station 13 (30.2 °C), which is located in the harbour water of Kota Agung (Fig. 5.4.). There was no significant correlation with salinity, indicating a minor role of freshwater inflow on water temperature in the study area.

### 5.1.2. Salinity and turbidity

Fig. 5.7 and 5.8 show the distribution of salinity and turbidity, respectively. Low salinity and high turbidity levels always prevailed in the vicinity of the Semangka river inflow. At the other sites, salinity was distinctly higher and turbidity was generally low. The lowest annual average in salinity prevailed at Semangka river mouth (6.8). It increased rapidly in the river plume (station 1 ; 28.3) and reached relatively high levels at the other stations (including the harbour site), ranging from 32.5 to 33.8. There were significant differences in salinity both between seasons and sites (ANOVA,  $p < 0.001$ ). A LSD-Test (Least Significant Difference) showed that the spatial differences were mostly due to the stations subjected to riverine influence. On a seasonal scale, salinity slightly increased during the rainy season at all stations which are not directly influenced by river discharge, which might be caused by the influence of high saline waters entering the bay from the Indian Ocean.

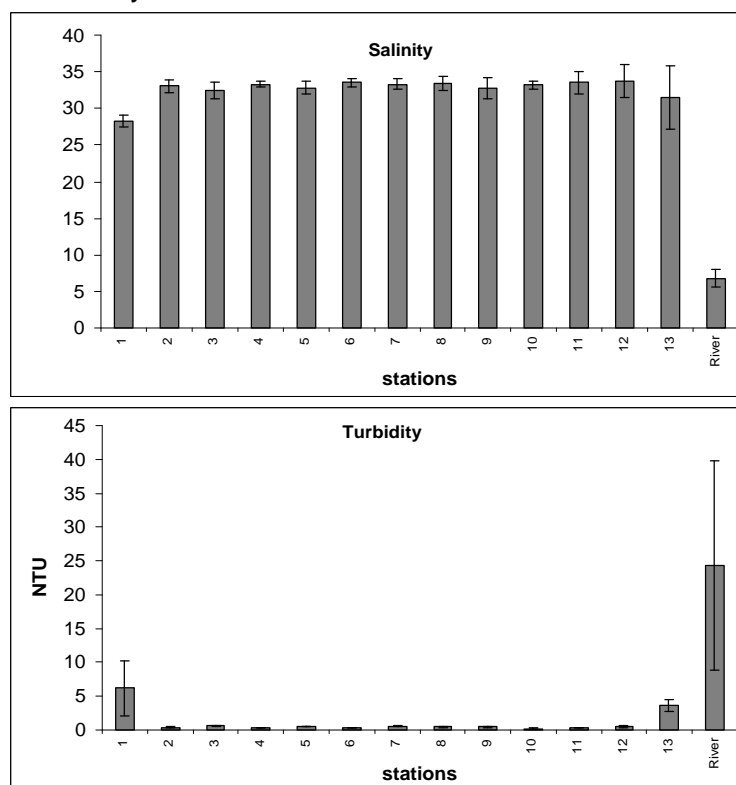
With respect to turbidity levels, there was a significant spatial variation (ANOVA,  $p < 0.001$ ) but only a small and not significant temporal variation. The lowest annual average prevailed at the offshore station 10 (0.26 NTU), while the highest annual average was observed in the river mouth (24.27 NTU). Other stations with high turbidity levels were stations 1 (river plume) and 13 (harbour waters), with an annual average of 6.20 NTU and 3.66 NTU, respectively. The highest average of turbidity prevailed in the dry season of May 2001 (8.24 NTU) and the lowest occurred during the rainy season of October 2001 (0.66 NTU).

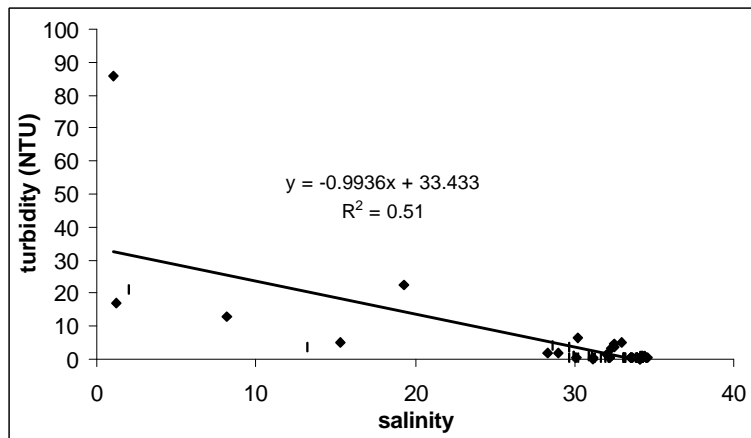
There was a strong inverse correlation between salinity and turbidity (Fig.5.6) ( $p < 0.001$ ; linear regression,  $R^2 = 0.51$ ). This high correlation indicates the prominent role of river discharge for the turbidity regime in the bay.

**Fig. 5.5.**

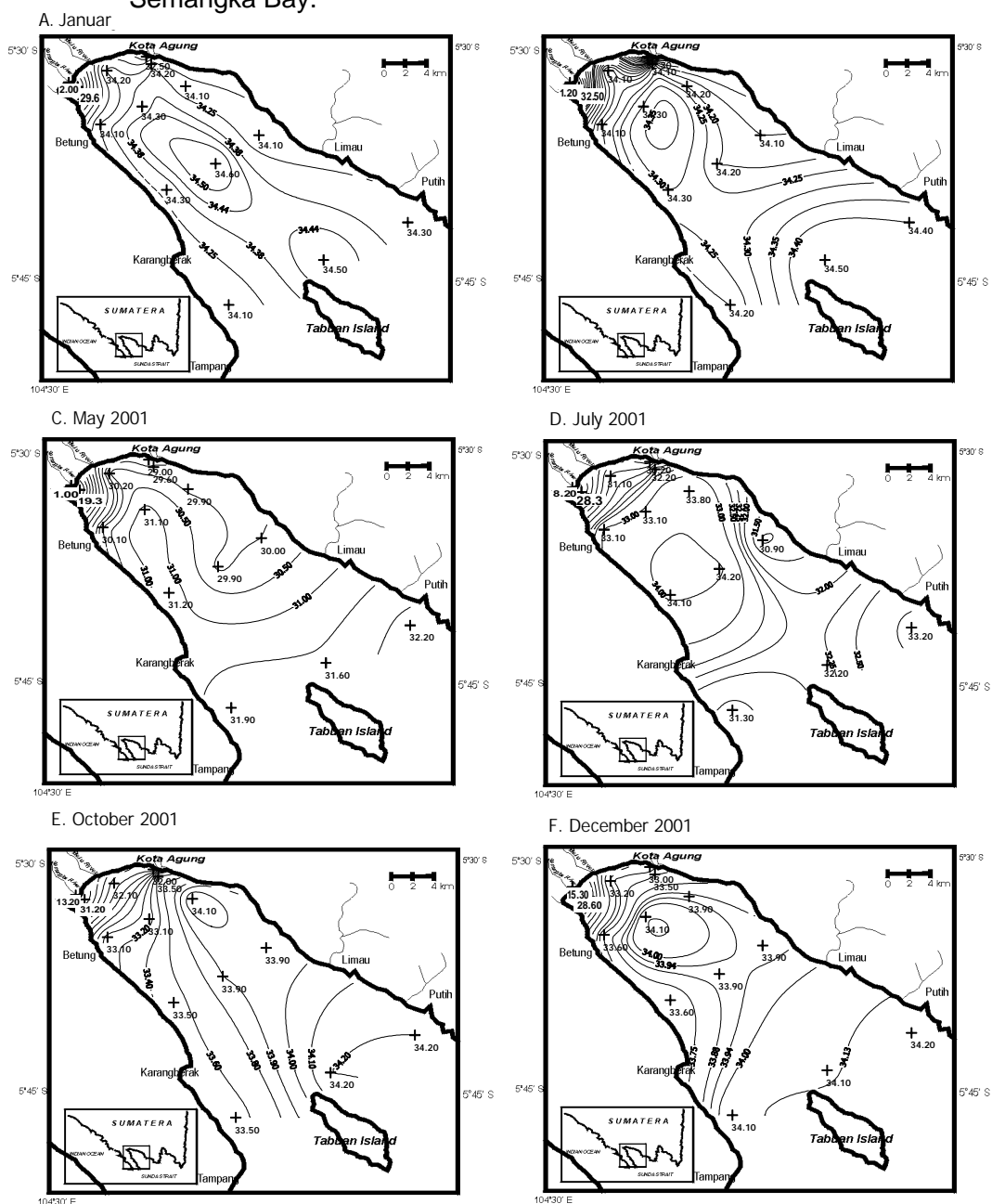
Annual average salinity (upper graph) and turbidity (lower graph) in Semangka Bay. Bars are standard deviations calculated from 6 data.

River = Semangka river mouth.

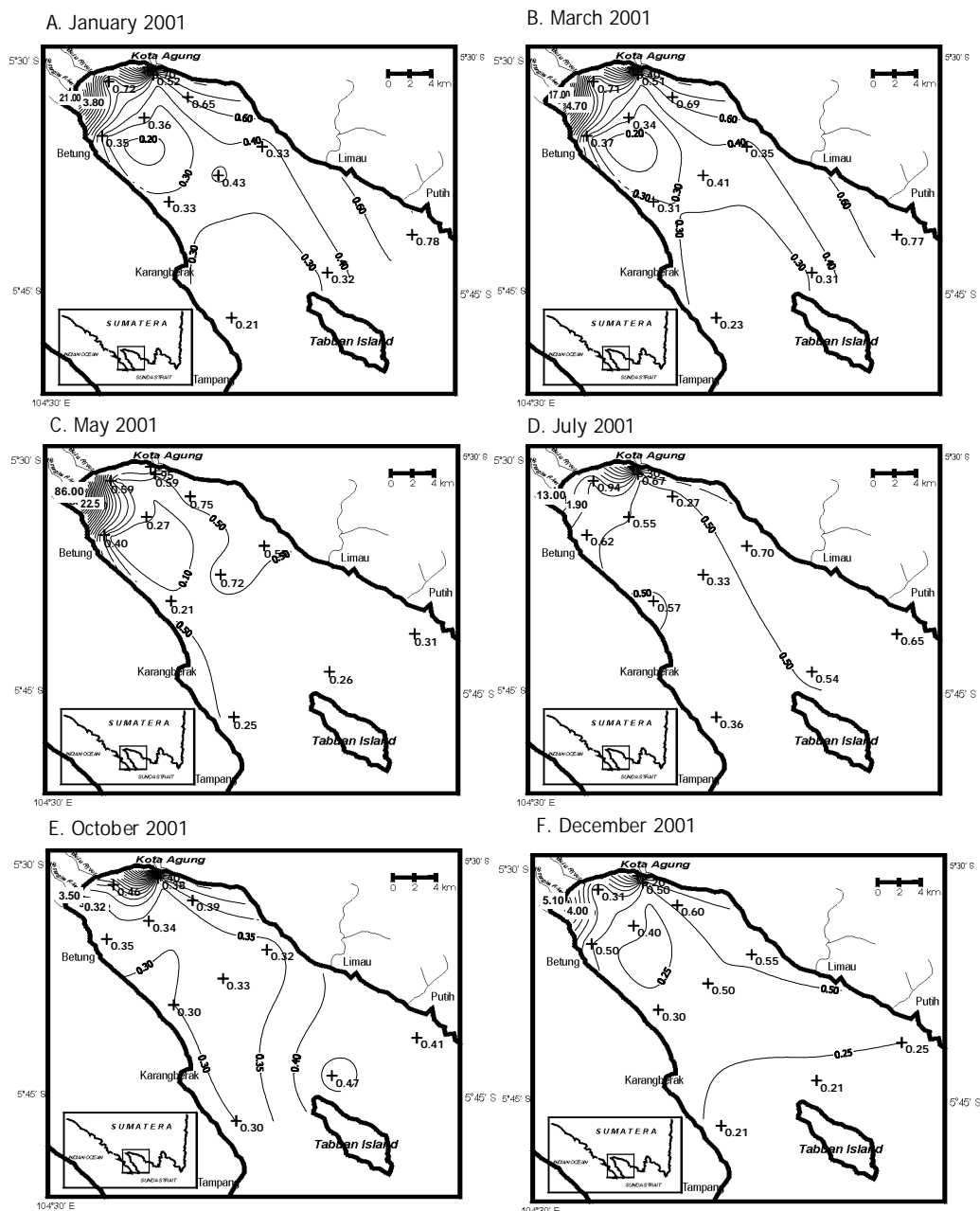




**Fig. 5.6.** Linear regression between salinity and turbidity (NTU) in Semangka Bay.



**Fig. 5.7.** Salinity contours in Semangka Bay. A: Januar 2001. B: March 2001. C: May 2001. D: July 2001. E: October 2001 and F: December 2001.



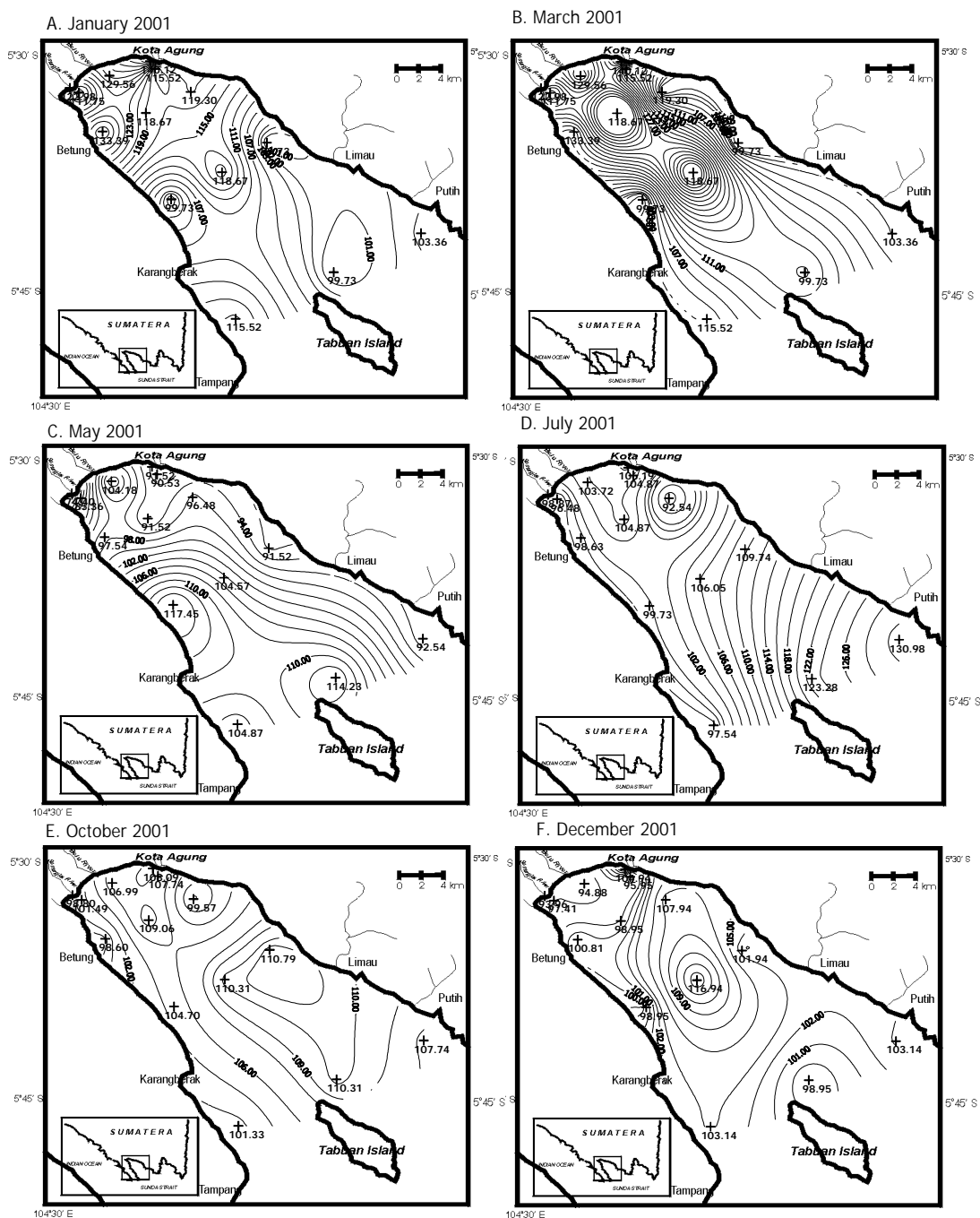
**Fig. 5.8.** Turbidity (NTU) contours in Semangka Bay. A: January 2001. B: March 2001. C: May 2001. D : July 2001. E : October 2001 and F: December 2001.

### 5.1.3. Dissolved oxygen and pH

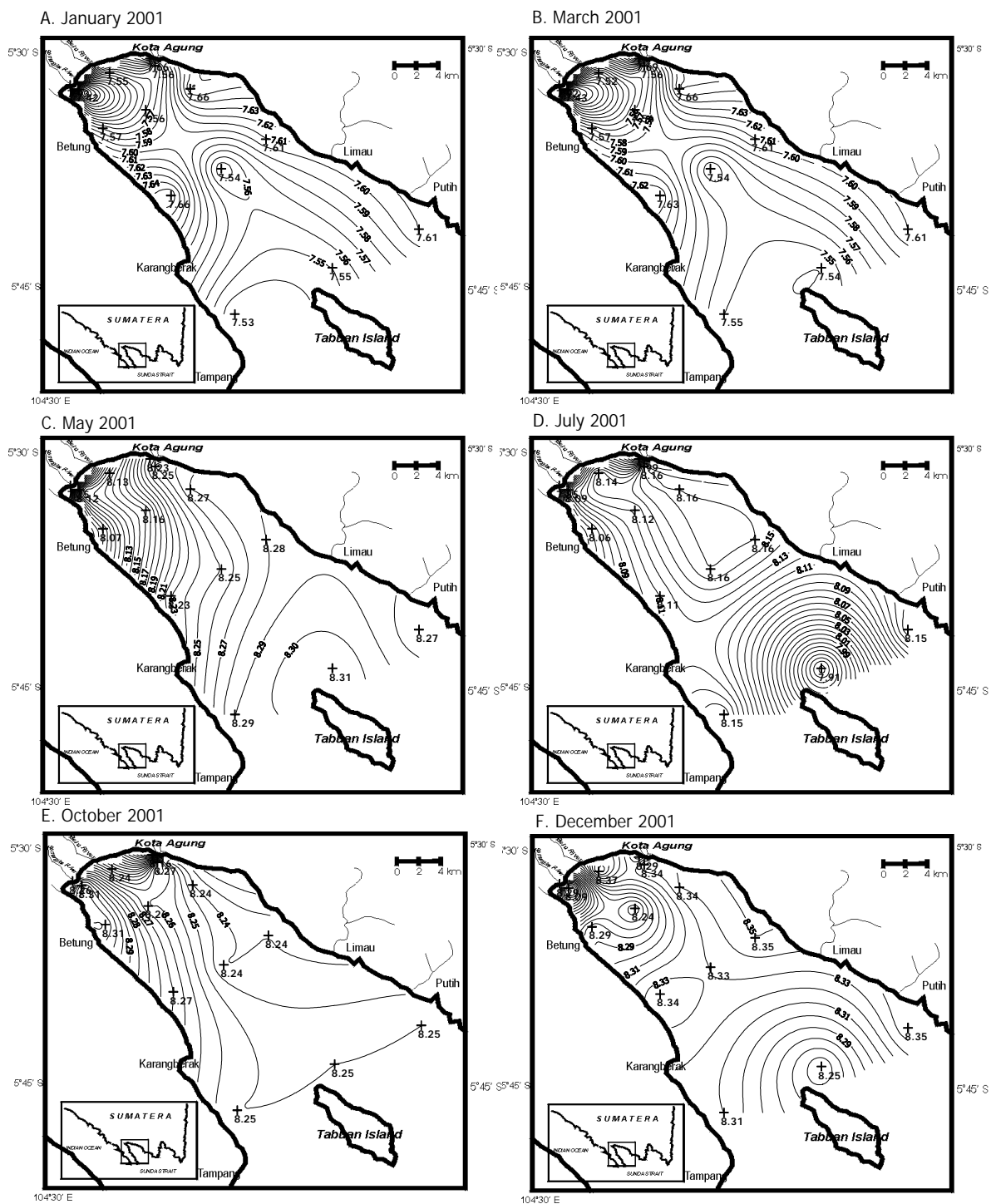
Fig. 5.9. shows the dissolved oxygen saturation values for each of the temporal surveys. There were no significant differences in oxygen saturation (%) levels both with respect to spatial and temporal scales. Relatively high oxygen saturation prevailed at all stations. Extreme values ranged from 74.40 % (station 1, May 2001) to 146.75 % (station 8, March 2001). Relatively low oxygen saturation levels prevailed in the turbid waters of the river mouth and its surrounding areas as well as at station 13 (harbour waters). A significant correlation was observed between oxygen saturation and turbidity (Pearson's  $r = -0.23$ ). By contrast, the linear regression between salinity and oxygen saturation (Fig. 5.11.) was not significant, indicating a minor role of freshwater discharge for the oxygen conditions in the bay.



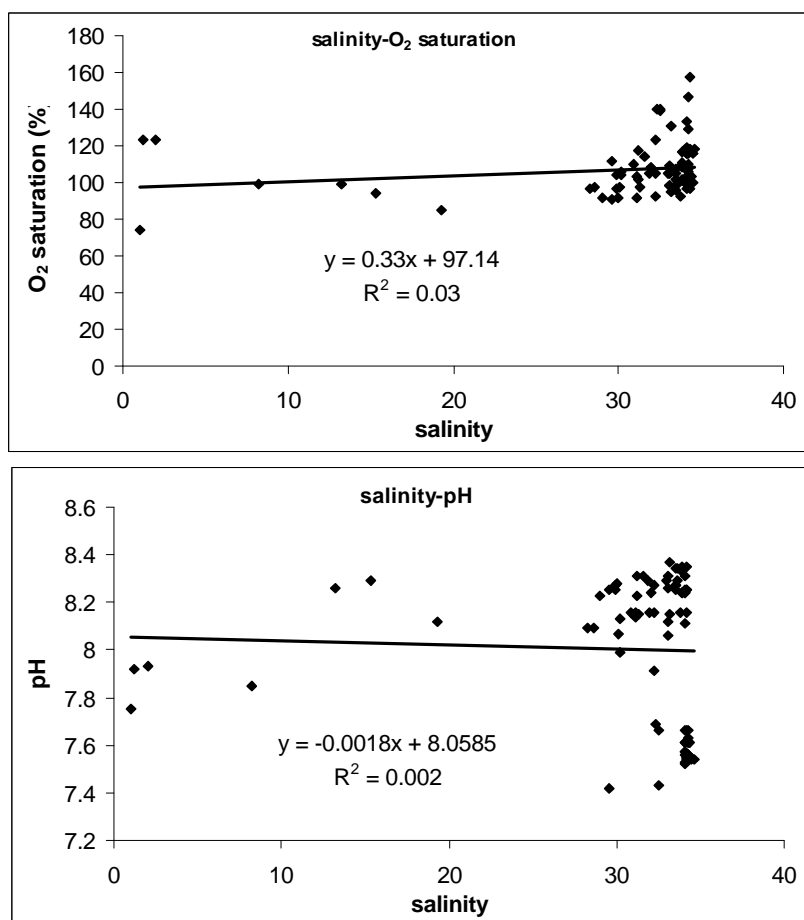
As in the case of oxygen saturation levels, pH values were not significant difference in spatial and temporal scales. The pH ranged from 7.42 (stations 1 in January 2001) to 8.34 (station 7, December 2001). In an average, lowest pH values were observed during January 2001 and March 2001, while highest means occurred during October 2001 and December 2001. There was no significant influence of river inflow on pH values (Fig. 5.11).



**Fig. 5.9.** Dissolved oxygen saturation (%) contours in Semangka Bay. A : January 2001. B: March 2001. C: May 2001. D : July 2001. E : October 2001 and F: December 2001.



**Fig. 5.10.** pH contours in Semangka Bay. A: January 2001. B: March 2001. C: May 2001. D : July 2001. E : October 2001 and F: December 2001.



**Fig. 5.11.** Linear regression between salinity and dissolved oxygen saturation with pH in Semangka Bay.

#### 5.1.4. Nutrient loads from the river

The main river in the area is the Semangka River, which flows to the bay after passing through a more natural landscape and several agricultural areas without passing through the urban area of the main town. Estimates of monthly nutrient loads were performed by using monthly mean river discharges and the nutrient concentrations at the river mouth (Table 5.1.). For the months without *in situ* nutrients measurements, the monthly nutrient loads were estimated by using the nutrient concentration values of the closest survey's month. Annual nutrient loads were calculated by summing up the monthly nutrient loads (Table 5.1.). The loads of nitrate, nitrite and phosphate show a similar pattern, exhibiting high values during the dry period in spite of reduced water discharge. High nitrate and phosphate concentrations during the dry period might be related to high intensity of rice field culture activities along the river banks and the associated fertiliser input into the river. On the contrary, ammonium and silicate were high during the rainy season (October and December 2001 ; Table 5.1.), indicating the precipitation and drainage of the catchment area are important factors for these inputs. Semangka River exhibited higher loads of nitrate when compared to that of ammonium, which may be due to a dominance of natural or agricultural nitrogen sources in its catchment area as well as the dominance of nitrification processes along the river.

**Table.5.1.** Estimates of nutrient loads from Semangka River in seasonal scale ( $t\text{ month}^{-1}$ ) and the annual nutrient loads ( $t\text{ y}^{-1}$ ).

Semangka River						
	NO <sub>3</sub>	NO <sub>2</sub>	NH <sub>4</sub>	DIN	PO <sub>4</sub>	SiO <sub>4</sub>
January	69.42	1.97	1.02	72.42	48.14	618.18
February	177.59	5.05	2.61	185.25	123.16	1581.40
March	140.18	6.46	22.30	168.93	76.23	1248.28
April	157.02	7.23	24.97	189.23	85.39	1398.22
May	132.71	2.63	11.27	146.62	40.58	994.39
June	105.36	2.09	8.95	116.40	32.22	789.47
July	68.56	1.59	10.71	80.86	4.09	1132.10
August	75.13	1.74	11.73	88.60	4.48	1240.49
September	3.20	0.33	43.21	46.74	1.85	679.45
October	4.78	0.49	64.54	69.80	2.76	1014.73
November	9.78	0.28	77.60	87.66	0.06	2370.47
December	13.96	0.40	110.71	125.06	0.08	3381.93
Annual load	957.70	30.25	389.62	1377.56	419.02	16449.11

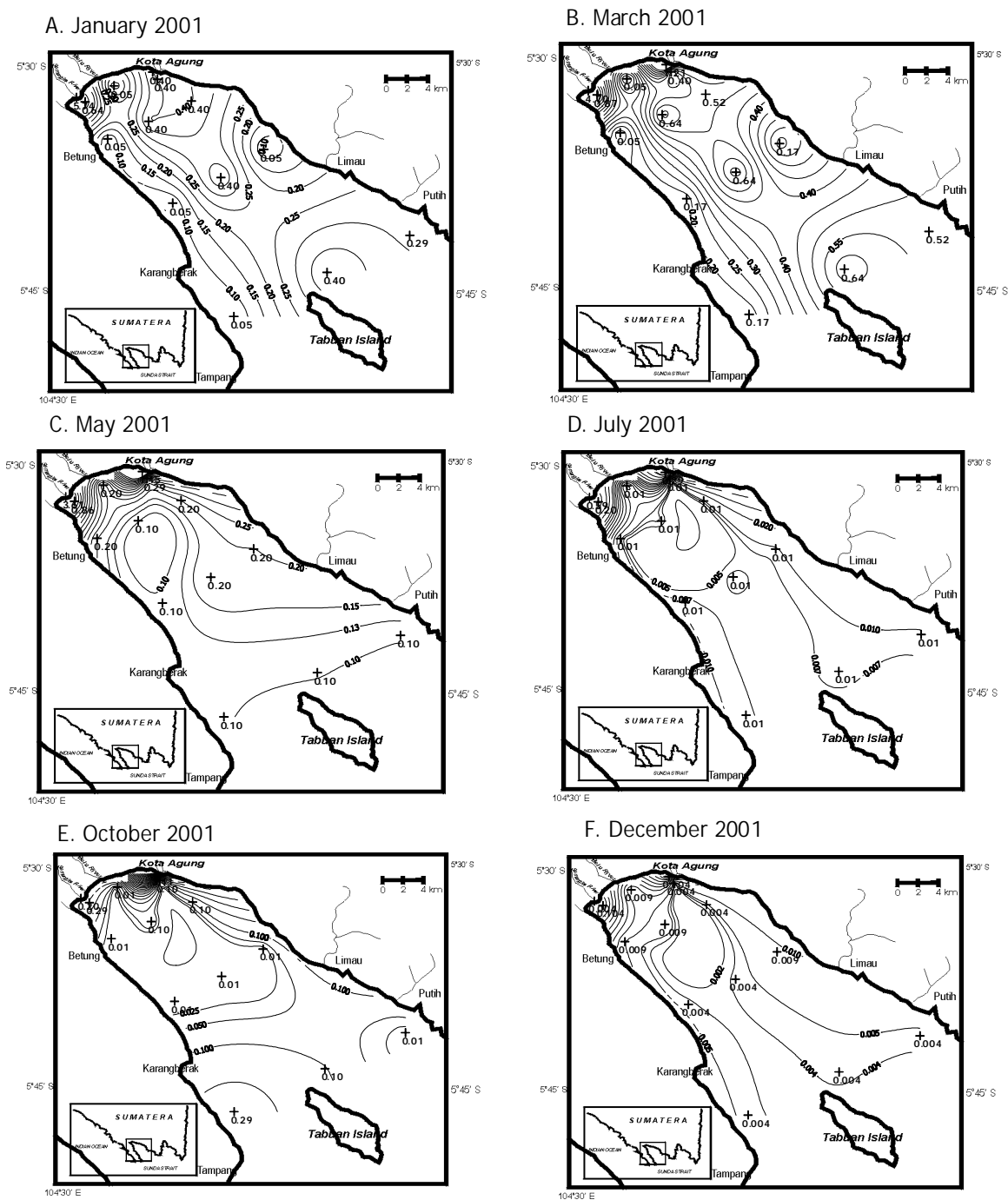
### 5.1.5. Dissolved inorganic nutrients

#### 5.1.5.1. Phosphate (PO<sub>4</sub><sup>-3</sup>-P)

Significant differences in phosphate concentrations were observed both in spatial and seasonal scales (ANOVA,  $p < 0.001$ ). The general pattern was characterised by high levels in the river mouth, river plume (station 1) and in the harbour waters (station 13), while concentrations were much lower in the offshore stations (Fig.5.12). Phosphate minima prevailed at the outermost station (station 12) in December 2001 ( $0.004\ \mu\text{M PO}_4\text{-P}$ ), while maxima prevailed in the river mouth in January 2001 ( $5.744\ \mu\text{M PO}_4\text{-P}$ ). This gradient is commensurate with the patterns of salinity and turbidity and in keeping with the generally high nutrient levels in the river water. Pearson's correlation shows strong relationship ( $p < 0.001$ ) between salinity-phosphate (Pearson's  $r = -0.72$ ) and turbidity-phosphate (Pearson's  $r = 0.59$ ).

High phosphate concentrations at station 13, which is located in the harbour waters, but is not receiving any considerable amounts of freshwater, may be due to the presence of several sewage canals. In additions, fishermen activities and the resulting waste may amplify the nutrient input to this site.

Seasonal variation in phosphate concentrations showed lowest average levels in December 2001 ( $0.020\ \mu\text{M PO}_4\text{-P}$ ) and highest average was in March 2001 ( $0.767\ \mu\text{M PO}_4\text{-P}$ ). The low average phosphate concentration in December 2001 is in accordance with the low phosphate concentration and load of the river.



**Fig. 5.12.** Phosphate ( $\mu\text{M PO}_4\text{-P}$ ) contours in Semangka Bay. A: January 2001. B: March 2001. C: May 2001. D : July 2001. E : October 2001 and F: December 2001.

### 5.1.5.2. Nitrate [ $\text{NO}_3^-$ -N]

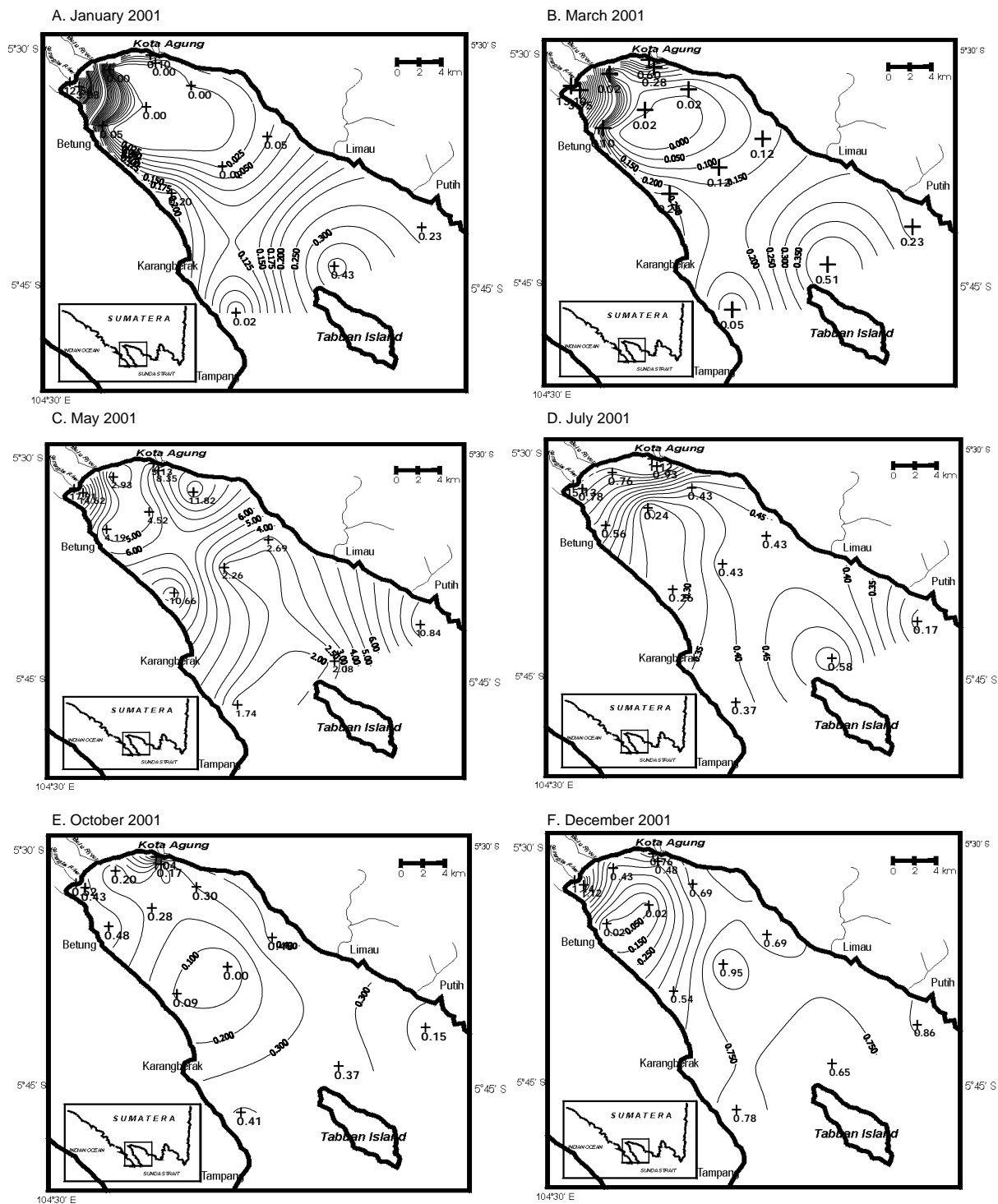
There were significant spatial and temporal differences in the nitrate concentration of the bay (ANOVA,  $p < 0.001$ ). Fig.5.13. shows the distribution of nitrate, exhibiting a decreasing gradient down the bay. The spatial pattern was relatively similar between each temporal survey, showing high values in the river mouth and its surrounding area as well as at the harbour site. There was a high inverse correlation between nitrate and salinity (Pearson's  $r = -0.75$  and linear regression  $R^2 = 0.57$ ), indicating that the nitrate source was freshwater discharge. The maximum annual average accounted for  $10.06 \mu\text{M}$  prevailed in the river mouth, while minimum average of  $0.56 \mu\text{M}$  occurred at the outer part of the bay (station 10). Absolute nitrate minima was observed at station 3 ( $0.001 \mu\text{M NO}_3\text{-N}$ ) in January 2001, while maxima prevailed at Semangka river mouth ( $17.91 \mu\text{M NO}_3\text{-N}$ ) in May 2001. Stations 5 and 7 too, have relatively high nitrate concentrations, indicating a strong influence of the neighbouring harbour and the town activities at those sites (average of  $1.70 \mu\text{M NO}_3\text{-N}$  and  $2.21 \mu\text{M NO}_3\text{-N}$ , respectively).

On a seasonal scale, nitrate showed maximum mean levels in May 2001 ( $7.13 \mu\text{M NO}_3\text{-N}$ ) and a minimum average in October 2001 ( $0.35 \mu\text{M NO}_3\text{-N}$ ). High average nitrate level in May is concomitant with high loads from the river and the influence of the Sunda Strait water masses, which are high in nitrate concentrations.

### 5.1.5.3. Nitrite [ $\text{NO}_2^-$ -N]

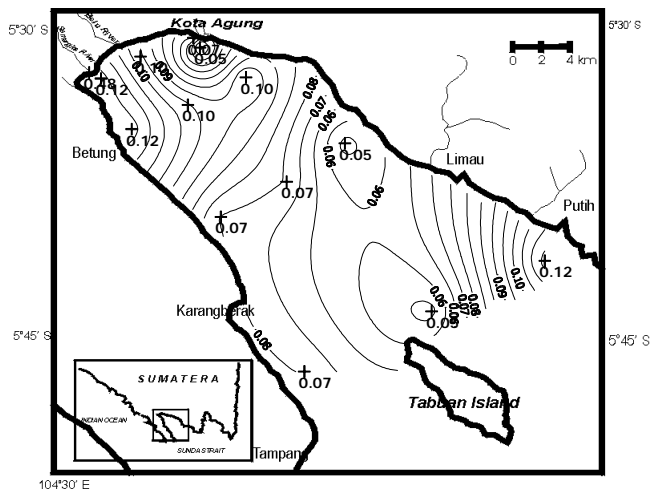
There were significant differences in nitrite concentration between sites and seasons (ANOVA,  $p < 0.001$ ), with typically high levels in the river influenced areas and in the harbour water, and rapidly decrease in concentrations in the offshore. The maximum annual average accounted for  $0.39 \mu\text{M NO}_2\text{-N}$  prevailed in the river mouth, while minimum average of  $0.04 \mu\text{M NO}_2\text{-N}$  occurred at the outer part of the bay (station 10).

Pearson's correlation resulted in a significant inverse correlation between salinity and nitrite, showing a strong role of river input for the nitrite distribution in the bay (Pearson's  $r = -0.68$  and linear regression  $R^2 = 0.47$ ). The lowest temporal average of nitrite prevailed in December 2001 ( $0.05 \mu\text{M NO}_2\text{-N}$ ), while the highest was observed in March 2001 ( $0.19 \mu\text{M NO}_2\text{-N}$ ), which is in keeping with high nitrate concentrations during that period. Hence, a high and significant relationship between nitrate and nitrite was found (Pearson's  $r = 0.55$ ).

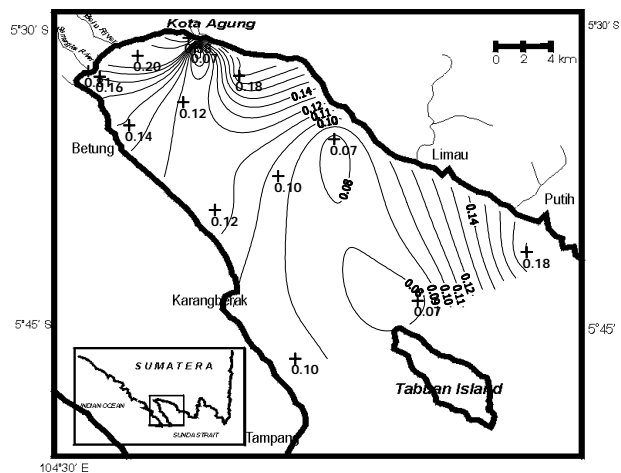


**Fig. 5.13.** Nitrate ( $\mu\text{M NO}_3\text{-N}$ ) contours in Semangka Bay. A: January 2001. B: March 2001. C: May 2001. D : July 2001. E : October 2001 and F: December 2001.

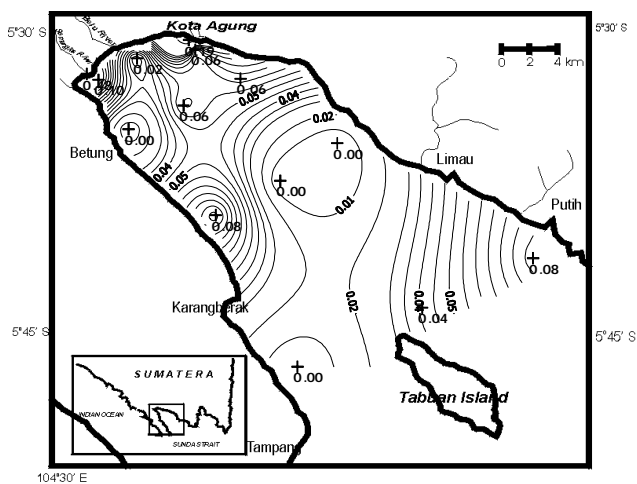
A. January 2001



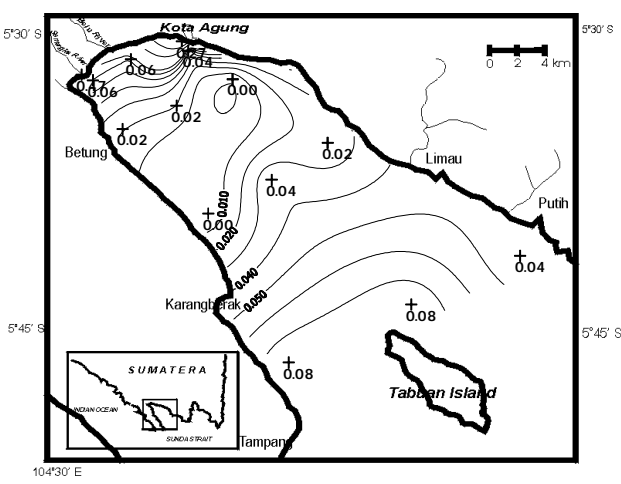
B. March 2001



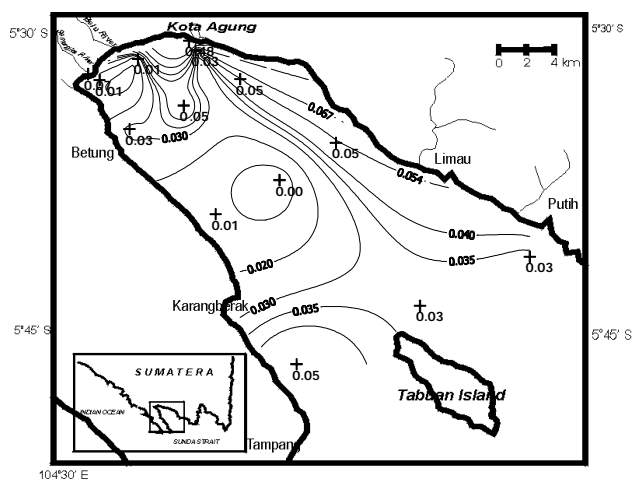
C. May 2001



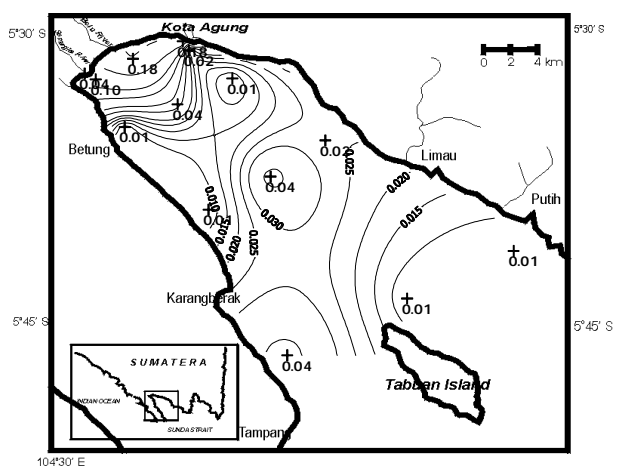
D. July 2001



E. October 2001

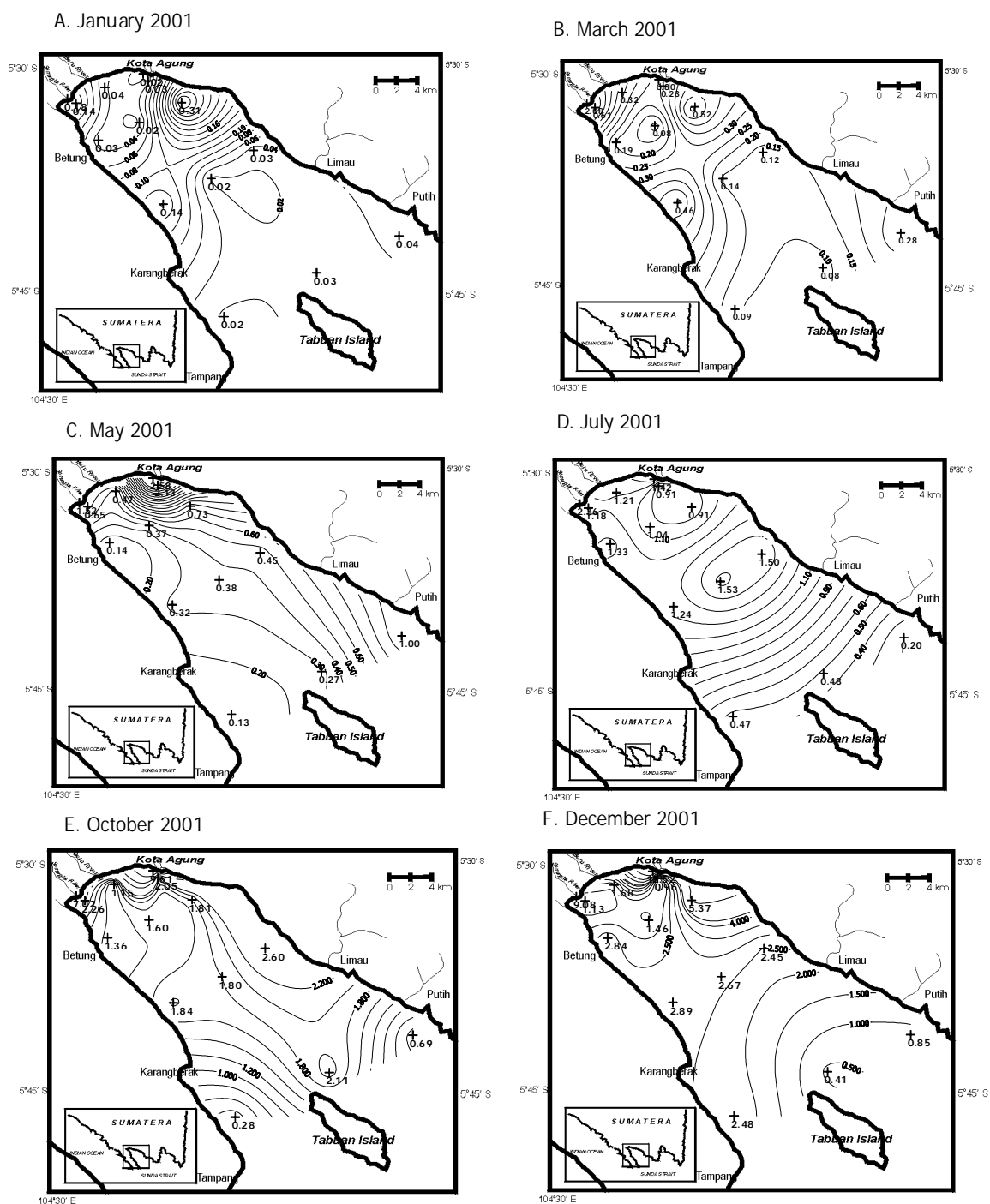


F. December 2001



**Fig. 5.14.** Nitrite ( $\mu\text{M NO}_2\text{-N}$ ) contours in Semangka Bay. A: January 2001. B: March 2001. C: May 2001. D : July 2001. E : October 2001 and F: December 2001.





**Fig. 5.15.** Ammonium ( $\mu\text{M NH}_4\text{-N}$ ) contours in Semangka Bay. A: January 2001. B: March 2001. C: May 2001. D : July 2001. E : October 2001 and F: December 2001.

#### 5.1.5.4. Ammonium ( $\text{NH}_4^+\text{-N}$ )

Fig. 5.15. displays the ammonium distributions in Semangka Bay. There were significant differences in ammonium concentrations both with respect to the spatial and temporal scales (ANOVA,  $p < 0.001$ ). In general, high ammonium prevailed in the river mouth and town harbour waters, then gradually decreased in the middle part of the bay. Spatial pattern is similar to that of nitrate and nitrite with high concentrations at the sites subjected to river discharge and in the harbour, and low levels in the middle and outer

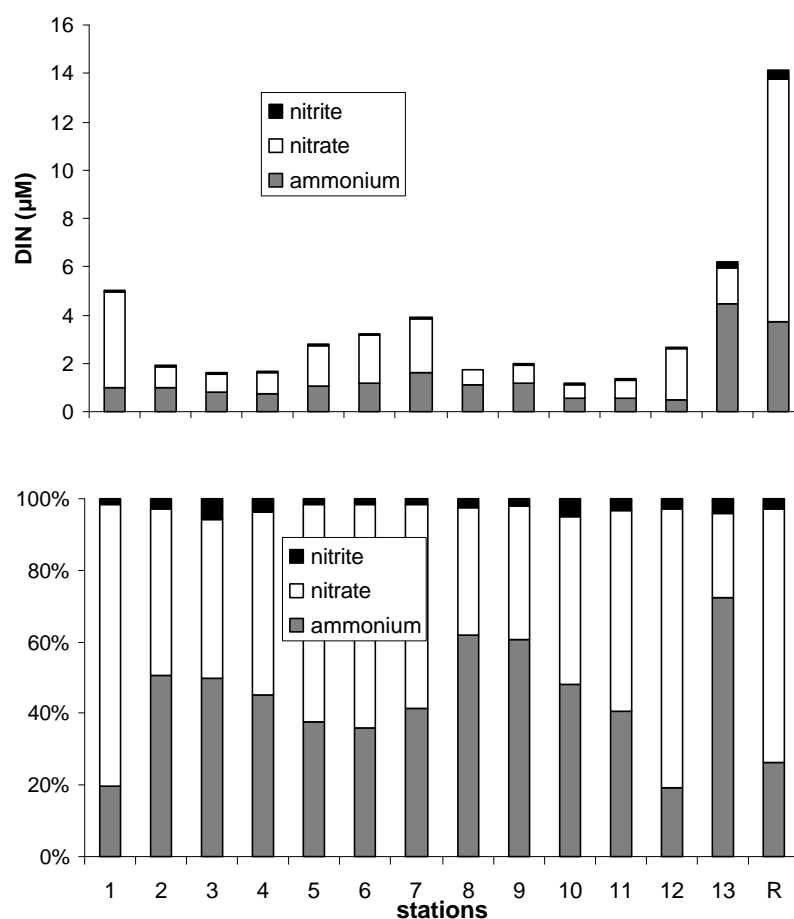
parts of the bay. High ammonium concentration prevailed in town-harbour waters, ranging from 0.02  $\mu\text{M NH}_4\text{-N}$  to 12.53  $\mu\text{M NH}_4\text{-N}$ . Fishermen activities and human sewage were responsible for the high ammonium in the harbour waters. In the river mouth, ammonium ranged from 0.19  $\mu\text{M NH}_4\text{-N}$  to 9.08  $\mu\text{M NH}_4\text{-N}$ , showing an important role of the incoming river on the distribution of ammonium in the bay. Besides those two sites, stations 5,6,7,8 and 9 have high ammonium concentrations, ranging from 1.05  $\mu\text{M NH}_4\text{-N}$  to 1.61  $\mu\text{M NH}_4\text{-N}$ . At the outer part of the bay, ammonium reduced, ranging from 0.51  $\mu\text{M NH}_4\text{-N}$  to 0.58  $\mu\text{M NH}_4\text{-N}$ . Ammonium concentrations too, were strongly correlated with salinity, showing that river discharge played an important role on ammonium distribution in the bay (Pearson's  $r = -0.44$  and linear regression  $R^2 = 0.35$ , Fig.5.18).

Temporal variation shows a maximum average of ammonium concentrations in December 2001 (average of 3.34  $\mu\text{M NH}_4\text{-N}$ ), while a minimum occurred in January 2001 (average of 0.08  $\mu\text{M NH}_4\text{-N}$ ). High average level also prevailed in October 2001 (2.58  $\mu\text{M NH}_4\text{-N}$ ), suggesting a relationship between ammonium and precipitation intensity. High ammonium concentrations during high rainfall periods might be related to intensive flushing of the town's sewage water from the canals into the bay. High ammonium concentrations during that period were observed in the harbour waters. As has been mentioned previously, a series of small sewage canals flow into the harbour. In addition, the intense fish processing activities in the harbour area during that period may be another local source of ammonium at this site. During the high fish catch period (September to December), the harbour is intensively used especially for cleaning the landed fishes. In January and February, however, which are high rainfall periods too, fish catches and processing in the harbour area are distinctly lesser.

#### **5.1.5.5. Dissolved inorganic nitrogen (DIN)**

DIN concentrations are dominated by those of nitrate (> 50%), especially in the vicinity of river input areas (Fig.5.16.). At the river mouth and at the surrounding sites, nitrate formed more than 80% of DIN, illustrating that the incoming river is a main source of nitrate rather than of ammonium. Contrary to this, DIN concentrations in the harbour waters (station 13), were dominated to about 75% by ammonium. At most of the other stations, nitrate and ammonium showed more or less equal parts.

The dominant role of nitrate for total inorganic nitrogen levels may be an indication for a minor importance of domestic waste emissions for the nutrient situation in Semangka Bay.



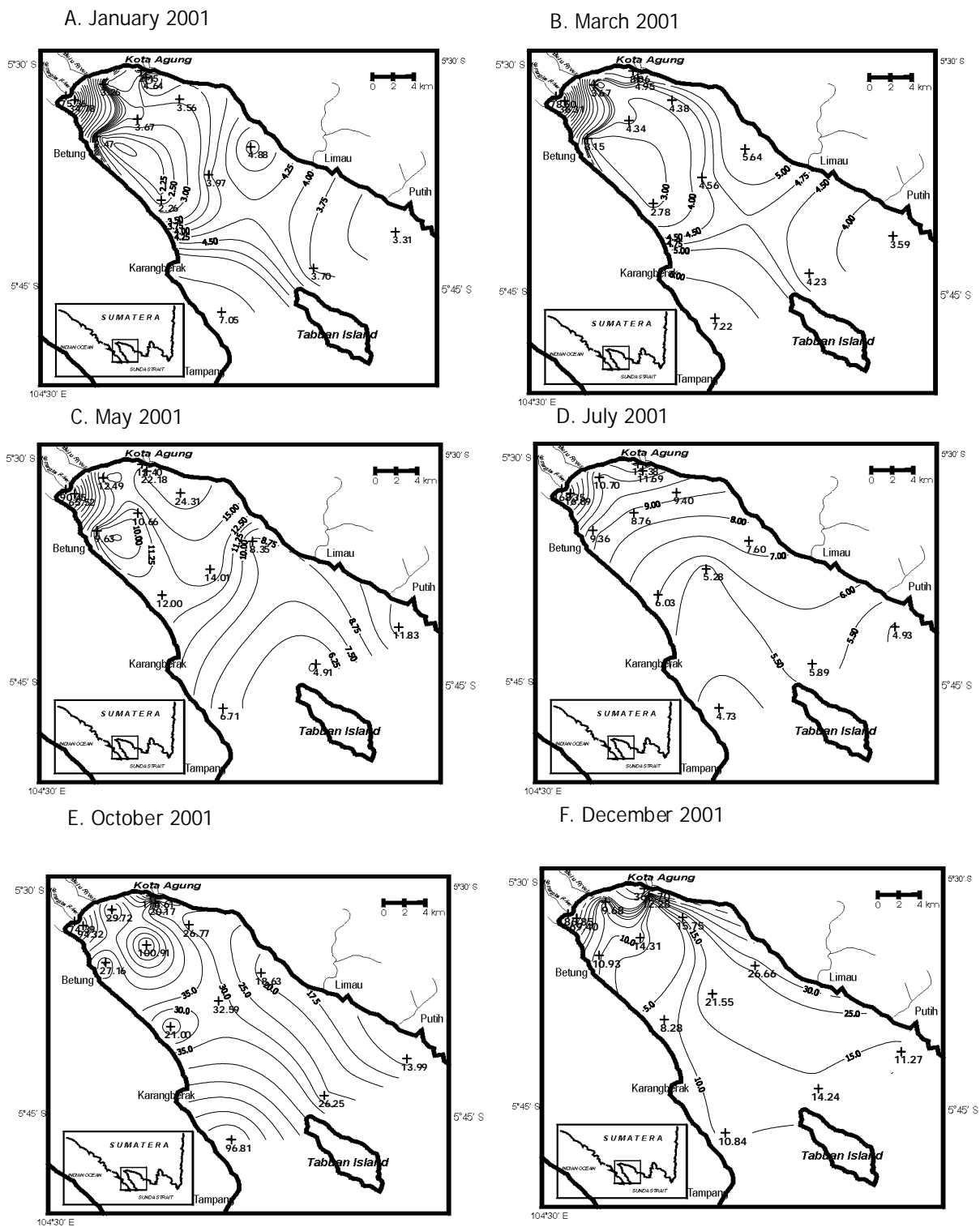
**Fig. 5.16.** Annual mean DIN concentration composed of nitrite, nitrate and ammonium (upper graph) and percent contribution of each nitrogen species (lower graph) in Semangka Bay. R = Semangka river mouth.

### 5.1.5.6. Silicate [ $\text{SiO}_4$ ]

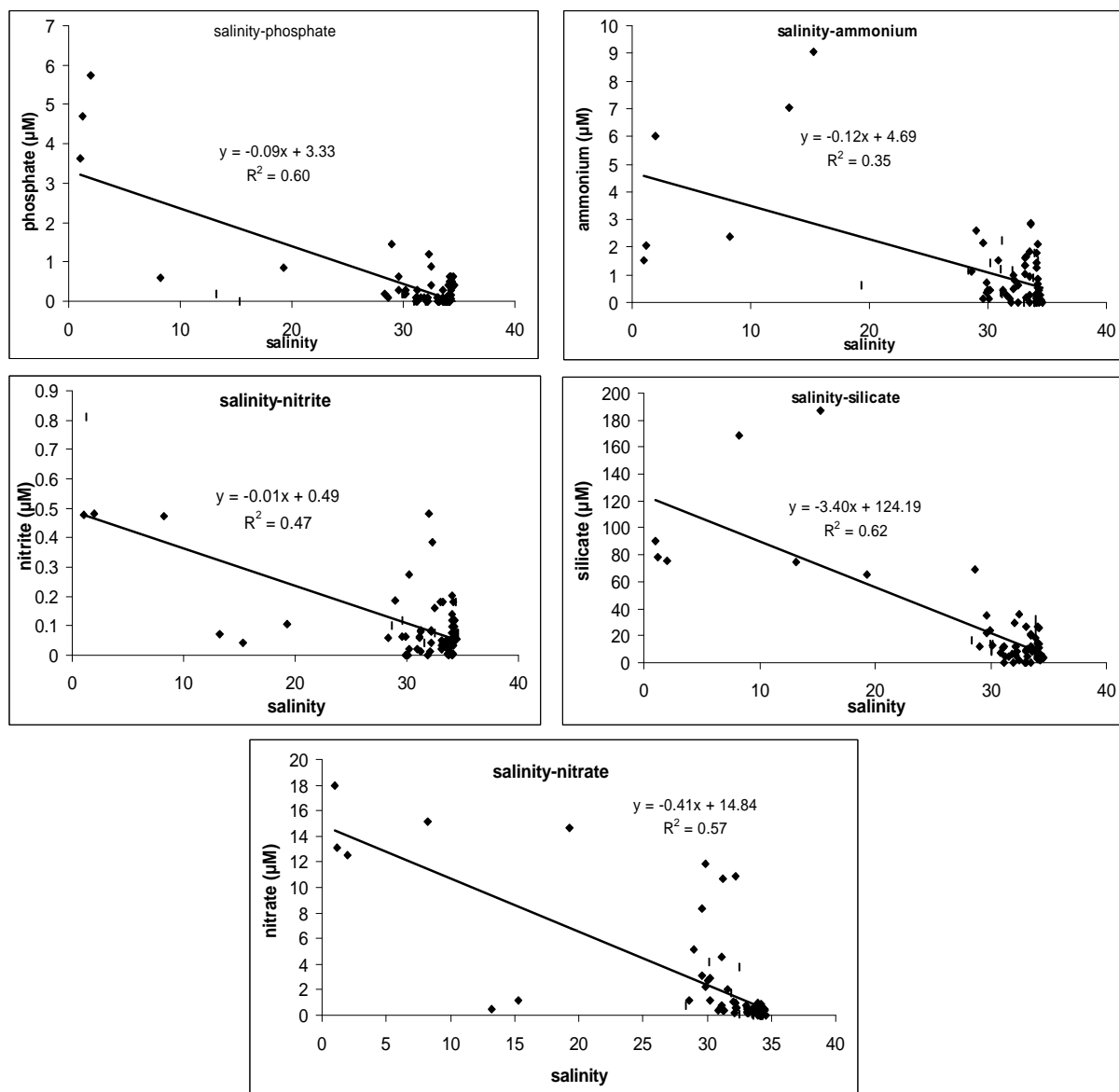
There were significant differences in the silicate levels (Fig.5.17) both between sites (ANOVA,  $p < 0.001$ ) and seasons (ANOVA,  $p < 0.01$ ). Highest concentrations up to 187  $\mu\text{M}$  Si were measured at the river mouth and sometimes in the harbour waters. Some stations further offshore still showed relatively high silicate levels, showing that this nutrient species is rather rapidly distributed over the whole bay.

River discharge seems to be the prominent factor for silicate distribution in the bay, as can be traced from the strong inverse correlation between silicate and salinity ( $p < 0.001$ ; Pearson's  $r = -0.58$ ; linear regression  $R^2 = 0.62$ ).

Seasonal variation of silicate shows a maximum whole bay spatial average in December 2001 (55.55  $\mu\text{M}$  Si), while minimum mean levels prevailed in January 2001 (11.07  $\mu\text{M}$  Si). High average silicate concentrations also prevailed in October 2001 (49.81  $\mu\text{M}$  Si), suggesting a close relationship between silicate and rainfall pattern.



**Fig. 5.17.** Silicate ( $\mu\text{M Si}$ ) contours in Semangka Bay. A: January 2001. B: March 2001. C: May 2001. D: July 2001. E: October 2001 and F: December 2001.



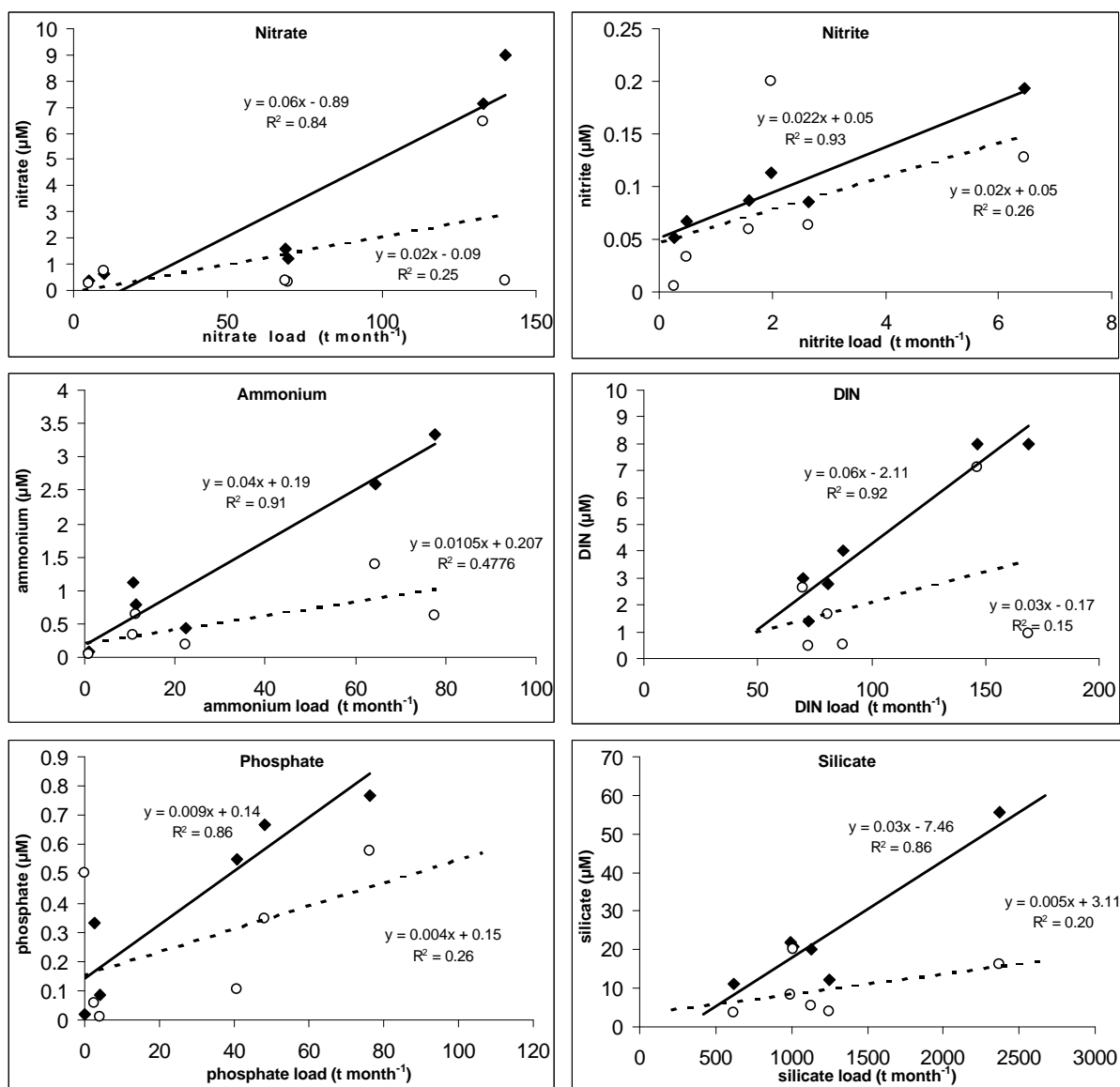
**Fig. 5.18.** Linear regression between salinity and nutrients (ammonium, phosphate, silicate, nitrite and nitrate) in Semangka Bay.

### 5.1.5.7. Correlation between nutrient load and nutrient concentration in the bay

Two types of linear regressions between riverine nutrient loads and nutrient concentrations in the bay were performed (Fig.5.19.), using the average nutrient concentrations in the inshore waters (stations 1,2 and 3), which are subjected to a direct nutrient inputs, as well as those of the offshore sites (stations 10,11 and 12) of the different seasonal surveys.

Comparison among these 2 linear regressions allows for assessing the impact of riverine nutrient loading on the nutrient concentrations in the recipient bay waters.

Nutrient loads were strongly correlated with the nutrient concentration in the inshore waters, but they much less with the offshore waters. This shows that the variability of nutrient levels in the outer part of the bay is not only controlled by river discharge, but also due to additional sources, such as incoming water masses from the Sunda Strait and the Indian Ocean. Especially during the dry season, Semangka Bay waters are influenced by the water masses of the Sunda Strait, whereas during the rainy season, advection from the Indian Ocean plays a major role (Hendiarti *et al.*, 2002).



**Fig. 5.19.** Linear regressions between nutrient loads and ambient concentrations in Semangka Bay. Solid lines : regression between nutrient loads and average inshore nutrient concentration. Dotted lines: regression with average offshore nutrient levels.

#### **5.1.5.8. Molar ratio of dissolved inorganic nitrogen to phosphate (DIN:P) and to Silicate (DIN:Si).**

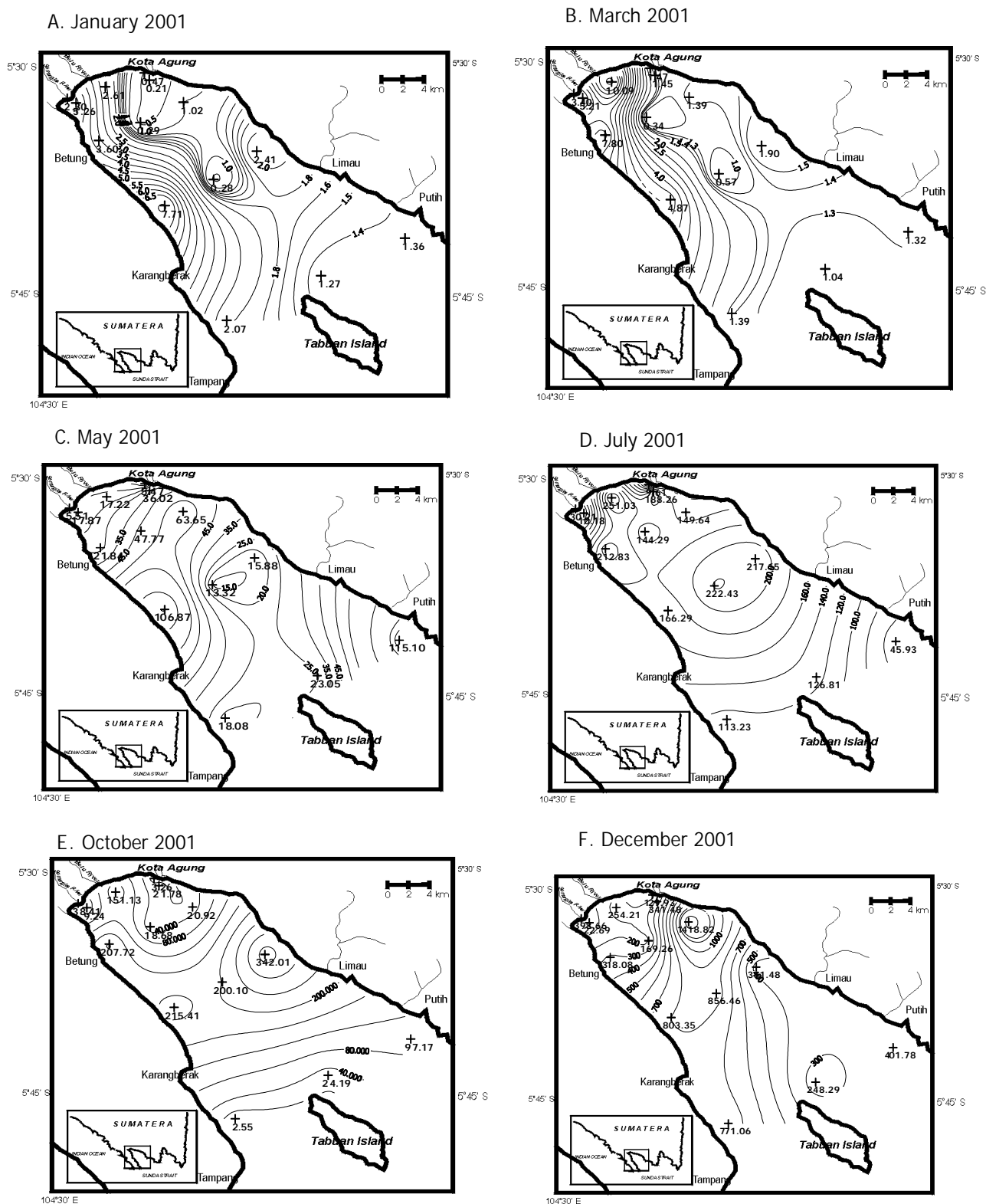
Fig. 5.20. displays the contours of the DIN:P ratios throughout the study period. Fig.5.22.A. shows the DIN:P ratio of the different stations together with the arbitrary Redfield ratio of 15 for average phytoplankton nutrient uptake (Redfield *et al.*, 1963). Values higher than 15 indicate potential phosphorus limitation, while values below 15 indicate a potential nitrogen limitation. There was no significant difference in DIN:P ratios between sites but they were significantly different between seasons (ANOVA,  $p < 0.001$ ). Low ratios of less than 5 prevailed during January and February 2001 due to low DIN concentrations. In May 2001, higher ratios of 5.5 to 115.1 were observed, increasing during July, October and December 2001 up to absolute maxima of 2398.

In the spatial scale, the DIN:P ratio increased along with salinity. Pearson's correlation analysis showed a moderate correlation between DIN:P ratio to salinity ( $p < 0.01$  ; -0.23), indicating a moderate influence of river inputs on this variable. Low values in and around the river mouth were mostly due to elevated phosphate concentrations.

The ratios of DIN to Si were low ( $< 1.0$ ) at all stations and temporal surveys (5.22.B). These low values indicate a potential N limitation. DIN/Si ratios showed significant spatial (ANOVA,  $p < 0.05$ ) and temporal differences ( $p < 0.001$ ). Inversely, low values were observed at the river mouth and surrounding sites (ranging from 0.05 to 0.22). They increased in the more offshore waters (ranging from 0.49 to 0.92). Highest annual average accounted for 0.36 (station 6); while lowest mean ratios were observed in the river mouth (0.11).

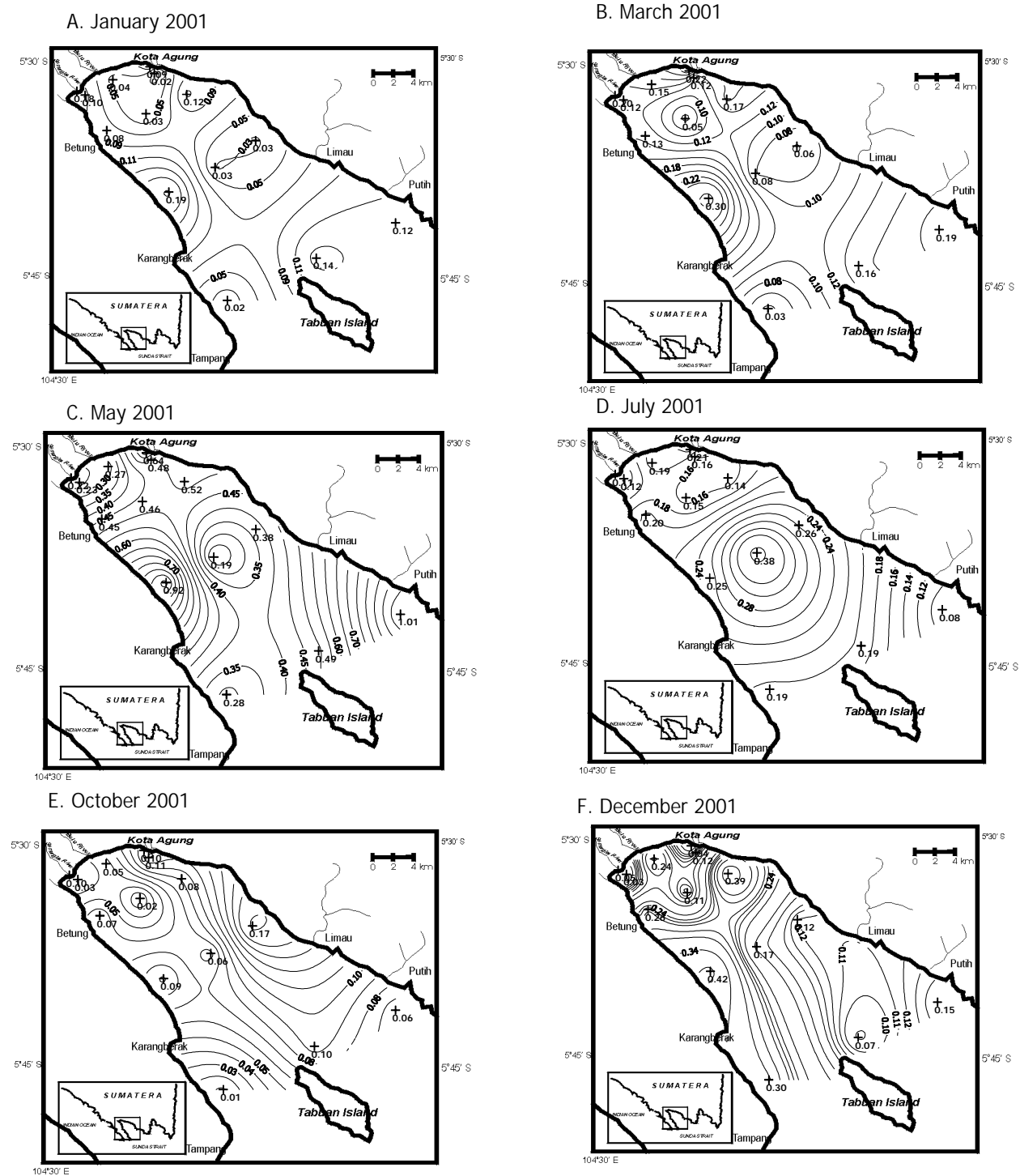
On a temporal scale, May 2001 exhibited the highest DIN:Si ratio (0.47), and October 2001 the lowest (0.07). The high average ratio in May was caused by high nitrate concentrations, which might be a consequence of nitrate emission from agricultural activities.

To sum up, nitrogen and phosphate seem to be the potential limiting nutrients in the bay. There were no indication of silicate limitation, which was due to the continuous supply of silicate through the river.

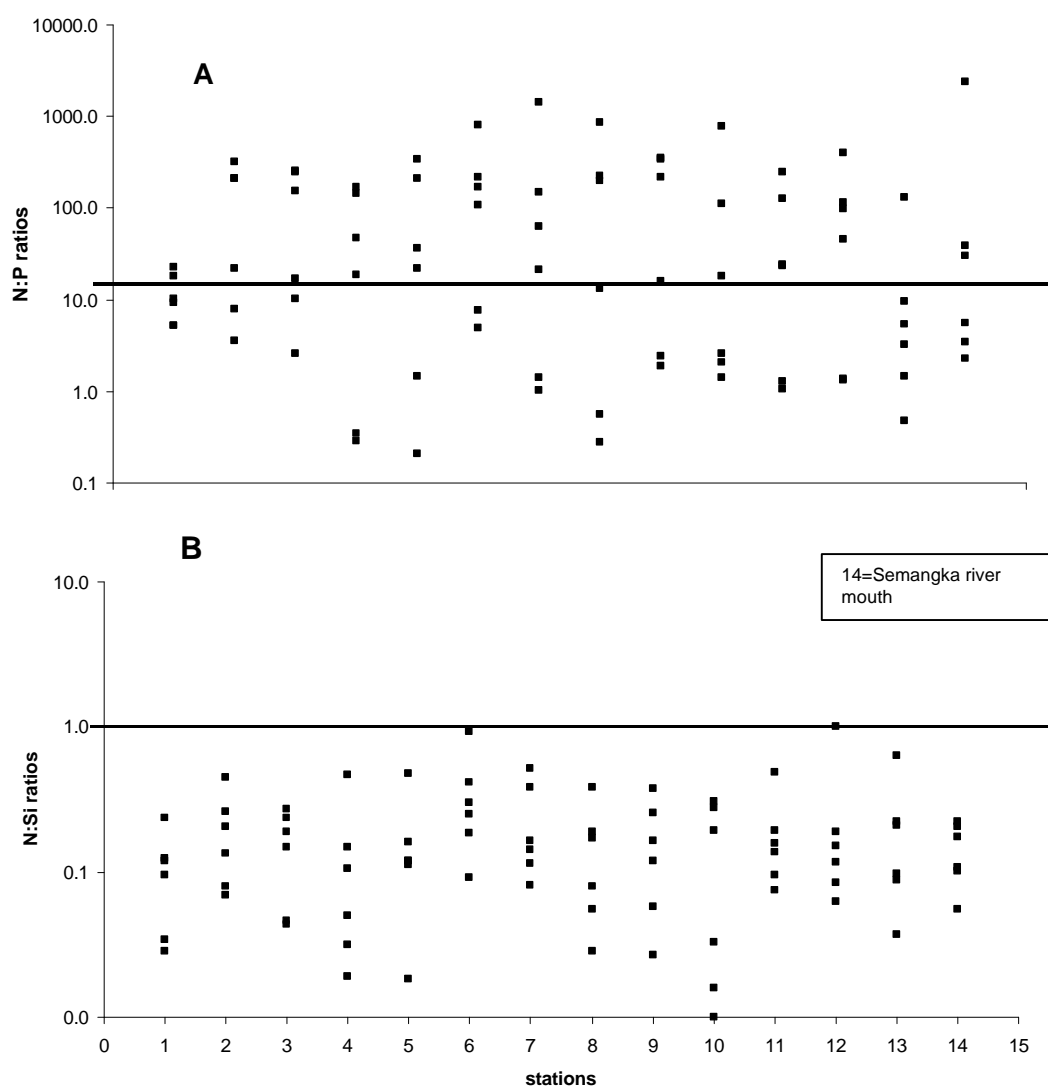


**Fig. 5.20.** DIN : P ratio contours in Semangka Bay. A: January 2001. B: March 2001. C: May 2001. D : July 2001. E : October 2001 and F: December 2001.





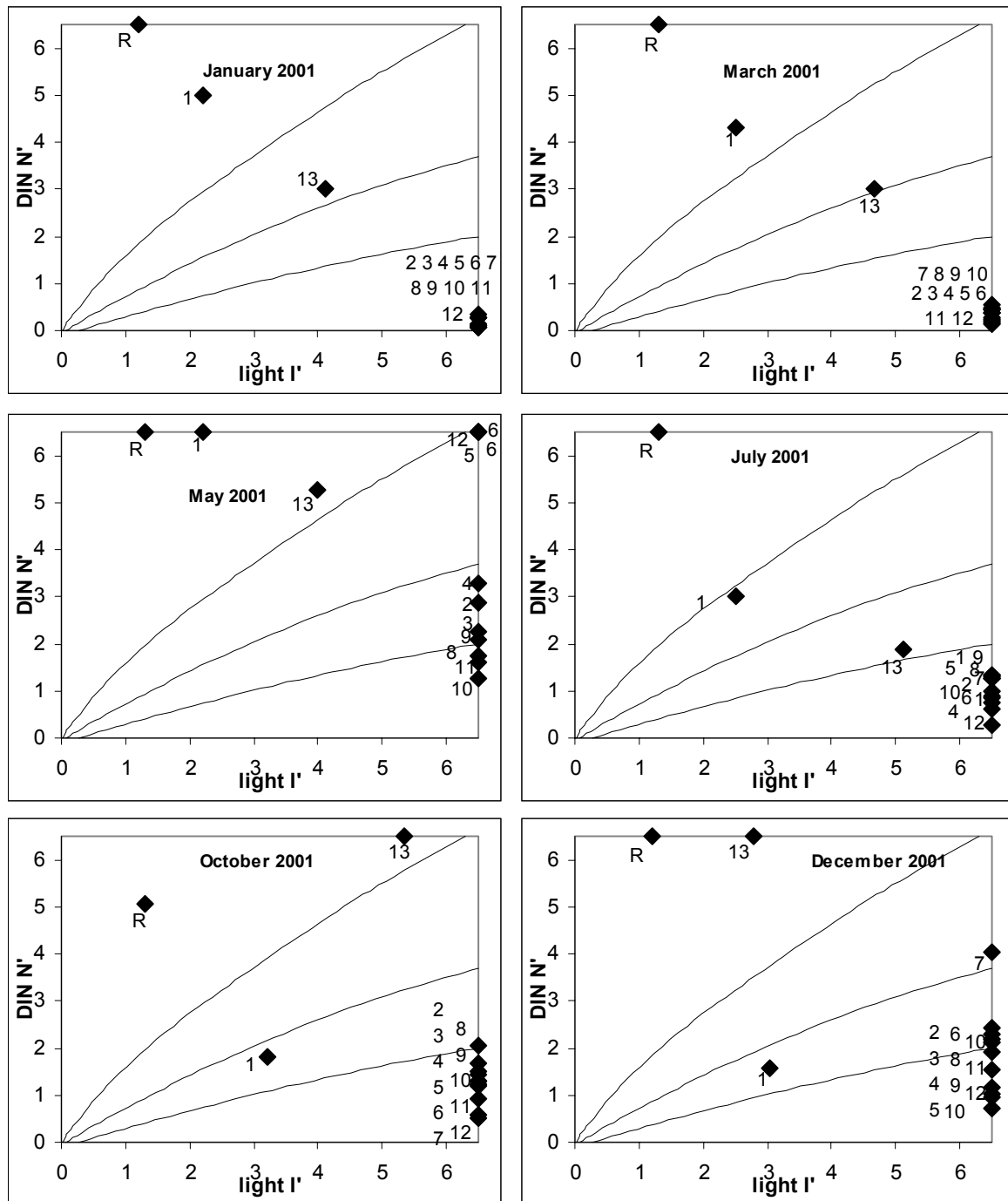
**Fig. 5.21.** DIN : Si ratio contours in Semangka Bay. A: January 2001. B: March 2001. C: May 2001. D: July 2001. E : October 2001 and F: December 2001.



**Fig. 5.22.** Molar ratios of DIN:P (A) and DIN:Si (B) at each station in Semangka Bay. Horizontal lines indicate where DIN:P is 15 (A) and DIN:Si is 1 (B).

### 5.1.6. Phytoplankton growth rate sensitivity to light and nutrients

Based on the procedure developed by Cloern (1999) (see chapter 2.3.), nutrient (DIN) and light resources were plotted in a phytoplankton resource limitation diagram for each temporal survey (Fig.5.23). The figure shows that the phytoplankton communities in the whole area of Semangka Bay are predominantly limited by nutrient resources rather than by light availability throughout the year. The diagrams also illustrate that stations in the river mouth and surrounding (R and 1) are subjected to strong light limitation. During May, October and December 2001 also, station 13 (harbour waters) was limited by light.

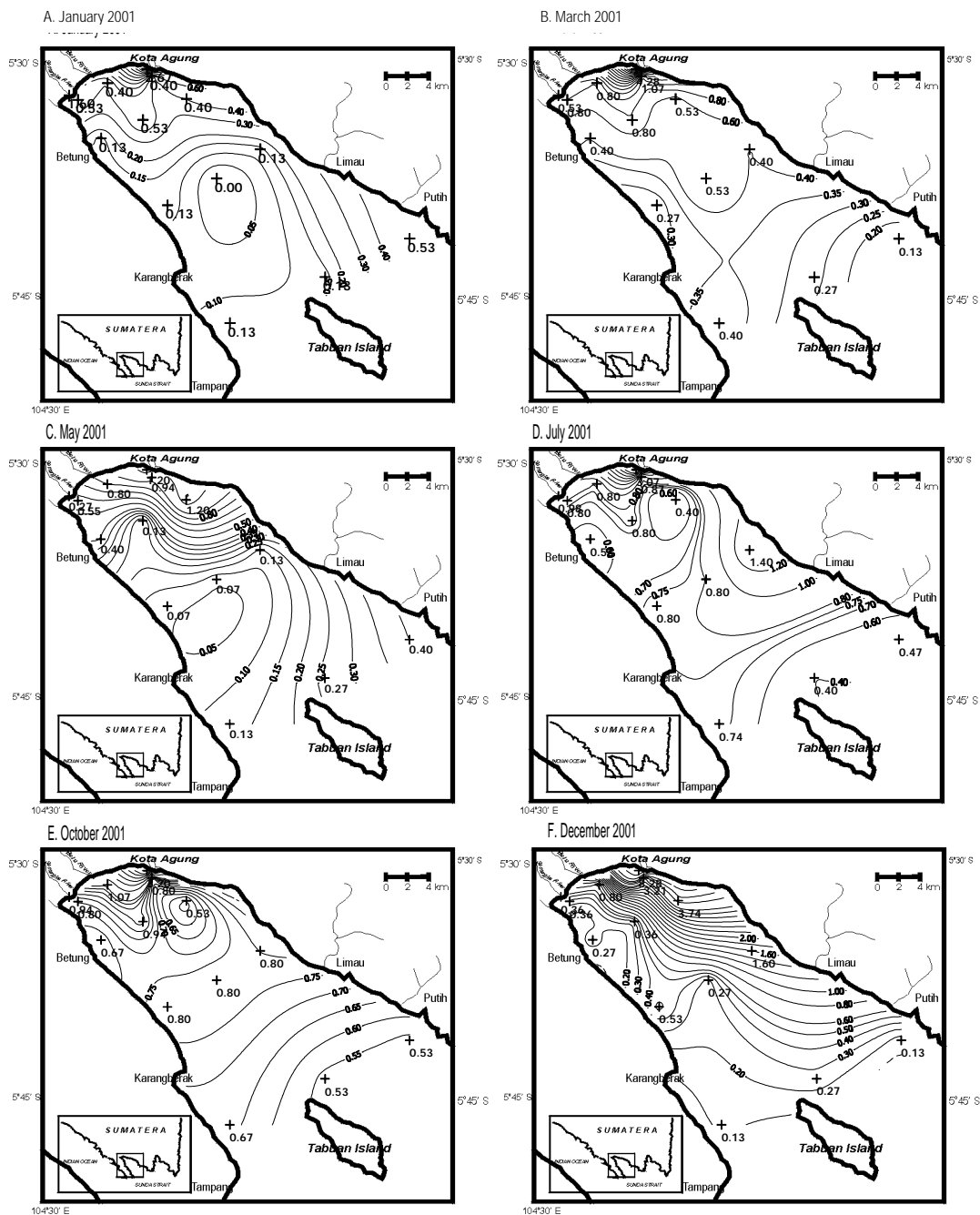


**Fig.5.23.** The light and nutrient resources for phytoplankton growth in Semangka Bay. Dark diamonds show positions of light and nutrient measurements on the resource limitation map. Numbers indicate sampling stations. (calculation was performed according to the procedure of Cloern, 1999, see methods). R=Semangka river mouth.

### 5.1.7. Chlorophyll *a*, phytoplankton community and pigments

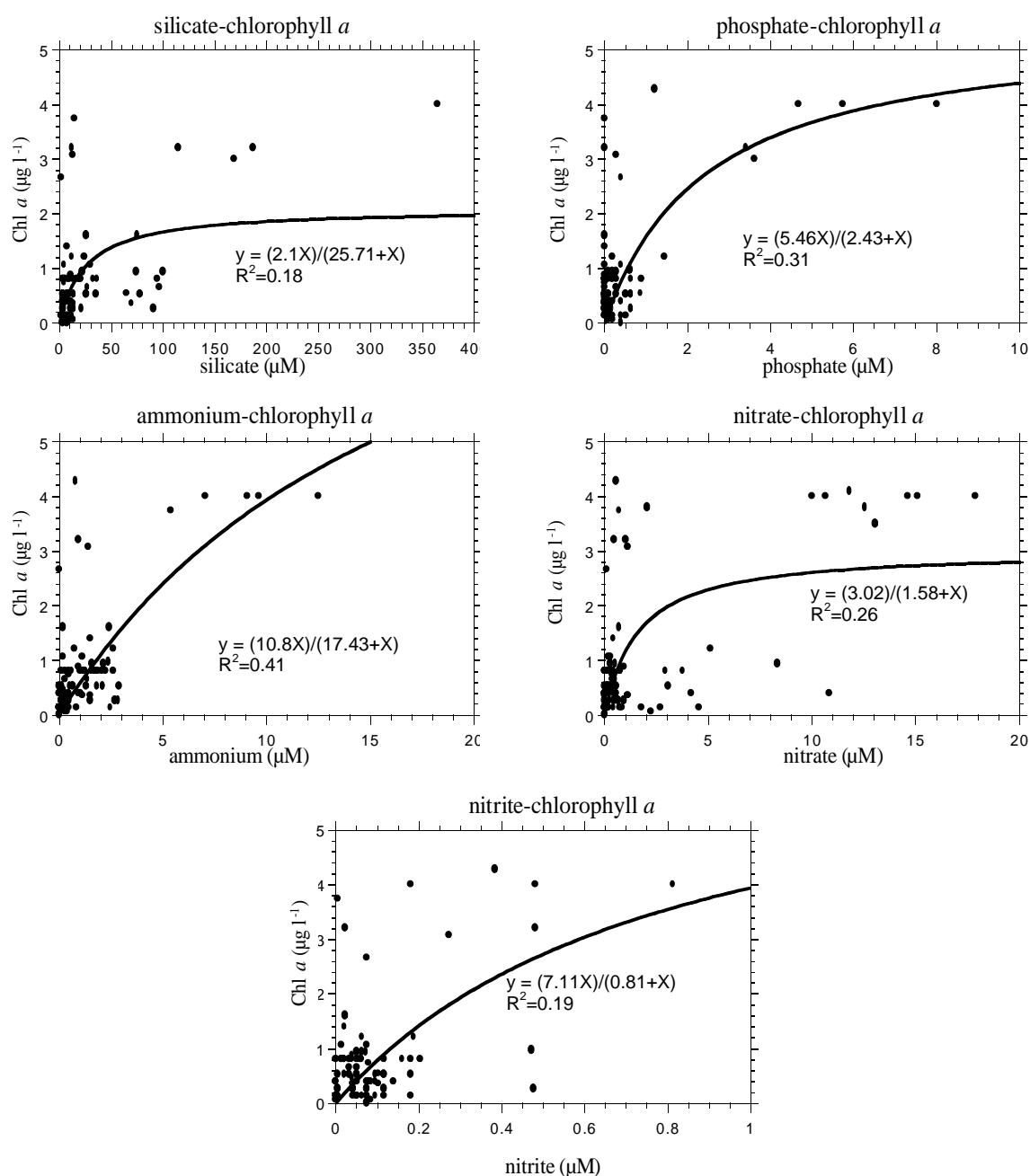
The chlorophyll *a* distribution at each temporal survey showed a clear spatial differentiation (Fig.5.24)(ANOVA,  $p < 0.001$ ). Sum-squared evaluation in Anova revealed that spatial variation accounted for 55% of the total variability. In contrast to Jakarta and Lampung bays, the river mouth and its plume in Semangka Bay seem not to be a favourable site for phytoplankton development as indicated by low chlorophyll *a* concentrations ( $0.26$  to  $1.60 \mu\text{g Chl } a \text{ l}^{-1}$ ) at these sites. This is certainly due to the poor

light conditions in the turbid river plume water. Hot spots of phytoplankton biomass are in the town harbour (station 13), where chlorophyll *a* concentrations ranged from 1.2 to 8.3  $\mu\text{g Chl } a \text{ l}^{-1}$ . In this more stagnant water, light and nutrients are sufficiently available to support phytoplankton growth. Also, other sites in the vicinity of the harbour (stations 5 and 7) showed relatively high chlorophyll *a* levels. In the outer part of the bay, low chlorophyll *a* values, not exceeding 0.74  $\mu\text{g Chl } a \text{ l}^{-1}$  prevailed, which is in keeping with the low nutrient concentrations in this area.

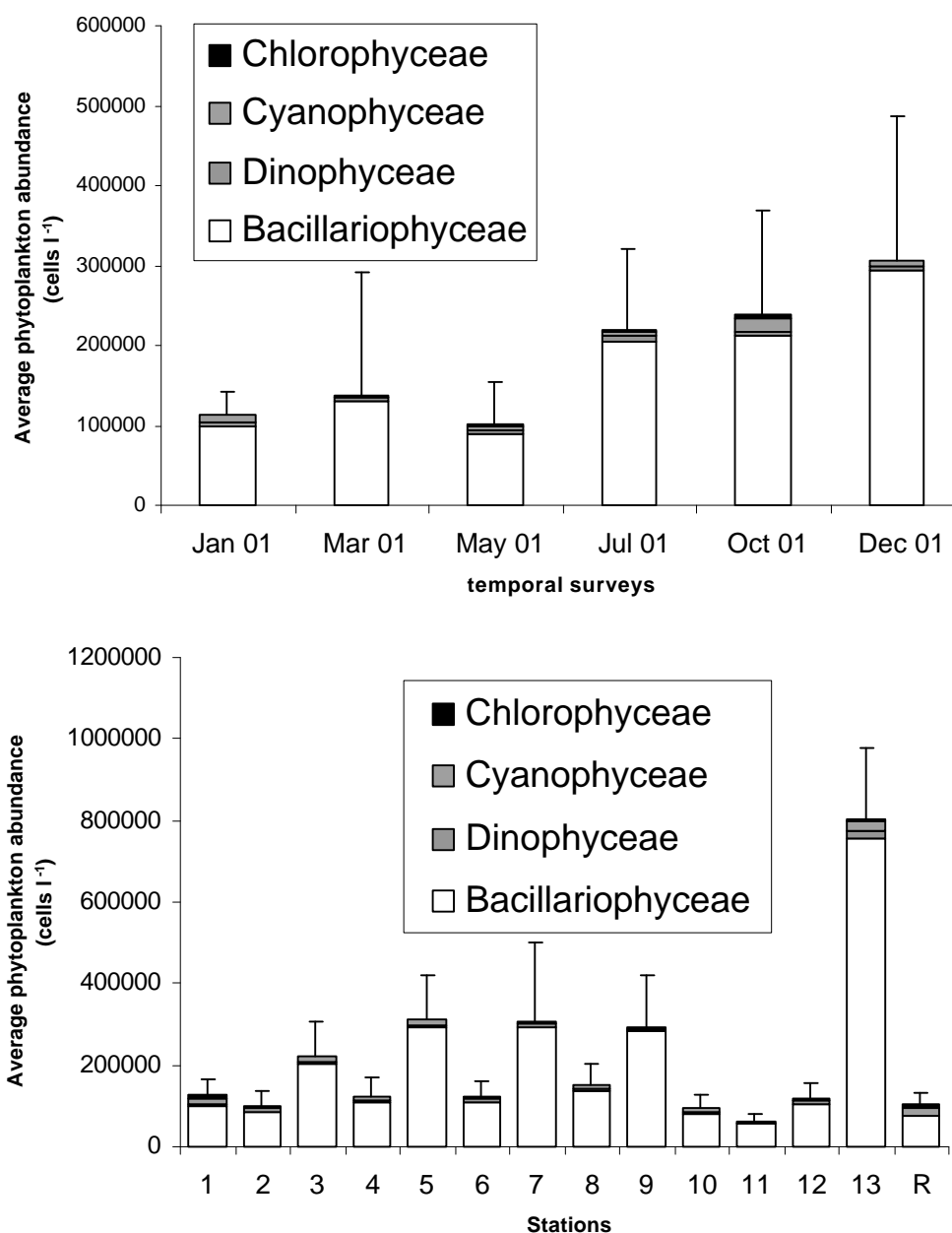


**Fig. 5.24.** Chlorophyll *a* contours ( $\mu\text{g l}^{-1}$ ) in Semangka Bay. A: January 2001. B: March 2001. C: May 2001. D : July 2001. E : October 2001 and F: December 2001.

A strong seasonal variation in phytoplankton biomass was observed. Highest mean levels of chlorophyll *a* were achieved in December 2001 ( $1.45 \mu\text{g Chl } a \text{ l}^{-1}$ ), while a minimum average concentration prevailed in May 2001 ( $0.47 \mu\text{g Chl } a \text{ l}^{-1}$ ). This seasonal pattern is commensurate with the temporal availability of ammonium and silicate, indicating a growth controlling role of those nutrients on the phytoplankton in the area. However, the  $Z_{\text{mix}}:Z_{\text{eu}}$  ratio also played an important role for the distribution of phytoplankton biomass in the area, since chlorophyll *a* concentrations were correlated with the ratio of  $Z_{\text{mix}}:Z_{\text{eu}}$  (Pearson's  $r = -0.32$ ). This can partly be a result of vertical dispersion of the biomass over the mixed water column, whereas light limitation is very likely to occur in the river plume.



**Fig.5.25.** Exponential correlations between nutrients and chlorophyll *a* in Semangka Bay.



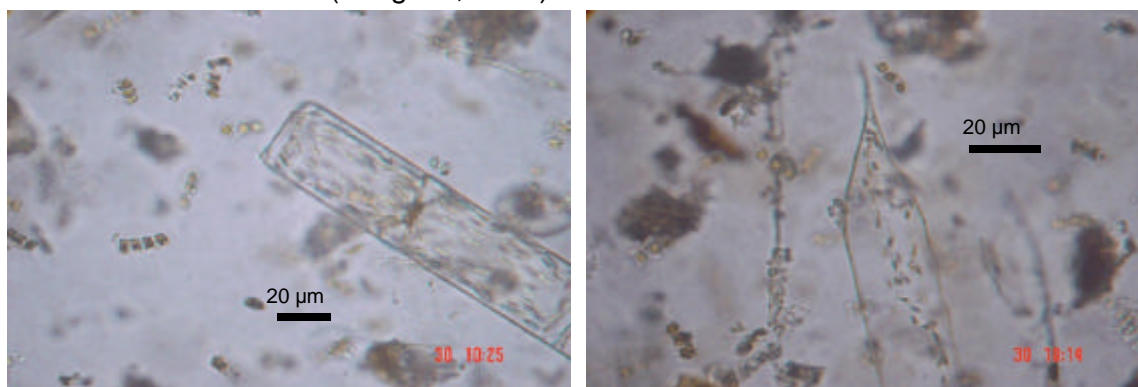
**Fig. 5.26.** Average abundance of phytoplankton (cells l<sup>-1</sup>) in Semangka Bay, in temporal scale (above) and spatial scale (below). R = Semangka river mouth. Bars are standard deviations.

Fig. 5.25. shows hyperbolic relationship between the different nutrient species and chlorophyll *a*. A strong correlation between ammonium and chlorophyll *a* is obvious ( $p < 0.001$ ;  $R^2$  is 0.41), while the other nutrients showed only a low correlation with chlorophyll *a*.

Phytoplankton cell abundance at the river mouth station and the neighbouring station 1 was only moderate (38397 cells l<sup>-1</sup> to 255050 cells l<sup>-1</sup>), and far below that of station 13, which ranged from 292312 cells l<sup>-1</sup> to 1229642 cells l<sup>-1</sup>, and those of Stations 3 and 5 which are located close to the harbour area (between 94833 to 551693 cells l<sup>-1</sup> and from 140573 to 759088 cells l<sup>-1</sup>, respectively). At the other stations, phytoplankton abundance was generally low, ranging from 28679 to 102395 cells l<sup>-1</sup>. Thus, the spatial

phytoplankton abundance was in keeping with that of chlorophyll *a*. Phytoplankton abundance and chlorophyll *a* concentration were also positively significantly correlated ( $p < 0.001$  ; Pearson's  $r = 0.75$ ), indicating a low variation on phytoplankton group composition at all stations. In the river plume, phytoplankton abundance was regulated by the high turbidity levels, whereas the high phytoplankton abundance in the harbour waters was mainly due to adequate nutrients and light availability.

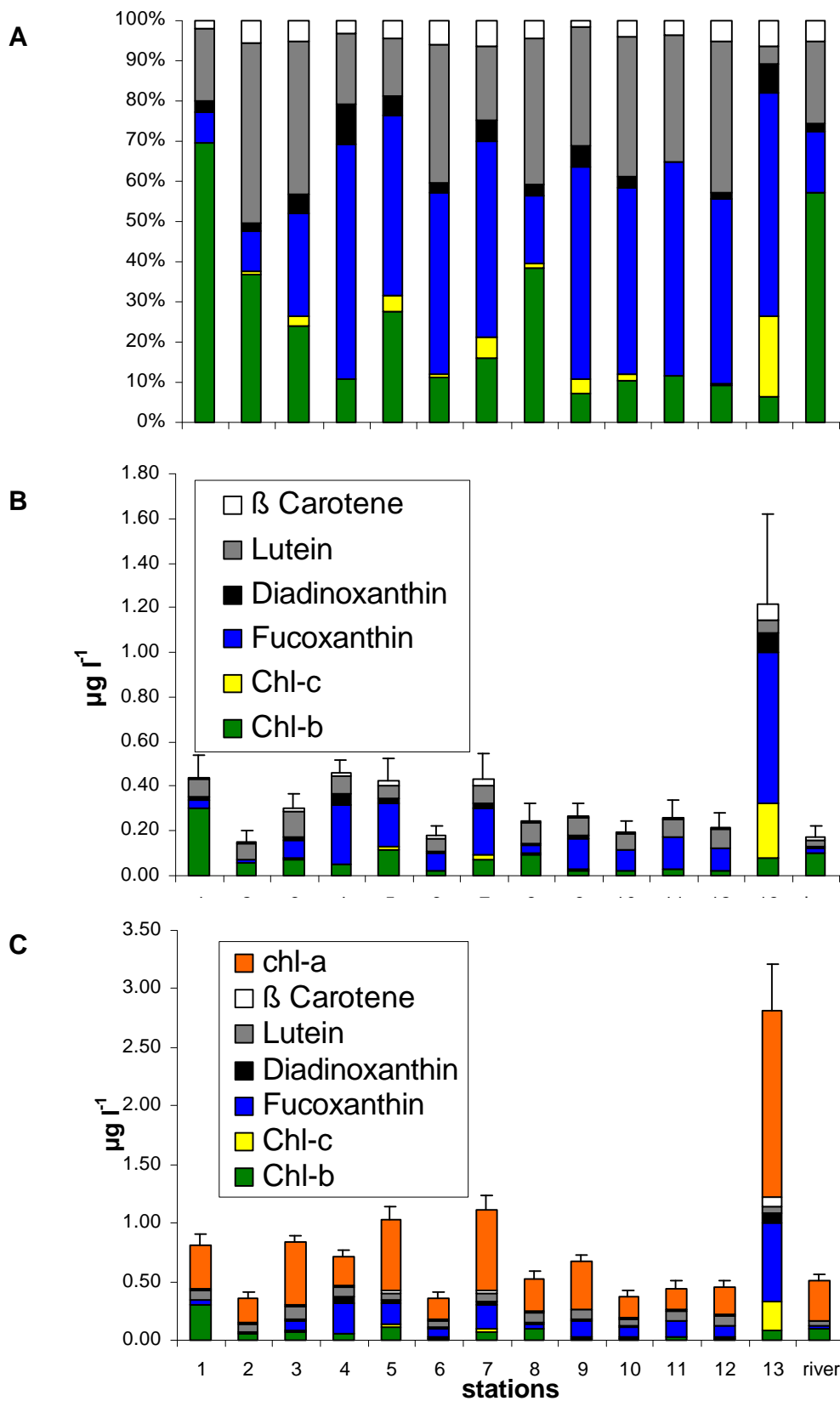
The phytoplankton community was generally dominated by diatoms (*Chaetoceros* spp., *Guinardia flaccida* and *Rhizosolenia indica*), especially at the offshore stations. Besides diatoms, dinoflagellates (*Ceratium* spp.), cyanophyceae (*Trichodesmium* spp.) and chlorophyceae (*Scenedesmus* spp.) were found in limited numbers. Dinoflagellates, which were mainly dominated by *Ceratium furca*, showed slight increase at station 13 (harbour) (Fig.5.26). This maybe a result of the more stagnant condition at this site, because the actively swimming dinoflagellates are able to keep themselves in the water column under this condition (Margalef, 1978).



**Fig.5.27.** Pictures of dominant phytoplankton species in Semangka Bay. *Guinardia flaccida* (left) and *Rhizosolenia indica* (right).

Highest mean phytoplankton abundances were found in December 2001 (around 320000 cells  $l^{-1}$ ), while lowest occurred in May 2001 (around 100000 cells  $l^{-1}$ ). This is in keeping with the seasonal chlorophyll *a* pattern, which reached its maximum in December 2001.

In addition to microscopic analysis, phytoplankton groups were identified through determination of algal pigments using HPLC. Low pigment concentrations were observed in the river mouth and at station 1 (river plume). They were dominated by chlorophyll *b* (to about 70%), which is an indicator for chlorophyceae. A high concentration of fucoxanthin was observed in the harbour water (station 13) ( $1.22 \mu g l^{-1}$ ), indicating that diatoms make up the level at this site, whereas chlorophyceae (Chl *b*) contributed to a low part to the phytoplankton stock in the harbour than at the other sites. At the other stations, algae pigments were usually dominated by fucoxanthin and Chl *b* (Fig. 5.28.).



**Fig. 5.28.** Annual mean concentrations of different pigments in Semangka Bay. (A) comparison in percentage (B) comparison without Chl *a* and (C) comparison includes Chl *a*. River = Semangka river mouth. Bars are standard deviations.



### 5.1.8. Planktonic primary production

Fig. 5.29. shows P-E curve parameters obtained from 3 stations representing different ambient conditions in Semangka Bay. The Chlorophyll-specific maximum photosynthesis rate ( $P_{\max}^B$ ) ranged from 2.61 to 5.36, from 2.24 to 8.08 and from 2.25 to 5.99 mg C mg Chl<sup>-1</sup> h<sup>-1</sup> at stations 1, 4 and 11, respectively (Fig. 5.30.A). Station 1 is located in the river plume, representing high nutrient water, station 4 represents middle part of the bay, while station 11 represents outer part of the bay, which is under the influence of water masses from the Sunda Strait/Indian Ocean. In the river plume water,  $P_{\max}^B$  was reached at much higher light saturation levels, reflecting the turbid water conditions at this site. Station 4 exhibited highest photosynthetic rates. Although station 1 was rich in nutrient, the maximum photosynthetic rate slightly lower than in the centre of the bay, which may be due to the different species composition at this site, which was characterized by high of chlorophyceae.

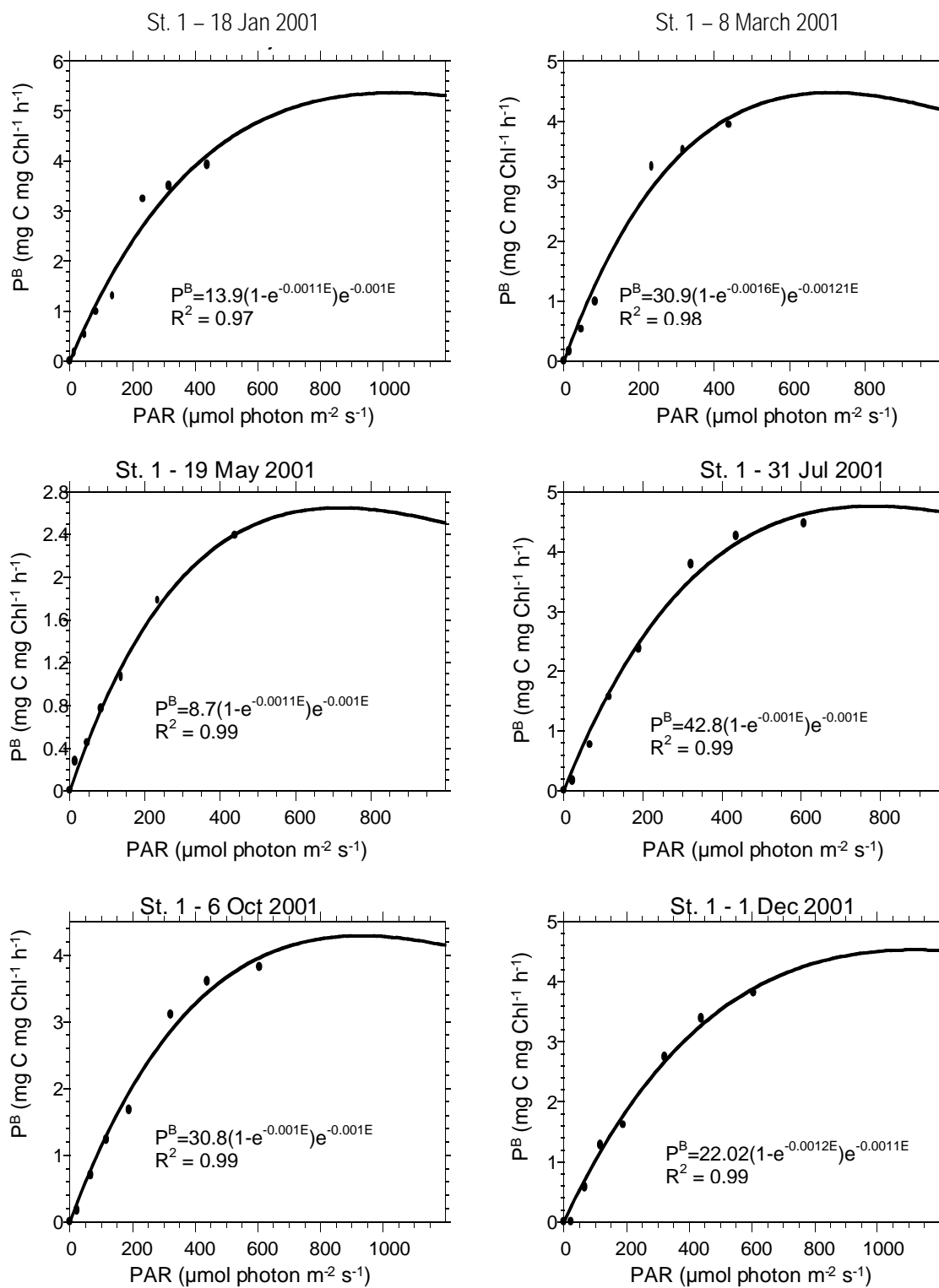
The slope of P versus E curves ( $\alpha^B$ ) (Fig. 5.30.B), which indicates the rate of photosynthetic efficiency, was significantly related to  $P_{\max}^B$  (Pearson's  $r=0.63$ ). In Semangka Bay, it ranged from 0.007 to 0.047 mg C mg Chl<sup>-1</sup> h<sup>-1</sup> ( $\mu\text{mol photons m}^{-2} \text{s}^{-1}$ )<sup>-1</sup>, with maximum level always prevailed at station 4, and lowest at station 1. The slope was significantly and positively correlated with  $E_k$  ( $p<0.01$ ; 0.43).

Compensation light intensity values ( $E_k$ ) were relatively high throughout the year (Fig. 5.30.C), indicating acclimatisation of the algae to strong light. The range was between 89.01 and 406.86  $\mu\text{mol photons m}^{-2} \text{s}^{-1}$ .

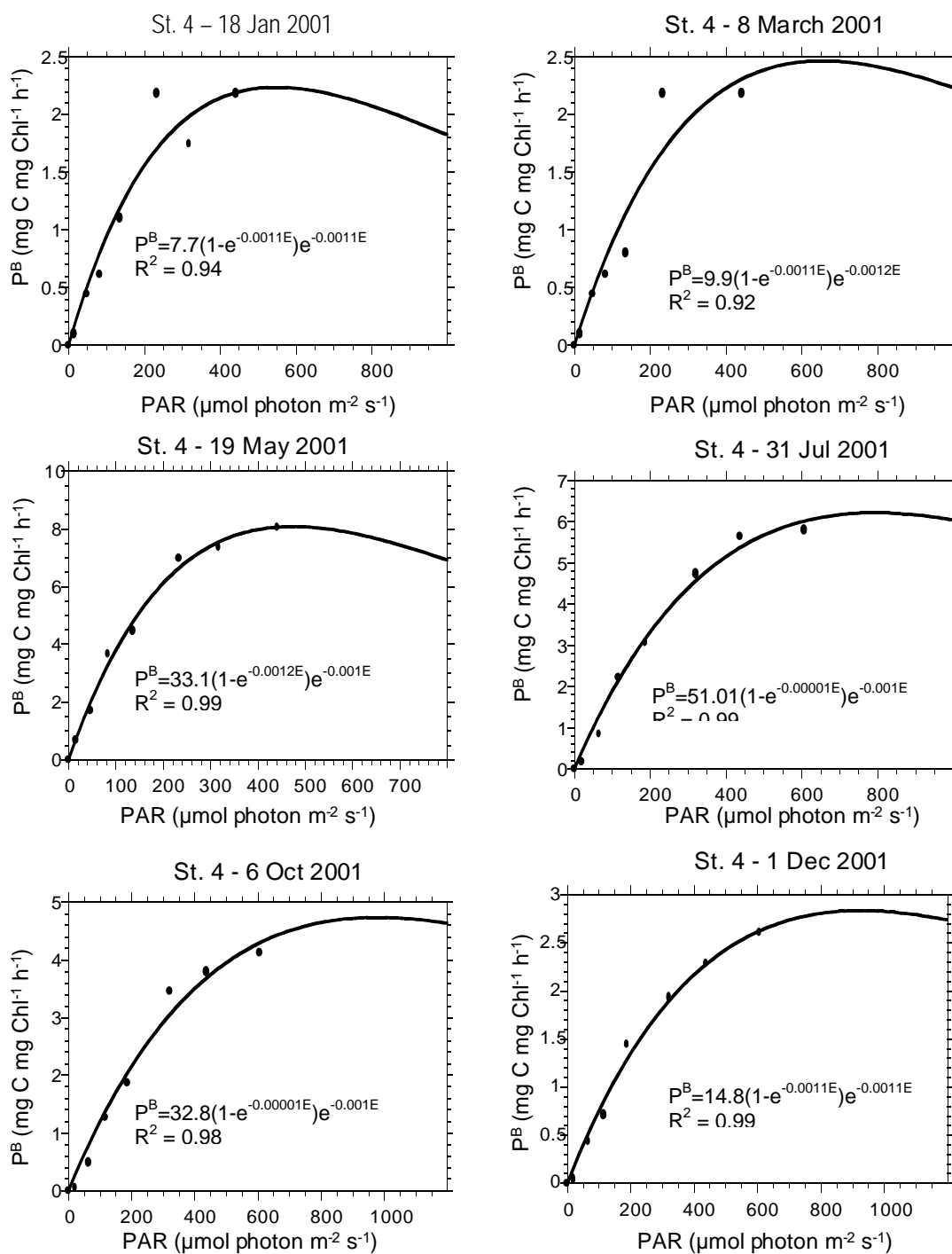
Daily water column primary production estimates showed a clear spatial and seasonal pattern (Fig. 5.30.D). Highest production was usually observed at station 4 (30 to 184 mg C m<sup>-2</sup> d<sup>-1</sup>), being considerably lower at station 11 (16 to 73 mg C m<sup>-2</sup> d<sup>-1</sup>) and finally lowest at station 1 (10 to 52 mg C m<sup>-2</sup> d<sup>-1</sup>).

This spatial pattern is in line with the distribution of chlorophyll *a*, phytoplankton abundance and the attenuation coefficient ( $p<0.01$  ; Pearson's  $r = 0.41, 0.33, -0.79$ , respectively).

Annual primary production estimates for 2001 were calculated by summing up the daily water column production over the year (Fig. 5.31). Annual primary production estimates accounted for 13.89 g C m<sup>-2</sup> y<sup>-1</sup>, 39.94 g C m<sup>-2</sup> y<sup>-1</sup> and 22.21 g C m<sup>-2</sup> y<sup>-1</sup> for station 1, 4 and 11, respectively. Thus, Nixon (1995), Semangka Bay has to be classified as an oligotrophic system (below 100 g C m<sup>-2</sup> y<sup>-1</sup>).



**Fig. 5.29.A.** P-E curves of phytoplankton primary production at station 1, Semangka Bay during 6 different temporal surveys.



**Fig. 5.29.B.** P-E curves of phytoplankton primary production at station 4, Semangka Bay during 6 different temporal surveys.

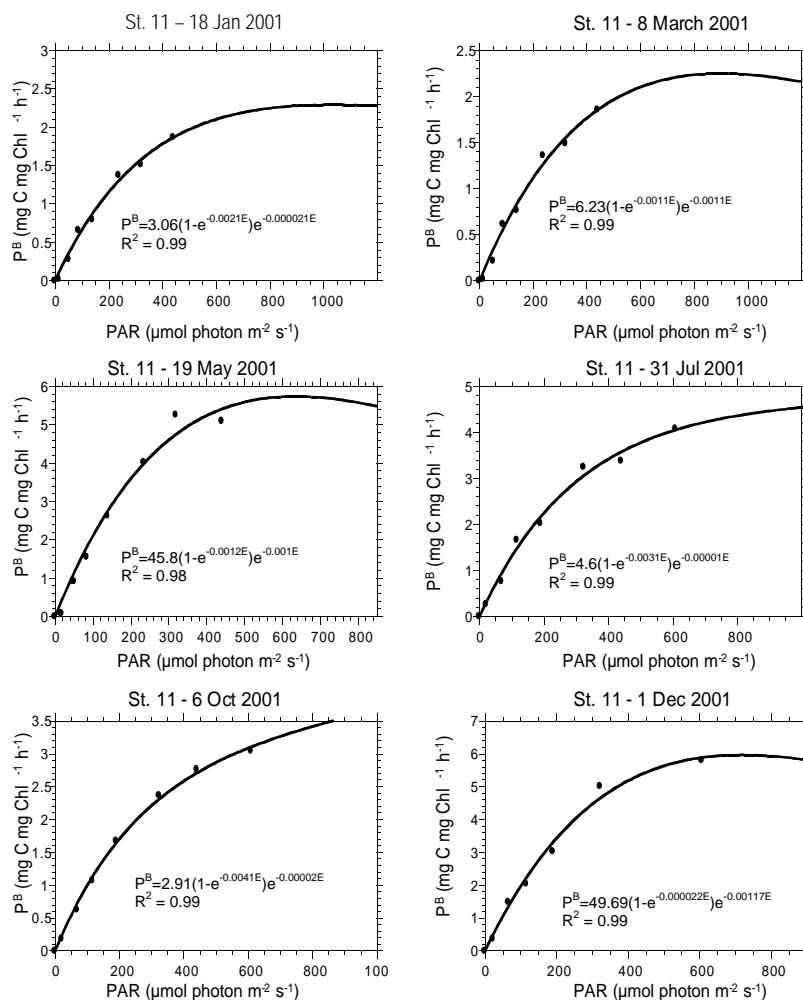


Fig. 5.29.C. P-E curves of primary production at station 11, Semangka Bay.

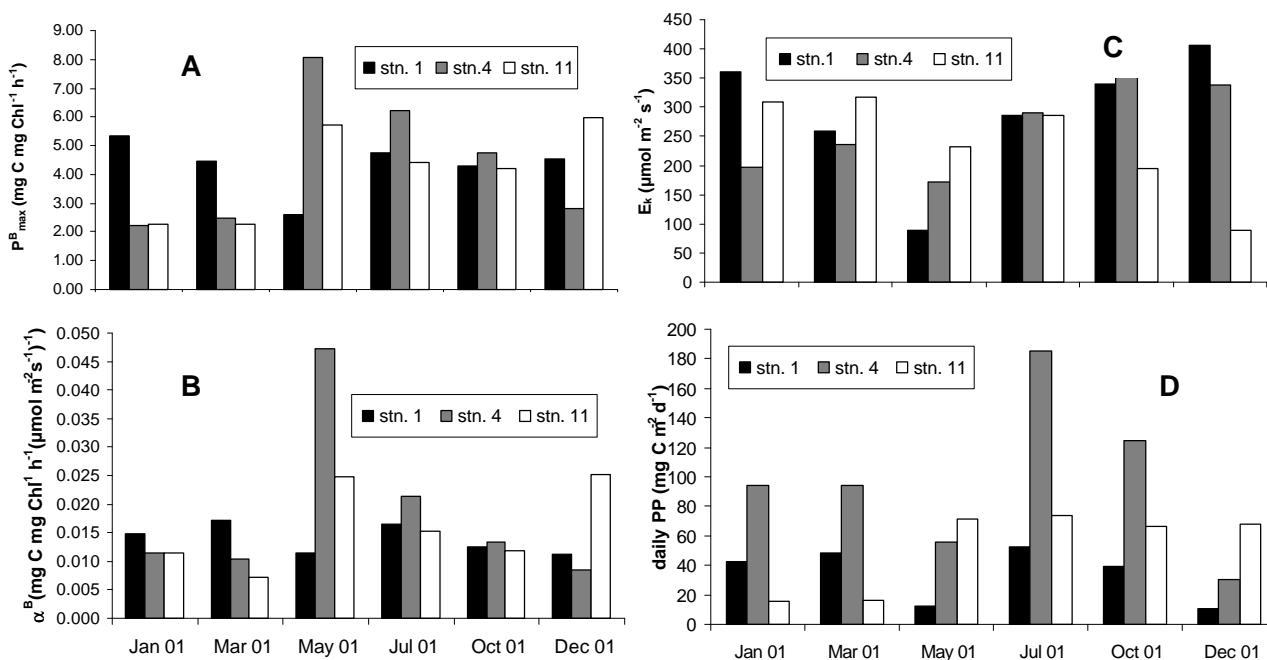
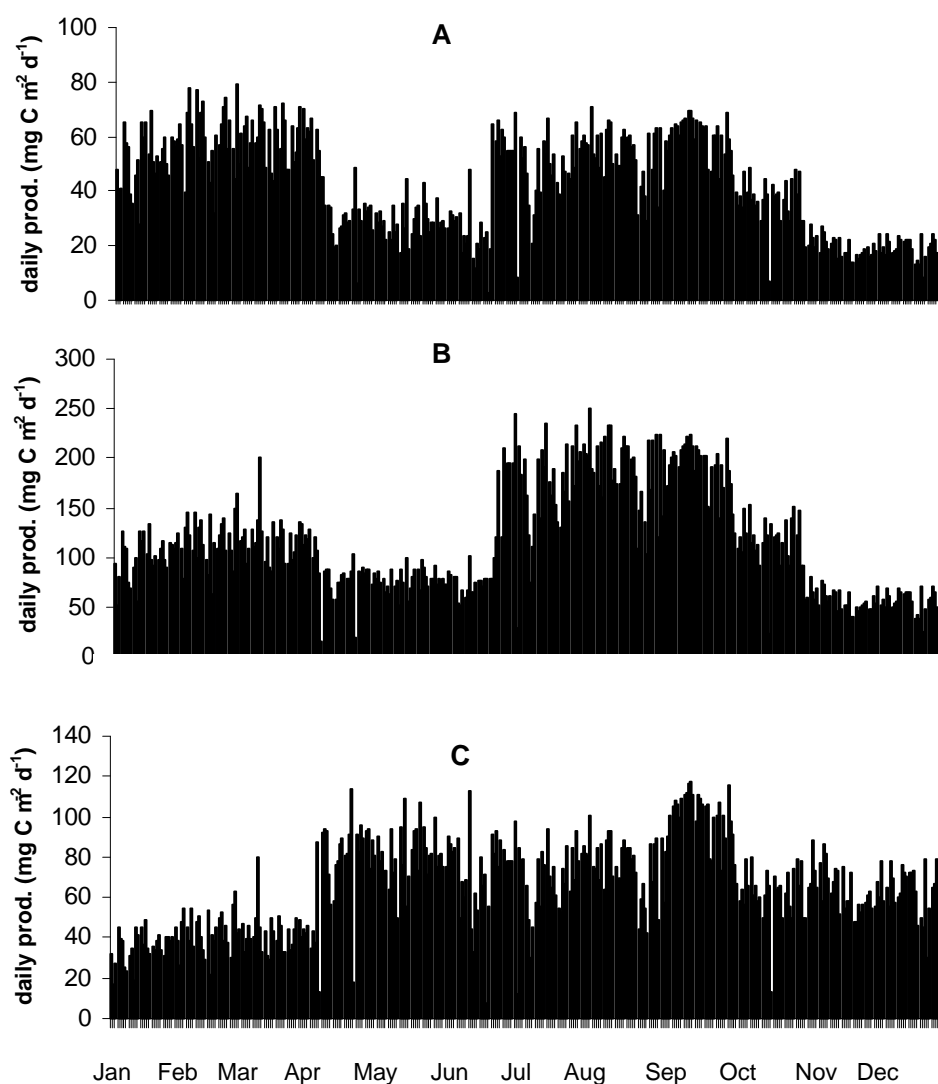


Fig. 5.30. Annual cycle of P versus E parameters and daily production in Semangka Bay. (A) maximal rate of Chl-specific photosynthesis ( $P^B_{max}$ ); (B) slope ( $\alpha^B$ ); (C) light saturation parameter ( $E_k$ ) and (D) daily production (PP).

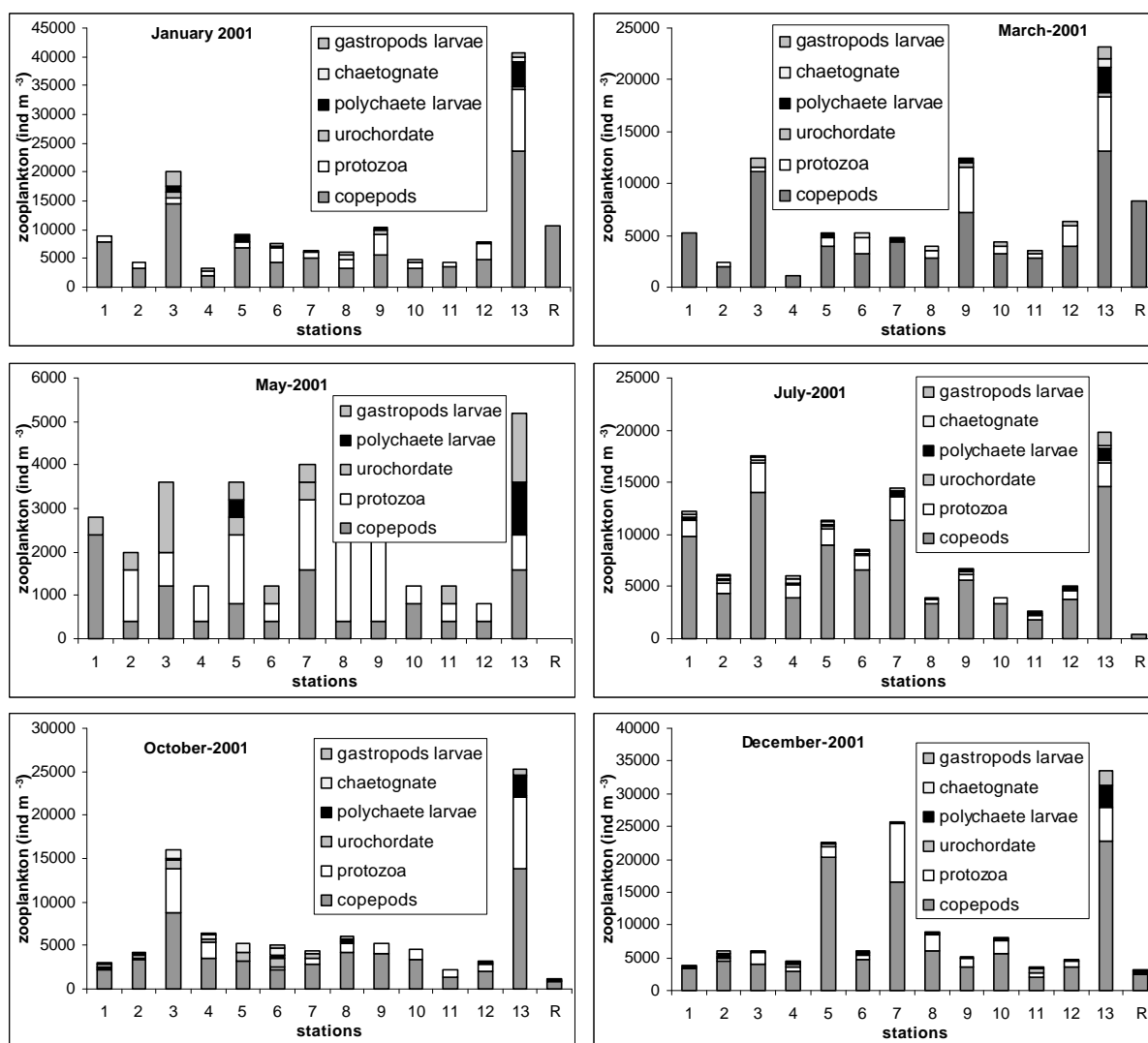


**Fig. 5.31.** Primary production in Semangka Bay during the year 2001. (A) station 1 ; (B) station 4 and (C) station 11.

### 5.1.9. Zooplankton community

The area was characterized by rather low zooplankton abundance, not exceeding 40000 ind m<sup>-3</sup>. In general, zooplankton communities at all stations were dominated by copepods (*Acartia* spp. and *Paracalanus* spp.) and followed by protozoa (Fig.5.32.). Other groups were found in a minor proportion such as gastropod larvae, polychaete larvae and urochordates.

The highest zooplankton abundance was observed at station 13 (harbour waters), while lowest prevailed at the river mouth and in the plume (station 1). This is in line with the distribution pattern of phytoplankton biomass and cell abundance ( $p < 0.001$ ,  $R = 0.71$ ), indicating a close coupling between predators and prey.



**Fig.5.32.** Zooplankton groups at each sampling station and sampling time in Semangka Bay. R = Semangka river mouth.

### 5.1.10. Cluster and Principal Component Analysis

Cluster analysis for Semangka Bay resulted in 4 distinct spatial groups of stations, which are : (1) station 13 (town-harbour site) ; (2) stations 3, 5,7 and 9 ; (3) stations 2,1 and river mouth and (4) stations 10,4,6,12, 8 and 11 (Fig.5.33.).

Station 13 (harbour waters), stands alone due to its distinct characters, which were also obvious from the PCA (Fig.5.34.) : high nutrient and phytoplankton biomass levels, high concentrations of algal pigments, low salinity, moderate Secchi depth and low  $Z_{mix}$ - $Z_{eu}$  (Fig.5.34).

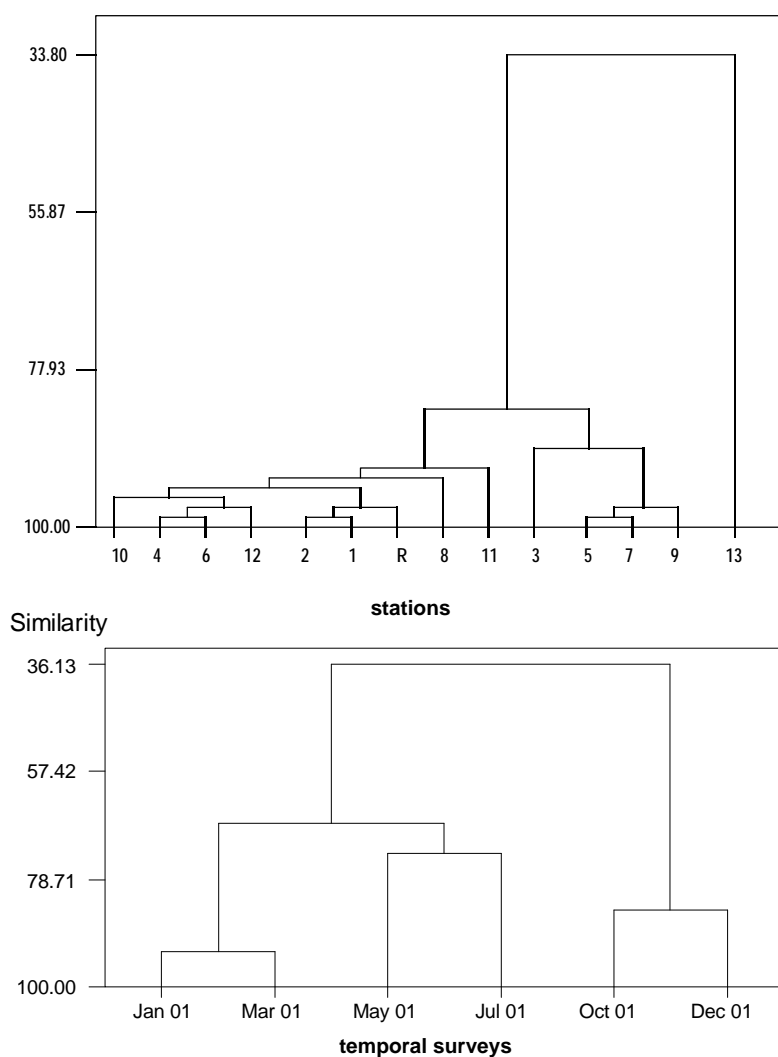
The second cluster group (stations 3,5,7,9) was located in the inner part of the bay and is only slightly influenced by freshwater discharge and harbour water. It is characterized by moderate values of nutrients, phytoplankton abundance, phytoplankton biomass and other environmental variables.

The third group consists of stations which were influenced by river run off such as the river mouth, stations 1 and 2, with own common characterisation such as high nutrients, high turbidity, low Secchi depth, and low phytoplankton biomass and abundance.

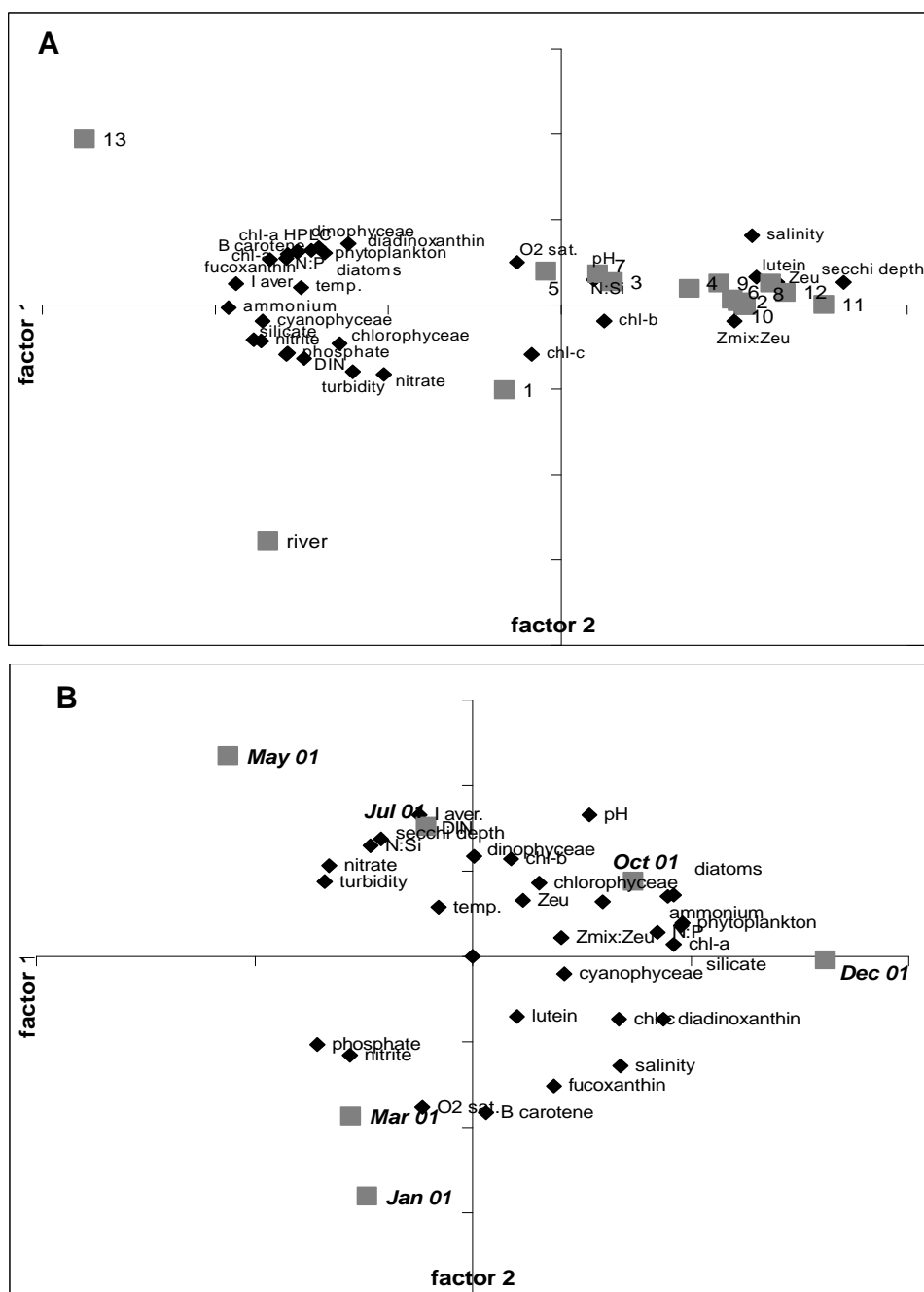
The last group consists of the stations which were located in the middle and outer parts of the bay. This group typically exhibited low nutrient concentrations, low phytoplankton biomass, low algal pigments, low turbidity, high salinity, high Secchi depth and high  $Z_{mix}:Z_{eu}$ .

Temporal variation (Fig. 3.33.B. and Fig.3.33.B.) shows the occurrence of three distinct periods throughout the year. The first consists of January and March 2001, the second of May and July 2001 and the third of October and December 2001.

Biplot PCA analysis (Fig.5.34.) showed that January and March 2001 were characterized by elevated phosphate and nitrite levels. May and July 2001 were typically high in nitrate, while October and December 2001 featured high ammonium and silicate concentrations. These results are in keeping with the seasonal variability of nutrient loads from the Semangka River.



**Fig. 5.33.** Cluster diagram of station (upper) and temporal surveys (lower) calculated based on 32 variables in Semangka Bay. R=river mouth ; 13=town harbour waters.



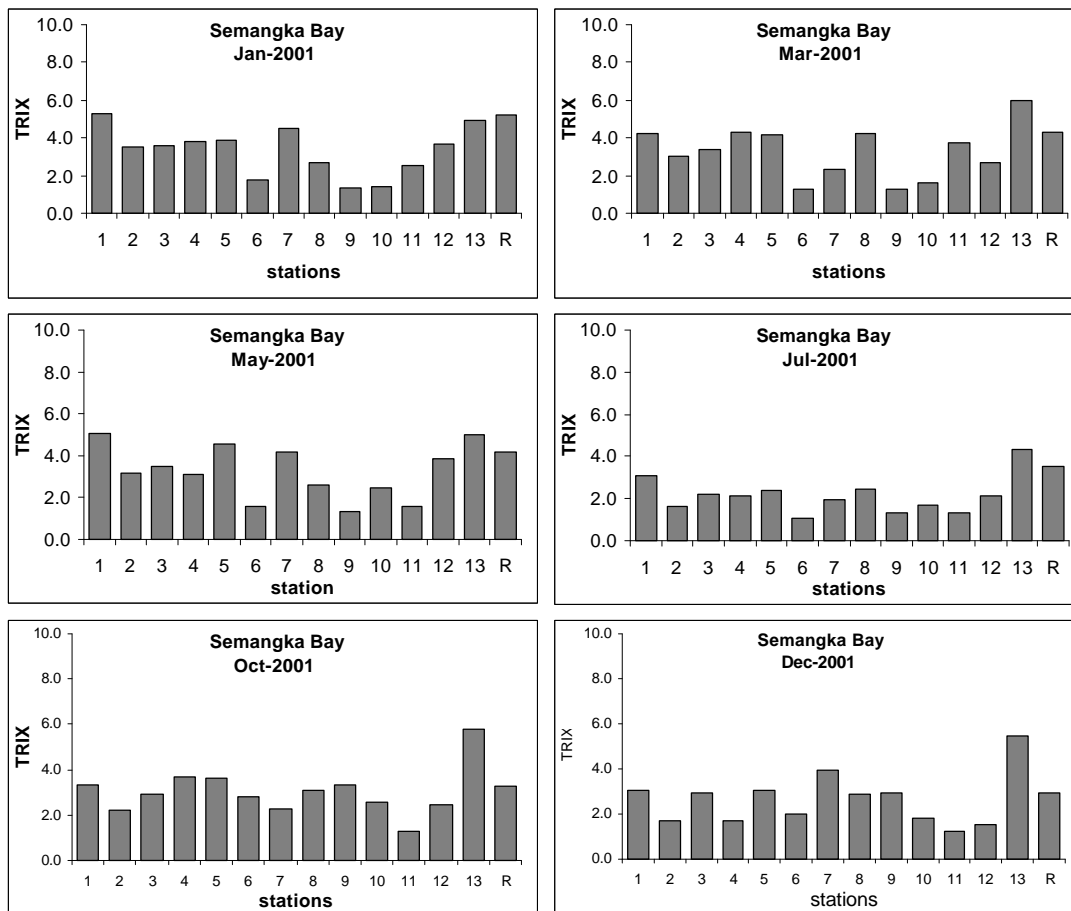
**Fig. 5.34.** Biplot of principal component analysis of all 32 environmental variables calculated based on stations as object (A) and time of sampling as object (B) in Semangka Bay.

### 5.1.11. Trophic states of Semangka Bay

TRIX calculations for all temporal surveys are shown in Fig.5.35, while Fig.5.36. shows the TRIX average values of spatial and temporal scales. Spatial variation showed that station 13 was high at each temporal survey (>6.0 in October and December 2001) and has to be classified as eutrophic throughout the year. Other sites were relatively low (<4), showing that those sites had a mesotrophic state. The outer part sites (stations 10,11 and 12) had generally low TRIX indices (<2) at almost at all temporal surveys, thus reflecting oligotrophic waters featured by low phytoplankton biomass and primary production levels.



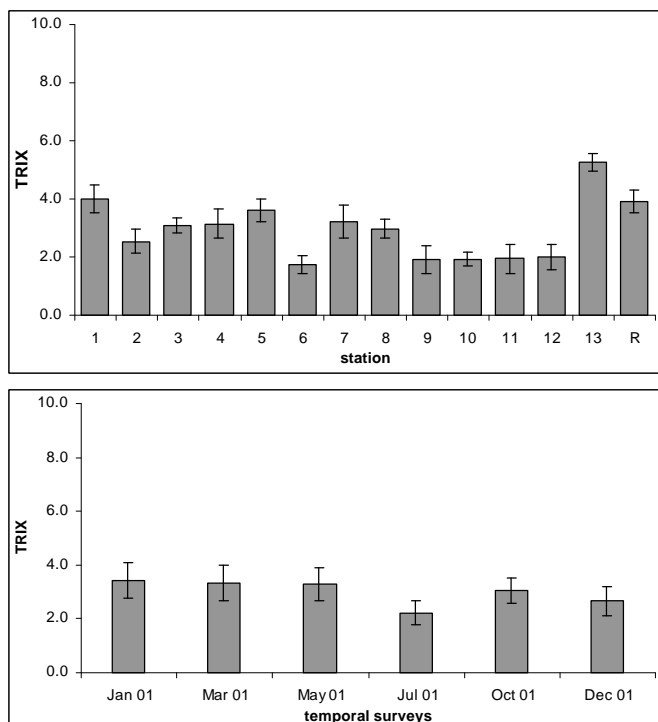
On a temporal basis, July 2001 was the lowest temporal average of TRIX, while January 2001 was the highest. Other temporal surveys have a relatively similar average TRIX values.



**Fig. 5.35.** TRIX for each measurement time in Semangka Bay. R = Semangka river mouth.

**Fig.5.36.**

Average TRIX values in spatial (upper graph) and temporal (lower graph) scales in Semangka Bay. R=Semangka river mouth. Bars are standard deviations.



## 5.2. Discussion on Semangka Bay

The combined results show that there are 4 different regimes with distinct ecological properties in Semangka Bay, which are : (1) the town harbour waters (2) the inner part of the bay, which are subjected to coastal and harbour influences (3) the inner part of the bay, which is subjected to direct riverine inputs and (4) the middle and outer parts of the bay, which are influenced by advection of the Indian Ocean waters. In the following, the abiotic and biotic features of these different regimes are briefly discussed.

### 5.2.1. Parameters related to underwater irradiance

Different to Jakarta and Lampung bays, the whole water column of Semangka Bay is not always homogeneously mixed, but exhibits a thermocline in its deeper region at a depth of about 60 to 150 m (Hendiarti, pers.comm.). Because the present study is restricted to the near-surface water column, a vertical resolution of the stratified water column needs to be performed in the future, in order to elaborate a sound balance of nutrient loads and the resulting responses of the system. As it is the case for the 2 other bays, a limited area encompassing the river mouth and the plume were always characterised by high turbidity levels. At the immediate seaward sites, however, turbidity steeply decreases, thus allowing for a much deeper euphotic depth.

In the harbour waters, the  $Z_{\text{mix}}:Z_{\text{eu}}$  ratio was lowest (around 1), which is mostly due to the relatively small water depth and a reduced turbidity, representing adequate light availability for phytoplankton growth.  $Z_{\text{mix}}:Z_{\text{eu}}$  ratios were high (>3) at the vicinity of the Semangka river inflow and at the surrounding sites, showing unfavourable light conditions for phytoplankton net production. This high ratio in spite of a shallow water depth, was mostly due to low  $Z_{\text{eu}}$ . Inner part of the bay, where river influence and turbidity are less, by a rather high water depth (around 50 m), resulting in an increase of  $Z_{\text{mix}}:Z_{\text{eu}}$  ratios (ranging from 1 to 2). In the middle and outer parts of the bay, these ratios remained high (around 3), due to the deep water column, and thus reduced light availability for net production of phytoplankton prevailed.

### 5.2.2. Nutrient concentrations and their loads from the river

DIN loads to the bay were mostly in the form of nitrate rather than ammonium, reflecting the dominance of nitrification process in the river system. Another direct source of nitrate might be from the application of mineral fertilizer in the agricultural areas. Semangka River is not passing big human settlements, but it flows through an agricultural area (rice fields) and small villages, the latter of which discharge untreated organic waste water. The organic nitrogen compounds are remineralized to ammonium, and under adequate oxygen conditions, are oxydized to nitrate. However, Semangka River is not the only nutrient source for the bay. The town harbour of Kota Agung represents another source of nutrients. At this site, a set of sewage canals enter the harbour, facilitating the transport of untreated town sewage. This discharge is amplified by emissions from the fish processing activities in the harbour area, discharging particulate and dissolved organic waste water. Quantification of these diffused nutrient inputs is rather difficult but its importance can be traced from the high nutrient concentrations in the harbour waters.

On a seasonal basis, DIN and silicate concentrations in the bay were higher during the rainy season than in the dry season, which is mostly caused by the increase of riverine loads. During the rainy season, silicate concentration in the river increases, which might be related to the more intense wash out and soil erosion in the upland-terrestrial system and the increased of river flow, which reduces silicate uptake in the upstream. At the same time, ammonium load and concentration also increase, which might be related to an increased flushing of remineralisation products from anthropogenic sewage from the minor settlements around the river, as well as due to a reduced nitrification activity as a results of high river flows. Compared to Jakarta and Lampung bays, nutrient loads in Semangka Bay were lower, except for silicate, the load of which was higher than of Lampung Bay.

The spatial pattern of nutrient concentrations in Semangka Bay showed high values in the vicinity of the Semangka River and the town-harbour waters, and much lower levels in the more offshore waters. This nutrient decrease might be caused by dilution with offshore water, which is less in nutrient concentrations or due to a rapid uptake by phytoplankton. Upward transport of nutrients from bottom waters seems to play a minor role in the stratified water column. There was no indication of upwelling in the area.

Phosphate, DIN and silicate concentrations in Semangka Bay are relatively lower than those of Lampung and Jakarta bays, especially for phosphate and DIN. However, silicate was well distributed throughout the bay, reflecting the influence of the Semangka river as the main source of silicate.

The influence of the Indian Ocean waters masses could be observed predominantly during the rainy season, resulting in reduced nutrient concentrations in the middle and outer parts of the bay. By contrast, during the dry season, a nutrient rich water masses from the Sunda Strait are entering the bay, resulting in slightly higher nutrient levels in the area.

It can be concluded that the spatial and temporal nutrient dynamics in Semangka Bay are a combined result of riverine input, human activities in the Kota Agung town and harbour, and of the water masses from the Indian Ocean during the rainy season and from the Sunda Strait during the dry season.

### 5.2.3. Phytoplankton biomass and community

Semangka Bay's chlorophyll *a* levels seem to be comparable with those of the tropical oceanic system (e.g. the Banda Sea in the eastern Indonesia). In the upper layer of the Banda Sea, chlorophyll *a* was extremely low ( $<0.5 \mu\text{g Chl } a \text{ l}^{-1}$ ), which is a typical feature of the upper mixed layer of a stratified oceanic water column in the tropics, where the stable of thermocline cut off nutrient supply from deeper water (Gieskes *et al.*, 1988).

In Semangka Bay, highest phytoplankton biomass prevailed at the town harbour waters, while lowest biomass were found in the middle and outer parts of the bay. In the town harbour waters, the adequate nutrient and better light availability (low  $Z_{\text{mix}}:Z_{\text{eu}}$ ) promote better phytoplankton biomass formation. By contrast, the river water is low in phytoplankton biomass, in spite of the non-limiting nutrients levels. Here and in the river-influence sites, poor light conditions due to a high turbidity limit phytoplankton growth. The other regimes in the bay were characterized by a low phytoplankton biomass ( $< 1 \mu\text{g}$

Chl  $a$   $l^{-1}$ ), which is in line with their low nutrient concentrations and the high  $Z_{mix}:Z_{eu}$  ratios. This in general reflects that phytoplankton development is likely a resource controlled system (bottom-up).

The grazing capacity of zooplankton was not specifically investigated in this study, but it can be approached through the abundance of zooplankton groups. In general, zooplankton abundances were moderate, with the marine copepod *Acartia* sp. and *Paracalanus* sp. dominating the community. The importance of macrozoobenthos grazing is limited, since the benthic zone in Semangka Bay is cut off from the upper layer, except at shallow sites, close to the river mouth and at the town harbour waters. However, in those possible benthic-grazing sites, there was no indication of filter feeder mollusc occurrence.

Domination of diatoms in Semangka Bay's phytoplankton communities seems to be closely related to the low N and P levels relative to the high silicate availability (Margalef, 1978). This is in conformity with Gieskes *et al.* (1988), which stated that diatoms are a predominant phytoplankton group generally encountered in the Indonesian ocean surface-oligotrophic region (Gieskes *et al.*, 1988). In town harbour waters, the occurrence of dinoflagellates and chlorophyceae increased, which might be caused by the more stagnant water column.

In general, phytoplankton abundance in Semangka Bay was much lower ( $< 500\ 000$  cells  $l^{-1}$ ) than in Jakarta and Lampung bays. This again reflects the strong links between nutrient availability and phytoplankton abundance.

#### 5.2.4. Planktonic primary production

Estimates of annual primary production ranged from 14 to 40 g C  $m^{-2} y^{-1}$ . Thus, with regards to the trophic classification of coastal ecosystems (Nixon, 1995), Semangka Bay can be classified as an oligotrophic system (below 100 g C  $m^{-2} y^{-1}$ ). When compared to Jakarta and Lampung bays, the annual production of Semangka Bay was lower. Contrary to the other two bays, planktonic primary production in the nutrient rich river plume was lower than that of the offshore sites, which is supposed to be caused by strong light limitation, due to a higher suspension load of the river and deeper mixed layer.

The spatial pattern of the maximal rate of photosynthetic ( $P_{max}^B$ ) and the photosynthetic efficiency ( $\alpha^B$ ) followed that of phytoplankton biomass, with lower rate in the river plume. In general, these rates were lower than those of Jakarta and Lampung bays, reflecting the comparably low nutrient supply of the area.

The high  $E_k$  values indicate the acclimatisation of the phytoplankton community in Semangka Bay to high light intensities, and underline the importance of nutrient resource for primary production in the area.

As a conclusion, the low nutrient waters of Semangka Bay seem unable to sustain high primary production across the seasons. A sufficient nutrient supply at the river mouths and surroundings is counteracted by strong light limitation, resulting in low primary production. The only site in the bay with an elevated primary production is supposed to be the harbour water of Kota Agung town, where maximum phytoplankton biomass levels were observed. Unfortunately, this site was not incorporated in the primary production

measurements of this study. Further study on the factors controlling primary production in the area should involve this special case.

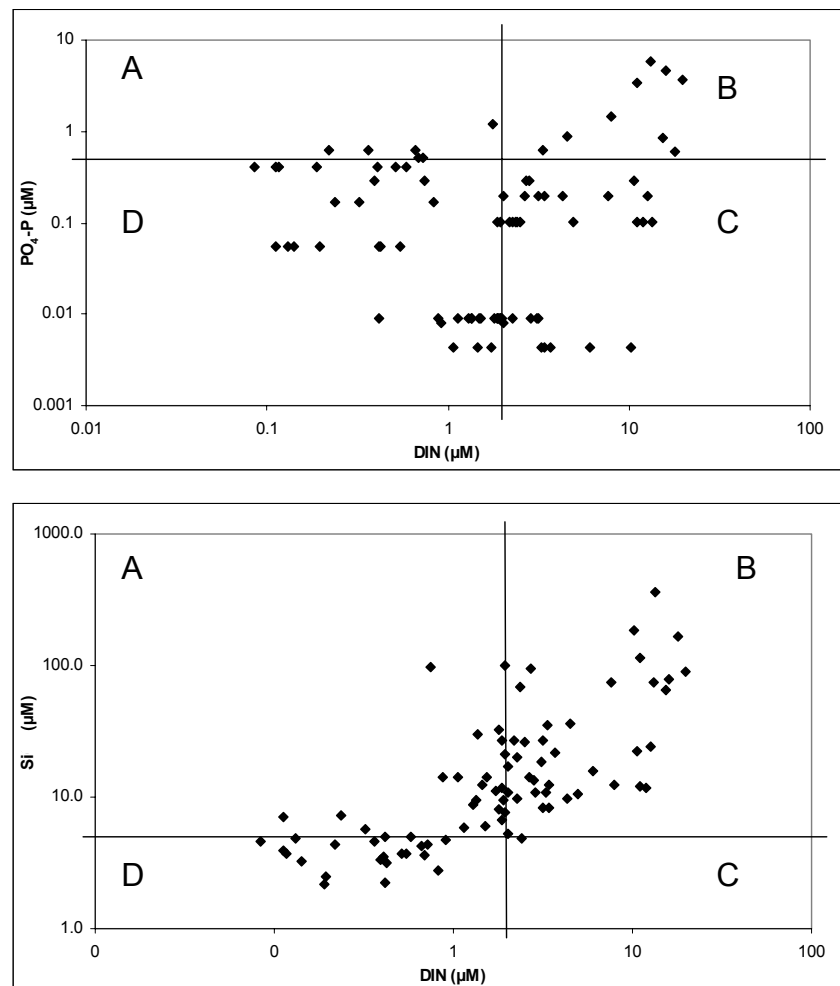
### 5.2.5. Nutrient limitation on phytoplankton growth

In order to get an idea of the potentially limiting role of the different nutrient species, a combination of techniques such as comparison of molar ratios and nutrient threshold values was used. In Semangka Bay, DIN:P ratios showed low values in the vicinity of the Semangka River and in the harbour waters ( $< 15$ ), while at the other sites, they generally exceeded 15 during the rainy season, and were below 15 during the dry season. This was mostly caused by change in the pattern of nutrient loads from the incoming river, which is high in phosphate loads during the dry season and ammonium during the rainy season. Diatoms which dominate the phytoplankton community get advantage from an increase of DIN:P ratios. Diatoms are a good indicator of N and Si sufficiency (Gieskes *et al.*, 1988 ; Cloern, 2001).

The ratio of DIN to silicate was low at almost all stations and during all temporal surveys ( $< 1.0$ ). Comparison with the respective Redfield number suggests a potential limitation of N relative to silicate in the study area. Silicate seems to be always sufficient in the bay throughout the year, as shown by high silicate concentrations, exceeding the threshold for phytoplankton growth ( $>5 \mu\text{M}$ ). River discharge seems to be a continuous source of silicate for the bay.

The dry season was characterized by low DIN concentrations, below the threshold value for nitrogen limitation. By contrast, phosphate levels were below the threshold value during the rainy season.

An exception were stations in the river mouth and the town harbour. Concentrations at these



**Fig.5.37.** Plot of DIN and PO<sub>4</sub> (above) and DIN and silicate (below) against nutrient thresholds values taken from literature. The D area on each figure defines the region for which nutrient concentrations are below half-saturation constants for nutrient uptake of natural phytoplankton populations, while the B area indicates the region where ambient nutrient concentrations are above these thresholds.

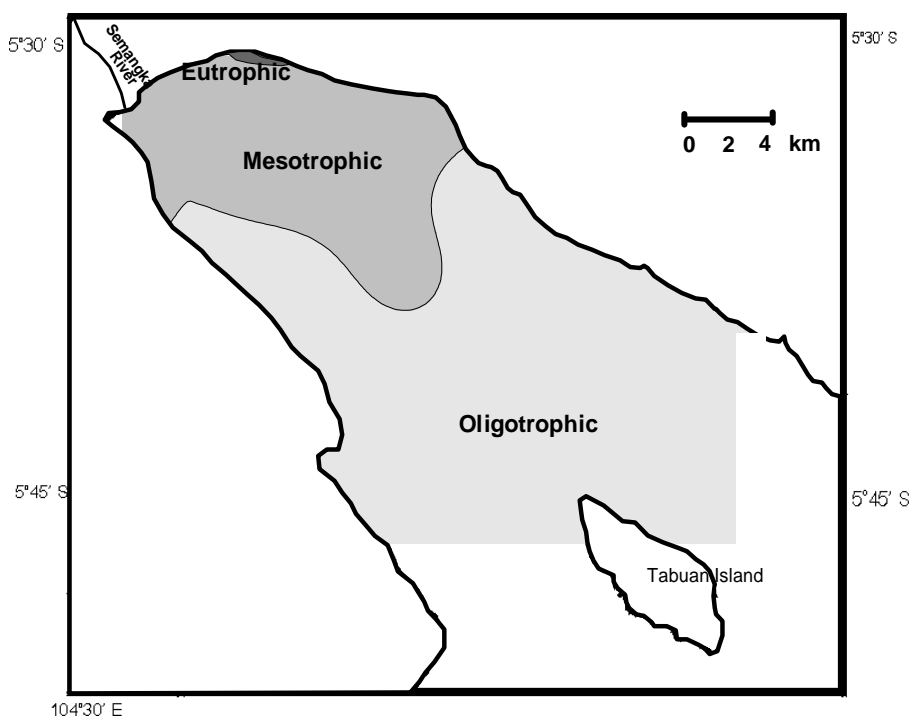
sites always exceeded threshold levels, and thus limitation is not likely to occur.

To conclude, in general, the phytoplankton growth in Semangka Bay is likely to be limited by phosphate during the rainy season and by nitrogen during the dry season.

### 5.2.6. Area zonation and trophic state of Semangka Bay

Calculation of TRIX resulted in 3 distinct trophic states of Semangka Bay (Fig 5.38), revealing that most of the bay (more than 50%) is oligotrophic. A mesotrophic state occurred in the inner part of the bay, while eutrophic levels occurred in the harbour waters only. This generally low trophic state was mostly due to a low nutrient supply from the land. Low human activities in its coastal area and the hinterland result in a more or less natural nitrification of Semangka Bay. Moreover, the hydrography character of the bay, which is profoundly deep and characterised by a permanent water stratification over a large area, resulting in low nutrient levels in the upper mixed layer all over the year and, thus, low phytoplankton biomass. Anthropogenic nutrient inputs from fish processing activities in the harbour area are not continuously lasting all year around. Only during the month of November to December, intense fishery related activities occur in the harbour area. The influence of nutrient rich Sunda Strait waters seems to be of minor importance for the bay area and only prevails during the dry season. This is because Semangka Bay is situated relatively far away from the Java Sea as the main source of nutrient rich open water masses.

The situation in Semangka Bay seems to be comparable with an oceanic oligotrophic tropical system rather than with a typical shallow and nutrient-rich coastal water, which is especially due to its considerable water depth and to the relatively low nutrient loads from freshwater discharge.



**Fig.5.38.** Projection map of spatial trophic states of Semangka Bay waters calculated on the basis of TRIX (Caiaffa, 1999; Nixon, 1995).

## 6. General discussion

In this chapter, a comparison between Jakarta, Lampung and Semangka bays is presented, focusing on the differences in water column irradiance, nutrients (loads and concentrations), phytoplankton biomass, primary production and trophic state. At the end of this chapter, possible management approaches and an outlook for future research are given. Table 6.1. lists the annual average parameters which are related to underwater irradiance, nutrient loads and concentrations, phytoplankton biomass and production, phytoplankton abundance and group composition and trophic state of each bay studied. Moreover, Fig.6.1 to 6.4. show a comparison between the bays for the annual average nutrient concentrations, phytoplankton biomass, primary production and a seasonal comparison of the nutrient species and phytoplankton biomass.

**Table 6.1.** Comparison between bays for the main parameters.

Parameters	Units	Jakarta Bay	Lampung Bay	Semangka Bay
<b>parameters related to underwater irradiance</b>				
- Secchi depth **	m	2.8 ± 2.1	8.6 ± 5.1	9.4 ± 5.9
- turbidity *	NTU	4.9 ± 7.6	2.2 ± 4.4	2.8 ± 9.9
- $Z_{mix}:Z_{eu}$ *	-	1.4 ± 0.6	1.5 ± 0.4	2.9 ± 1.8
<b>nutrient loads</b>				
- phosphate **	$t y^{-1}$	6 741	1 096	419
- DIN **	$t y^{-1}$	21 260	5 003	1 378
- silicate **	$t y^{-1}$	52 417	14 731	16 449
<b>nutrient concentrations</b>				
- phosphate **	$\mu M$	5.08 ± 11.73	2.32 ± 6.32	0.40 ± 0.95
- DIN **	$\mu M$	20.11 ± 36.88	14.29 ± 42.27	3.54 ± 4.56
- silicate **	$\mu M$	44.80 ± 97.29	39.34 ± 90.59	28.45 ± 51.44
<b>nutrient ratios</b>				
DIN:P **	-	60.0 ± 106.2	38.4 ± 94.8	146.8 ± 332.3
DIN:Si **	-	0.9 ± 1.44	0.5 ± 0.6	0.2 ± 0.2
<b>mean phytoplankton biomass</b>				
inner part of the bay **	$\mu g Chl a l^{-1}$	15.8 ± 2.11	9.9 ± 3.30	0.6 ± 0.12
middle part of the bay **	$\mu g Chl a l^{-1}$	7.8 ± 2.20	1.3 ± 0.20	0.7 ± 0.40
outer part of the bay **	$\mu g Chl a l^{-1}$	2.2 ± 0.28	0.6 ± 0.06	0.4 ± 0.10
<b>annual planktonic primary production</b>				
inner part of the bay	$g C m^{-2} y^{-1}$	503.1	196.7	13.9
middle part of the bay	$g C m^{-2} y^{-1}$	119.1	40.1	39.9
outer part of the bay	$g C m^{-2} y^{-1}$	46.5	30.8	22.2
<b>phytoplankton</b>				
-abundance **	million cells $l^{-1}$	4.4 ± 3.5	0.9 ± 1.4	0.2 ± 0.2
-group dominance	-	diatoms, dinoflagellates	diatoms, dinoflagellates	diatoms
<b>trophic state</b>				
TRIX **	-	5.6 ± 2.0	4.7 ± 1.9	2.9 ± 1.2

note : mean ± standard deviation

\*\* = ANOVA, significantly different at  $p < 0.001$ ; \* =  $p < 0.05$ .

## 6.1. Parameters related to underwater irradiance

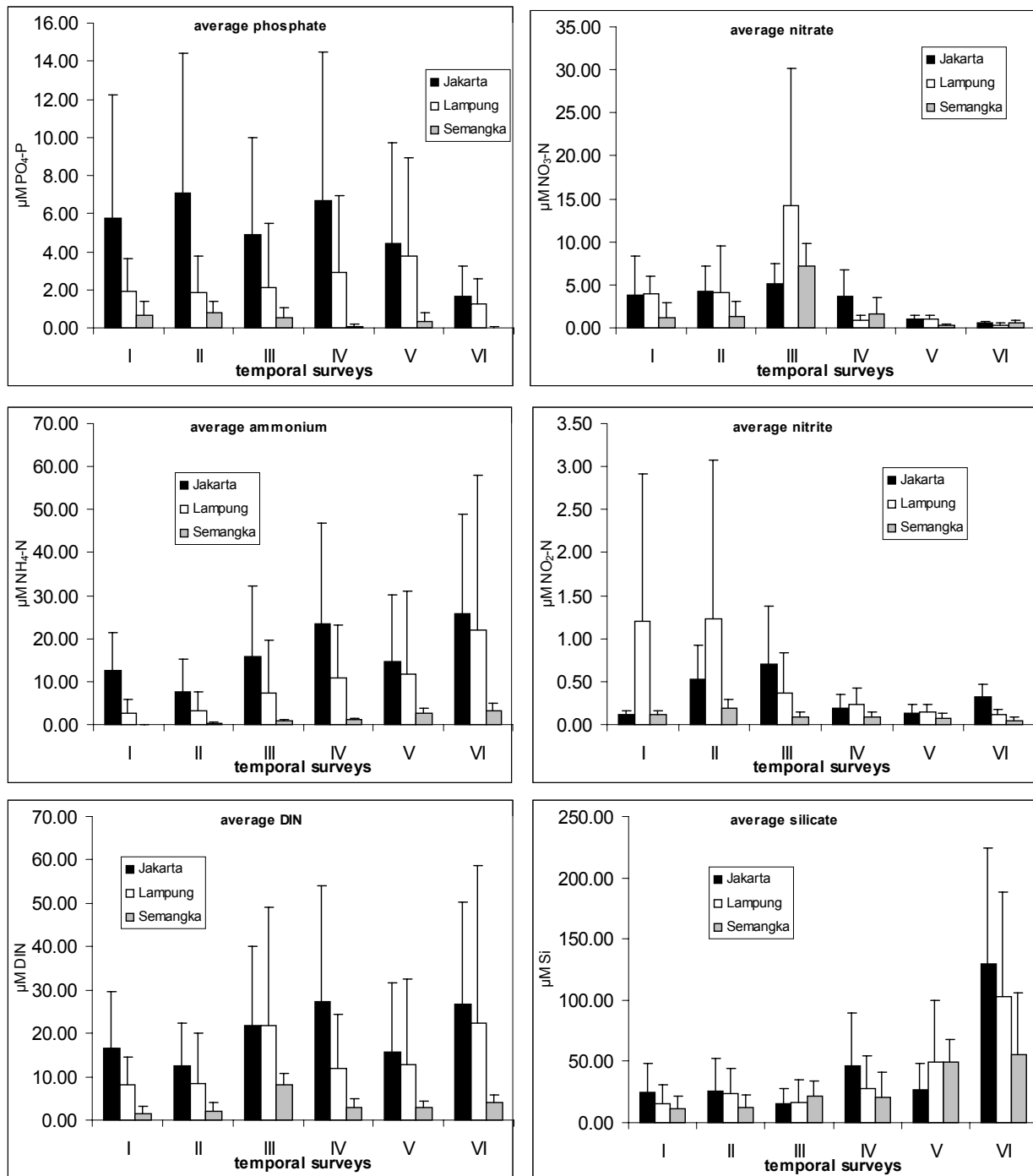
Comparison between bays shows that Jakarta Bay was the most turbid system among the 3 bays studied, which can be assessed from the significantly different annual average values of Secchi depth and turbidity (ANOVA,  $p < 0.001$ ) (Table 6.1.). Average of turbidity was by factor of 2 lower in Lampung and Semangka bays. In keeping with this, comparison between light and nutrient resources through Cloern's method (Cloern, 1999 ; Colijn and Cadée, 2003) also revealed that in Lampung Bay and even more in Semangka Bay, phytoplankton growth was more limited by nutrients than by light, except in the river mouths and its surrounding sites, because of the good light penetration into the water column. However, the light availability for phytoplankton as expressed by the  $Z_{\text{mix}}:Z_{\text{eu}}$  ratio was better in Jakarta and Lampung bays than in Semangka Bay. This is mainly caused by the shallower water depth of Jakarta and Lampung bays compared to Semangka Bay, causing a low  $Z_{\text{mix}}$ , and therefore a low ratio of  $Z_{\text{mix}}:Z_{\text{eu}}$ . A low ratio means that the average time spent by the phytoplankton cells in the illuminated water column increases, thus enabling a higher net photosynthesis.

In all bays studied, the spatial pattern of light availability for phytoplankton growth was relatively similar, showing better conditions in the inshore waters than in the offshore waters. The optimum zone for photosynthesis was close to the river plume, where water depth was still relatively small and turbidity decreased. This phenomenon of adequate growth condition for phytoplankton at river plume is a common feature for many other estuaries such as Pearl river estuary (Yin *et al.*, 2001) and Elbe river plume (Hesse *et al.*, 1995). In the offshore waters turbidity was much less, however, water column light availability was counteracted by the increase of water depth, resulting in a significant increase of  $Z_{\text{mix}}:Z_{\text{eu}}$  ratios.

## 6.2. Nutrient loads and concentrations

In keeping with the strong differences in human activities, Jakarta Bay receives a higher nutrient load than the two other bays, while Semangka Bay receives the lowest load (Table 6.1) (ANOVA,  $p < 0.001$ ). Consequently, annual averages of nutrient concentrations were higher in Jakarta Bay than in Lampung and Semangka bays, except for nitrate and nitrite levels, which were not significantly different (ANOVA,  $p < 0.01$ ). Relatively high nitrate and nitrite concentrations in Lampung Bay are supposed to be caused by the more intense agricultural activities during the dry period through the intense use of nitrate fertiliser. In addition, better oxygen conditions in the water may allow for a more intense conversion of ammonium to nitrite and nitrate. However, taken the sum of the dissolved inorganic nitrogen species (DIN), average DIN levels in Jakarta Bay were significantly higher than in the 2 other bays.





Surveys I, V and VI : the rainy season  
 Surveys II, III and IV : the dry season

**Fig.6.1.** Comparison of seasonal average values of phosphate, nitrate, nitrite, ammonium, DIN and silicate between Jakarta, Lampung and Semangka bays. I = Dec'00-Jan'01 ; II = Feb'01-Mar'01 ; III = Apr'01-May'01 ; IV = Jul'01 ; V = Sep'01-Oct'01 and VI = Nov'01-Dec'01. Bars are standard deviations calculated from 15 data (Jakarta Bay), 17 data (Lampung Bay) and 14 data (Semangka Bay). (Note : different scales in figures).

If the annual mean values of DIN and phosphate concentrations are compared to other tropical coastal areas subjected to human activities such as the Singapore Strait and the Johor Strait (Singapore), those of Jakarta Bay are higher, while those of Lampung and Semangka bays are lower. In the Singapore Strait, annual mean DIN and phosphate values were 3.6  $\mu\text{M N}$  and 0.3  $\mu\text{M PO}_4\text{-P}$ , respectively, whereas in the Johor Strait they accounted for 17.4  $\mu\text{M N}$  and 1.4  $\mu\text{M PO}_4\text{-P}$ , respectively (Gin *et al.*, 2000). These relatively low levels of nutrient concentrations in Singapore Strait is a result of the intense waste water treatment in the Singapore area and the high flushing rates of the system (Gin *et al.*, 2000). However, the situation in Jakarta Bay is less severe than that in the tropical Guanabara Bay (Brazil), which is hugely affected by the domestic waste water of around 11 million inhabitants from the city of Rio de Janeiro, which lacks any substantial sewage treatment. In the Guanabara Bay, the annual mean of DIN and phosphate were 56.9  $\mu\text{M}$  and 6.23  $\mu\text{M}$ , which are 3 and 1.5 times higher than those of Jakarta Bay, respectively (Ribeiro and Kjerfve, 2002).

Whereas phosphate concentrations were relatively stable along the year in Lampung and Semangka bays, in Jakarta Bay phosphate levels decreased by more than a factor of two during the rainy season (Fig.6.1.). This is caused by a decrease in the phosphate load during the rainy season which is likely to be due to the less intense agriculture in the area. Nitrate increased during the dry season in all bays. Especially in Lampung and Semangka bays, this may be due to the intense use of fertiliser in the rice-field cultures, contributing some nitrate from fertiliser leakage. DIN and silicate concentrations show similar patterns in all bays, with higher values during the rainy season. This is in keeping with the higher discharge of rivers, which transports a higher amount of the untreated waste water from the urban settlements. During the rainy season, in all bays studied, the loads of ammonium and silicate were strongly increased.

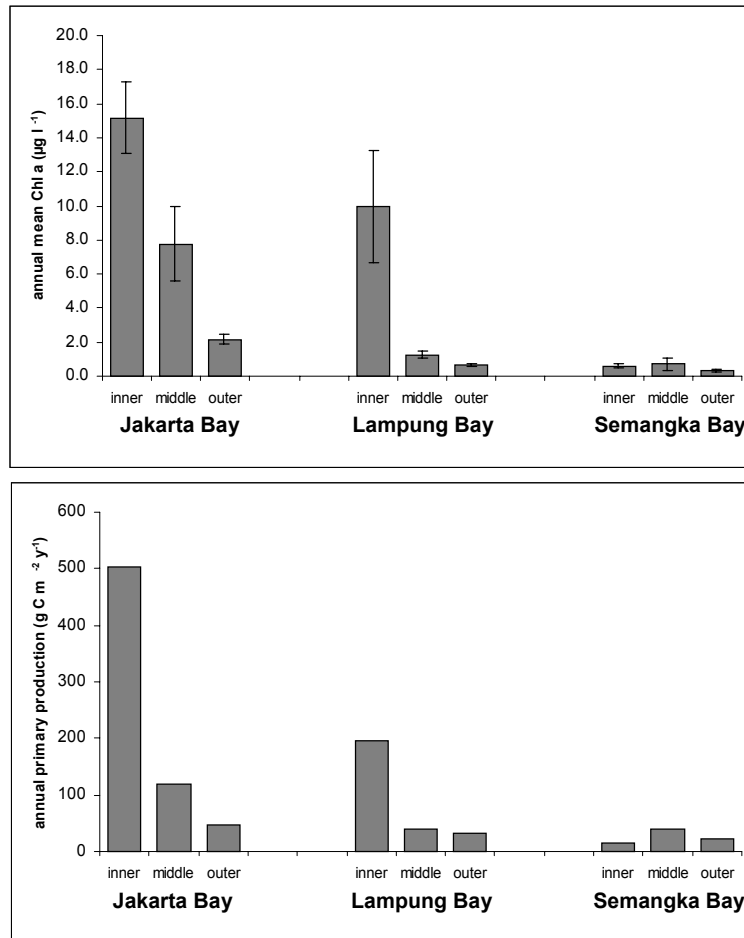
The higher average nutrient concentrations in Jakarta Bay may result in differences of phytoplankton biomass and primary production between the bays, which are discussed in the following chapter.

### **6.3. Phytoplankton biomass and production : response to differences in nutrient loads and concentrations**

Strong differences in phytoplankton biomass and production among the 3 bays studied can be clearly observed, with Jakarta Bay as the most productive bay, followed by Lampung Bay, and finally by Semangka Bay exhibiting the lowest values (Fig. 6.2.). Phytoplankton biomass in Jakarta Bay is lower than that of tropical Johor Strait waters (21.5  $\mu\text{g Chl } a \text{ l}^{-1}$ ), in spite of higher nutrient concentrations, but higher than that of Singapore Strait waters (1.7  $\mu\text{g Chl } a \text{ l}^{-1}$ ) (Gin *et al.*, 2000). The high chlorophyll *a* concentration in Johor Strait is suggested to be due to the relatively poor water exchange, which supports phytoplankton biomass accumulation (Gin *et al.*, 2000). However, the middle and outer parts of Lampung Bay and the whole of Semangka Bay are lower in phytoplankton biomass than Singapore Strait, which is consistent with their lower nutrient availability. The hypertrophic Guanabara Bay in Brazil shows much higher mean chlorophyll *a* values than Jakarta Bay. In this hypertrophic estuary, the annual mean chlorophyll *a* were extremely high in the inner part of the bay (98.7  $\mu\text{g Chl } a \text{ l}^{-1}$ ), decreased to 58.5  $\mu\text{g Chl } a \text{ l}^{-1}$  in the middle part and steeply decreased down to 24.5  $\mu\text{g Chl } a \text{ l}^{-1}$  in its outer part (Ribeiro and Kjerfve, 2002). The strong decrease of chlorophyll *a*

concentrations in the outer part of Guanabara Bay was caused by strong dilution with the lower chlorophyll *a* water masses of the Atlantic Ocean (Ribeiro and Kjerfve, 2002).

A distinct seasonal variation in chlorophyll *a* concentrations was common to all bays (Fig. 6.3). In Lampung Bay, elevated average chlorophyll *a* levels were observed during the



**Fig.6.2.** Comparison between different sites of Jakarta, Lampung and Semangka bays in the annual mean values of chlorophyll *a* (upper graph) and annual primary production (lower graph). Bars are standard deviations (upper graph).

dry period, whereas in Jakarta Bay, highest averages occurred during the rainy season. These discrepancies are closely related to the increase of nitrogen concentrations in the outer part of Lampung Bay during the dry period due to the possible nitrate input from the Sunda Strait, whereas Jakarta Bay receives a significant increase of nitrogen loads from the land during the rainy period.

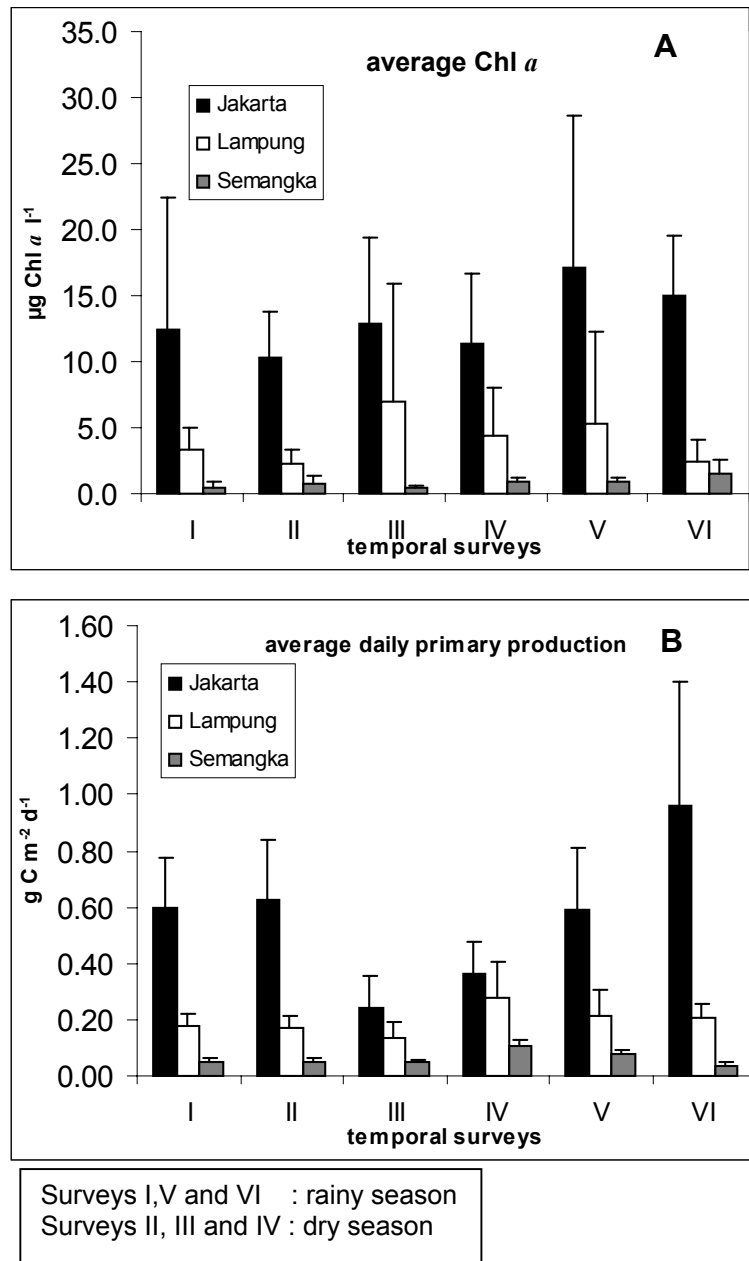
If the annual averages of chlorophyll *a* are compared with those in temperate coastal ecosystems, those of the inner waters of Jakarta Bay are similar, while those of middle and outer parts of the Jakarta Bay and the whole parts of Lampung and Semangka bays are lower. In the Marsdiep (the Netherlands), annual average chlorophyll *a* was  $12 \mu\text{g Chl } a \text{ l}^{-1}$  in 1986 (Cadée and Hegeman, 2002) and in the German Wadden Sea around  $15 \mu\text{g Chl } a \text{ l}^{-1}$  in 1996 (Tillmann *et al.*, 2000). However, the seasonal variation of chlorophyll *a* concentrations in these temperate waters are high, ranging from below  $0.1 \mu\text{g Chl } a \text{ l}^{-1}$  in winter and  $70 \mu\text{g Chl } a \text{ l}^{-1}$  in spring (Tillmann *et al.*, 2000). Comparison with the spring temperate values of chlorophyll *a*, these three bays results are lower. In the Colne

Estuary (England), average phytoplankton biomass ranged from  $0.5 \mu\text{g Chl } a \text{ l}^{-1}$  in March to  $37.5 \mu\text{g Chl } a \text{ l}^{-1}$  in July (Kocum *et al.*, 2002). Generally, spring blooms in temperate waters with low turbidity and high winter nutrient concentrations, reach higher maximal phytoplankton values than in tropical coastal waters.

Seasonal and spatial variation of primary production was mainly due to the varying nutrient loads from the rivers, and showed relatively high values during the rainy season, especially in Jakarta Bay. Spatial patterns generally reveal a high production zone in the inshore waters, and a low production in the offshore waters. However, in Semangka Bay, primary production was lower in the river plume than in the middle part of the bay, due to strong light limitation (see chapter 5.2).

Comparison of the annual primary production estimates of this study with those of other tropical coastal waters (Table 6.2) showed that the inner and middle parts of Jakarta Bay and the inner part of Lampung Bay are comparable with that of Delta Upang (Indonesia), while the middle and outer parts of Lampung Bay and the whole parts of Semangka Bay are lower than those of other tropical coastal areas in annual primary production. In the Lingayen Bay (the Philippines), which is subjected to a moderate anthropogenic nutrient enrichment from the land (McManus *et al.*, 2001), the annual primary production estimates ranged from  $93 \text{ g C m}^{-2} \text{ y}^{-1}$  in the outer part of the bay to  $167 \text{ g C m}^{-2} \text{ y}^{-1}$  in the inner part of the bay.

Comparison of the annual production estimates with world wide primary production values collected by Boynton *et al.* (1982) showed that the inner part of Jakarta Bay values are at the upper end of the range, while the middle and outer parts of Jakarta Bay are at the middle and lower ends, respectively. Annual primary production estimates of the inner part of Lampung Bay is at the middle of the range, while those of



**Fig.6.3.** Comparison between Jakarta, Lampung and Semangka bays in the seasonal average values of chlorophyll  $a$  (A) and daily primary production (B). I = Dec'00-Jan'01 ; II = Feb'01-Mar'01 ; III = Apr'01-May'01 ; IV = Jul'01 ; V = Sep'01-Oct'01 and VI = Nov'01-Dec'01. Bars are standard deviations.

the middle and outer parts of Lampung Bay as well as the whole parts of Semangka Bay are at the lower end. Boynton's primary production range for all marine planktonic systems worldwide is from around  $12 \text{ g C m}^{-2} \text{ y}^{-1}$  to  $520 \text{ g C m}^{-2} \text{ y}^{-1}$ .

**Table 6.2.** Annual phytoplankton primary production estimates of some tropical and temperate estuaries or coastal areas, including this study.

Area	Annual production ( $\text{g C m}^{-2} \text{ y}^{-1}$ )	Method	Source
<b>Tropical</b>			
<b>Lingayen Bay (the Phillipines) 1997-1999</b>			
- offshore part	93	$\text{O}_2$	McManus <i>et al.</i> (2001)
- inner part (Bolinao)	167	$\text{O}_2$	McManus <i>et al.</i> (2001)
<b>Delta Upang (Sumatera, Indonesia) 1975*</b>	240	$\text{O}_2$	Kaswadji (1976)
<b>Mallaca Strait, Indonesia, 1980</b>	90	$\text{O}_2$	Praseno (1980)
<b>Lampung Bay (Indonesia)</b>			
- inner part (Hurun coast) 1999 *	70	$\text{O}_2$	Tambaru (2000)
- inner part (Hurun coast) 2000 *	152	$\text{O}_2$	Sunarto (2001)
- inner part 2000-2001	196	$^{14}\text{C}$	this study
- middle part 2000-2001	40	$^{14}\text{C}$	this study
- outer part 2000-2001	31	$^{14}\text{C}$	this study
<b>Jakarta Bay (Indonesia)</b>			
- inner part 1983 *	301	$\text{O}_2$	Nontji (1984)
- inner part 1991 *	166 – 214	$\text{O}_2$	Kaswadji <i>et al.</i> (1993)
- inner part 2000-2001	503	$^{14}\text{C}$	this study
- middle part 1983 *	49	$\text{O}_2$	Nontji (1984)
- middle part 1983 *	55	$\text{O}_2$	Nontji (1984)
- middle part 2000-2001	119	$^{14}\text{C}$	this study
- outer part 2000-2001	47	$^{14}\text{C}$	this study
<b>Semangka Bay</b>			
- inner part (river plume) 2000-2001	14	$^{14}\text{C}$	this study
- middle part 2000-2001	40	$^{14}\text{C}$	this study
- outer part 2000-2001	22	$^{14}\text{C}$	this study
<b>Temperate</b>			
<b>Büsum, Wadden Sea 1995 and 1996</b>	124 and 176	$^{14}\text{C}$	Tillmann <i>et al.</i> (2000)
<b>Ems Dollard (1976-1980)</b>			
- inner part	70	$^{14}\text{C}$	Colijn (1983)
- middle part	91	$^{14}\text{C}$	Colijn (1983)
- outer part	283	$^{14}\text{C}$	Colijn (1983)
<b>Marsdiep area</b>			
- 1974-1975	145	$^{14}\text{C}$	Cadée and Hegeman (1979)
- 1981-1992	250-390	$^{14}\text{C}$	Cadée and Hegeman (2002)
<b>German Bight 1988-1989</b>	261	$^{14}\text{C}$	Joint and Pomroy (1993)

\* = recalculated into integrated water column primary production value by using the average depth of the area.

If the annual primary production estimates of this study are compared with those in eutrophied temperate coastal ecosystems such as the Wadden Sea, the inner part of Jakarta and Lampung bays exhibit slightly higher production levels, whereas the middle and outer parts of Lampung Bay and the whole area of Semangka Bay are less productive (Table 6.2). However, as for chlorophyll *a*, seasonal variation in tropical coastal ecosystems is much lower than in temperate ones. In the German Wadden Sea (Tillmann *et al.*, 2000), the annual phytoplankton primary production estimates accounted for 124 and 176  $\text{g C m}^{-2} \text{ y}^{-1}$  (1995 and 1996, respectively), with a large seasonal variation, ranging from the very low value in winter ( $0.005 \text{ g C m}^{-2} \text{ d}^{-1}$ ) to maximum values during the spring bloom ( $2.2 \text{ g C m}^{-2} \text{ d}^{-1}$ ). A similar seasonal variability prevails in the eutrophied western

Wadden Sea (Marsdiep) (Cadée and Hegeman, 1979). Here, annual primary production accounted for 145 and 135 g C m<sup>-2</sup> y<sup>-1</sup> for 1974 and 1975, respectively. As for chlorophyll *a*, the relatively low seasonal fluctuation of the tropical primary production shows the less importance of light resource in regulating the phytoplankton development compared to the temperate region. In the temperate region, seasonal variation of light plays an important role in controlling the seasonal variation of phytoplankton production, while in the tropical area, the always constant light throughout the year continuously support phytoplankton development. Considering the steady light supply in tropical systems, effects of anthropogenic nutrient enrichment may be much more severe and clear than in temperate regions.

Accordingly, the relation between nutrients and phytoplankton biomass and production in each bay were in line with the classical theory of nutrient - phytoplankton relationships (Margalef, 1978) : in all bays, phytoplankton biomass and production were high in the near-shore sites, then decreased in the offshore sites, which is commensurate with the decrease of nutrients. An exception was found in Semangka Bay, where the phytoplankton biomass was low in the nutrient rich river plume due to strong light limitation. In this bay, the highest phytoplankton biomass prevailed in the harbour waters, where nutrients and light were sufficiently available.

Comparison among the three bays studied shows that Jakarta Bay phytoplankton biomass was around 3-fold higher than that of Lampung Bay and 13-fold higher than that of Semangka Bay. This strong difference in phytoplankton biomass in the three bays shows the distinct phytoplankton response to nutrient enrichment. However, this response is not linear but site-specific, because it does not only depend on the magnitude of nutrient loads, but also on other local physical and biological factors. Lampung Bay seems to be more sensitive in the response of the phytoplankton to nutrient enrichment than the two other bays. The relatively low nutrient loads compared to those of Jakarta Bay (around 1:5), resulted in a relatively high phytoplankton biomass (around 1:3 compared to that of Jakarta Bay). This non-linear relationship between nutrient concentrations and phytoplankton biomass has been a major research item of coastal eutrophication research. Boynton *et al.* (1982) and Cloern (2001) collected a large amount of data on nutrients, phytoplankton biomass, and primary production from various estuaries all over the world, and concluded that only few of the commonly measured variables (such as nutrients) acted as significant predictors for phytoplankton biomass and production. In Boynton's review (Boynton *et al.*, 1982), 73% of the observed estuaries showed non significant correlation between nutrients and phytoplankton biomass, whereas only 18% were significantly correlated. This is supported by Cloern (2001), who came to a similar conclusion, after an evaluation of data from estuaries in north America and northern Europe. Some estuaries appear to be very sensitive in the response of phytoplankton to changes in nutrient inputs (e.g. Chesapeake Bay, Adriatic Sea, Baltic Sea, Black Sea, northern Gulf of Mexico), while others appear to have system attributes that reduce phytoplankton responses to nutrient enrichment (e.g. San Francisco Bay, Bay of Brest) (Cloern, 2001).

Cloern (2001) revealed that besides nutrient supply, there are at least 4 other factors that will either amplify or dampen the phytoplankton response on nutrient enrichment in a coastal water; those are : (1) tidal characteristics ; (2) horizontal transport; (3) optical (light) properties and (4) grazers. In the following paragraphs, these 4 factors, which

influence the response of phytoplankton to nutrient input in each bay are discussed in more detail.

The first factor is closely related to water movement. Difference in tidal type causes differences in physical turbulence and vertical mixing in the water column. Cloern (2001) showed that chlorophyll *a* concentrations in micro-tidal estuaries are about 10 times higher than in macro-tidal estuaries. He explained that the generation of turbulence by tidal stress is one of the mechanisms linked to macro-tidal conditions. Macro-tidal conditions also reduce the possibility of the occurrence of vertical stratification, which in turn will lead to an increase of the mixing depth and thus of the  $Z_{\text{mix}}:Z_{\text{eu}}$  ratio, hence to a reduced average light availability in the water column.

The second factor is horizontal transport, which determines the residence time of the water and the associated nutrients and plankton within coastal basins (Cloern, 2001). Although Jakarta Bay is a micro-tidal estuary (tidal range is around 0.90 m), which is smaller than that of Lampung Bay (1.46 m) and Semangka Bay (1.60 m), the water residence time is distinctly shorter (5 days), compared to Lampung Bay (15 days) and Semangka Bay (100 days) (Koropitan, pers. comm.). However, Jakarta Bay in spite of its shorter water residence time, seems still able to allow for the accumulation of phytoplankton biomass in its water column. Ortner and Dagg (1995) stated that accumulation of phytoplankton biomass will be limited, if the water residence time is shorter than the community growth rate. The result of nutrient addition experiment of this study showed that phytoplankton community growth rate in Jakarta Bay ranged from 0.12 to 0.48 per day. Thus, 5 days of water residence time seems adequate to support the growth of phytoplankton, which results in a high phytoplankton biomass accumulation. The role of residence time in relation to phytoplankton response to nutrient inputs is also obvious in Lampung Bay. In this bay, although nutrient loads are relatively low, longer residence times seem to be able to support nutrients and phytoplankton biomass accumulation in its waters. Meanwhile, in Semangka Bay, although residence time is much longer than the other two bays, its very low nutrient loads and unfavourable condition of light availability (high  $Z_{\text{mix}}:Z_{\text{eu}}$  ratios) are unable to support any substantial formation of phytoplankton biomass. These facts show that accumulation of phytoplankton biomass is not only governed by the resources of energy and matter (e.g. nutrient and light supply), but also regulated by hydrodynamic factors (e.g. such as water residence time) (Ortner and Dagg, 1995 ; Cloern, 1996 ; Cloern, 2001).

The third factor is a set of optical properties (briefly discussed in chapter 6.1), controlling light exposure of phytoplankton, expressed in this study as the ratio between mixing depth and euphotic depth ( $Z_{\text{mix}}:Z_{\text{eu}}$  ratio). This ratio is often used to test the possibility of bloom initiation and net primary production (e.g. Kocum *et al.*, 2002, Tillmann *et al.*, 2000).

As already mentioned in chapter 6.1., Jakarta and Lampung bays have lower  $Z_{\text{mix}}:Z_{\text{eu}}$  ratio's than Semangka Bay, mostly due to their shallower water depth. This factor seems to play an important role in supporting high phytoplankton production. In Lampung Bay, although nutrient input is low, a low  $Z_{\text{mix}}:Z_{\text{eu}}$  ratio allows for sustaining a moderate phytoplankton biomass in its water column. In Jakarta and Lampung bays, the critical mixing ratio ensured that phytoplankton cells maintained in a water column with a higher mean irradiance. In contrast, Semangka Bay, which has a deeper mixed layer and low nutrient loads, is unable to support any considerable phytoplankton biomass formation in its water column in spite of high water residence time.

The last attribute is grazing, which may effectively reduce biomass of phytoplankton. Zooplankton and benthic filter feeders are the dominant groups (Jassby *et al.*, 2002). In this study, quantification of zooplankton grazing rates on phytoplankton could not be performed. The impact of zooplankton grazing seems to be similar in these 3 bays, shown by the relatively similar prevalence of marine copepods (*Pseudocalanus* spp. and *Acartia* spp.). With respect to benthic filter feeders, the presence of green mussels (*Perna viridis*) in Jakarta Bay, which are widely cultured by local fishermen, may play an important role in controlling phytoplankton biomass. The biomass of phytoplankton decreased rapidly in the outer part of the bay just outside the culture areas of these filter feeder animals, which might be caused by the intensive grazing by these mussels. Suryono *et al.* (1999) conducted a laboratory scale experiment of the grazing of phytoplankton by *Perna viridis*, and concluded that on daily basis about 60% of the phytoplankton biomass is effectively grazed by this animal. A mass culture of *Perna viridis* seems to be an effective way to control the biomass of phytoplankton as a top-down management measure to reduce negative effects of nutrient enrichment in Jakarta Bay. The importance of grazers in controlling and regulating phytoplankton dynamics in marine waters has been revealed by Banse (2002), stating that the temporal change of phytoplankton biomass is not only driven by bottom-up resources such as light and nutrients, but mostly governed by the difference between growth rate and mortality, which includes grazing.

Apart from the four physical and biological factors described above, e.g. Downing (1991) revealed that the nutrient ratio in the water (N/P and N/Si ratios) is often viewed as an important factor regulating phytoplankton species composition. However, the use of ambient nutrient ratios to assess the potential nutrient limitation for phytoplankton has restrictions. The Redfield concept originally developed for open oceanic systems showed that the ratio of the maximum cell quotas for nitrogen and phosphorus is reached in oceanic systems when cells are growing close to their  $\mu_{\max}$  (Goldman *et al.*, 1979). Also Sommer (1994) revealed that the application of the Redfield ratio is suitable in the situation of maximum growth. However, the Redfield ratio of N/P = 15 has been widely used as a tool in assessing potential nutrient limitation of phytoplankton growth (e.g. Kocum *et al.*, 2002 ; Gin *et al.*, 2000). In this study, comparison between 3 bays showed a clear difference in the molar N/P ratio, with Jakarta Bay exhibiting the highest ratios. In Jakarta Bay, around 62% of measurements were above the 'threshold' value of 15, hence indicating potential P limitation, whereas in Lampung and Semangka bays, such measurements were around 26% and 50%, respectively. Meanwhile, N is likely to act as a potential limiting nutrient for phytoplankton growth in Lampung and Semangka bays. In all bays, however, N/P ratios were below the Redfield ratio along the river mouth and in the surrounding waters, indicating a strong influence of phosphate-rich freshwater inflow. In these areas, the decrease of N/P ratios was accompanied by an increase in flagellates and cyanobacteria, instead of diatoms. Again, in the more offshore waters, where N/P ratios increases, the presence of flagellates and cyanobacteria distinctly decreased. In the Gulf of Finland and Baltic Sea proper, blooms of nitrogen fixing cyanobacteria were always promoted by a low DIN:P ratio (Gammalgård and Ruokanen, 2002 ; Larssons *et al.*, 2001).

The ratio of N/Si was slightly different between bays. Semangka and Lampung bays exhibited N/Si ratios below 1, while Jakarta Bay was generally higher in this ratio (21%



above 1). The excess N loads in Jakarta Bay resulted in high N/Si ratios, while in Semangka and Lampung bays, relatively low N loads compared to those of Si, resulted in low N/Si ratios, and consequently to a potential N limitation in those bays. Low N/Si ratios in Lampung and Semangka bays allowed the diatoms to dominate the phytoplankton community. This is in conformity with Justic *et al.* (1995), which hypothesised that silicon availability might promote the importance of diatoms in coastal waters. In Jakarta Bay, the high absolute amount of silicate, too, supported a diatom dominated community in spite of the apparent potential silicate limitation as derived from the N/Si ratios. This fact shows that apart from nutrient ratios, the absolute amount of nutrient species in water also plays an important role in determining the occurrence of the predominant group of phytoplankton. The increase of the N:Si ratio is an important consequence of anthropogenic nitrogen enrichment. Also, there are indications that Si inputs decrease in some areas as a result of hydraulic engineering (i.e. dam construction). Altogether, changes towards a high N/Si load are held responsible for dramatic shifts in the phytoplankton composition from diatoms to flagellates (Kocum *et al.*, 2002), including the more frequent occurrence of harmful algae species (Glibert and Terlizzi, 2002).

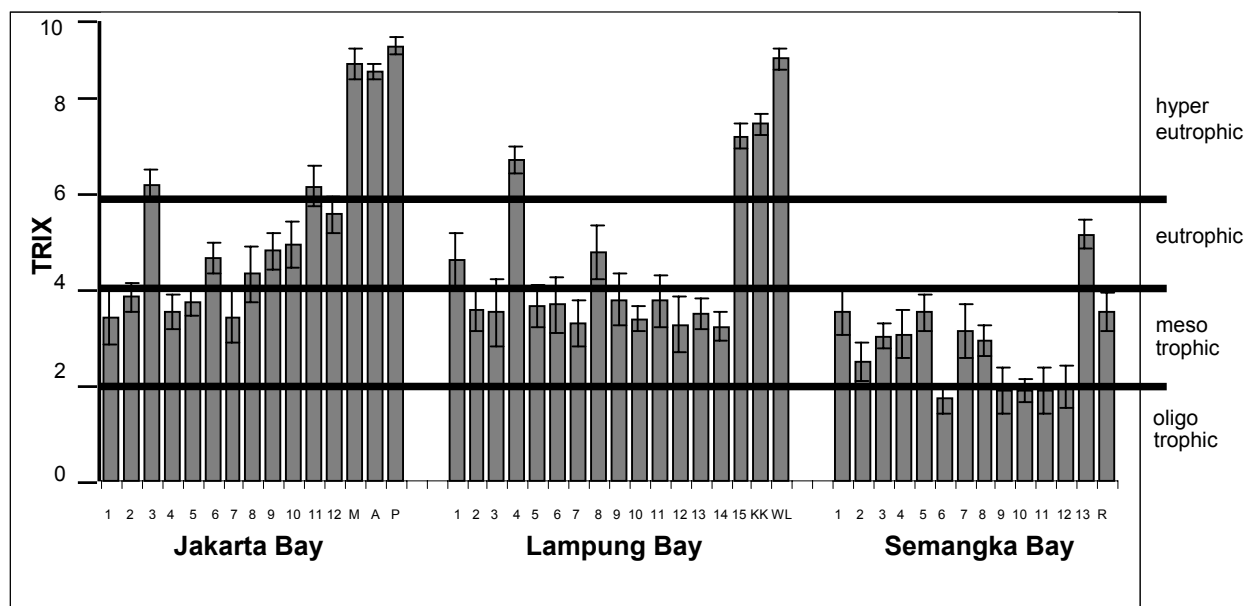
In summary, apart from the magnitude of nutrient inputs, several other physical factors are involved in the different response of phytoplankton to nutrient inputs in coastal waters. A differential importance of the physical factors seems reliable in explaining the difference in the relationship between nutrients (loads and concentrations) and phytoplankton responses in the three bays studied. Besides high nutrient loads, a more adequate light availability and the role of grazers act as the main controlling mechanisms for phytoplankton development in Jakarta Bay. In Lampung Bay, although nutrient input was low, but with longer water residence times and better light availability and the absence of large filter feeder populations supported a moderate phytoplankton biomass. Finally, in Semangka Bay, extremely low in nutrient loads, and with an unfavourable under water light availability, the ultimate result was a low phytoplankton biomass accumulation, in spite of the longer water residence time.

#### **6.4. Eutrophication and trophic states**

The Marine Trophic Index (TRIX) has been used in some European countries, especially due to its simplicity of application. Italian authorities use this index on a routine basis for monitoring the trophic state of the Adriatic Sea (Caiaffa, 1999). The European Community Joint Research Project has applied this index in the North Sea, close to the Skagerrak/Kattegat areas. The 4 parameters used in the calculation of TRIX are commonly measured during a standard monitoring of a water body. However, the general applicability of this index to other European waters is still subject to further evaluation (Ærtebjerg *et al.*, 2001).

In this study, the trophic state classification was based on the TRIX criteria developed by Caiaffa (1999) and also according to primary production criteria developed by Nixon (1995). By combining those criterion, distinct trophic states in the 3 bays studied were observed (Fig.6.4), pointing out Jakarta Bay as the most eutrophied, Lampung Bay as a moderate area and Semangka Bay as being the least eutrophied. This difference in trophic state is derived from the differences in nutrient enrichment from the land and the hydrographic characteristics of each bay. Therefore, combining these factors we could

conclude that a strong eutrophication process occurs in Jakarta Bay, and moderate and low ones in Lampung and Semangka bays, respectively. In Jakarta Bay, no oligotrophic zone was observed, showing that these waters have been profoundly influenced by



Notes :

M = Marunda river mouth; A = Angke river mouth; P = Priok river mouth; KK = Kota Karang river mouth; WL = Way Lunik river mouth; R = Semangka river mouth.

**Fig.6.4.** Comparison of the annual average of TRIX values between Jakarta, Lampung and Semangka bays. Trophic state classification is according to Caiiffa (1999).

human activities. Meanwhile, most of the Lampung Bay area is classified as mesotrophic state, whereas Semangka Bay was mostly dominated by mesotrophic and oligotrophic states.

## 6.5. Suggestions for future research and possible management options

The research on nutrient enrichment and its effects on coastal aquatic ecosystems in the tropical Indonesian waters has a high priority to be continued, especially in coastal regions with high population density. In the near future along with the increase of coastal population, the magnitude of eutrophication in some Indonesian coastal waters, especially in Jakarta Bay could further increase to a level, which may be undesirable for all 'users'. In order to avoid a collapse, preventive study on nutrient enrichment should be immediately continued in other coastal areas in the country, especially those subjected to high human activities.

The present study was conducted with several limitations, so that we are still unable to answer all questions regarding the ecological consequences of nutrient enrichment in tropical coastal ecosystems. However, fundamental information was achieved, enabling the development of both research and possible management actions in the area. The following investigations are necessary to fill some scientific gaps in tropical coastal waters affected by nutrient enrichment :

- studies on the coupling between pelagic and benthic communities, especially with respect to nutrient remineralisation processes, benthic primary production and sedimentation of organic material.
- studies on the grazing rate of herbivores on phytoplankton biomass, including that of green mussels (*Perna viridis*), which is widely found in Jakarta Bay. This investigation is also required to detect the fate of high phytoplankton biomass produced in Jakarta Bay as well as an evaluation of the secondary production in the area.
- to develop a detailed model, involving hydrodynamic and biological aspects, including the nutrient budgets, the fate of nutrients and phytoplankton biomass produced by primary production processes.
- to conduct a regular monitoring studies of the nutrient concentrations and phytoplankton in the study area.

The following recommendations are made as possible management measures to reduce eutrophication in the study area :

- to reduce N and P loads by installing sewage treatment facilities, especially in the city of Jakarta and other major cities in the country. Reduction of N and P is aimed to keep N or P to Si ratio low, preventing the occurrence of nuisance phytoplankton blooms. This is a high priority programme, which should be immediately implemented.
- a culture of green mussels (e.g. *Perna viridis*) could be used as an effective top-down control of phytoplankton biomass in Jakarta Bay. Further investigation on the pollutant content in the mussels should be performed prior to be marketed.
- to improve the awareness within Indonesian society towards a clean marine and aquatic environment.

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## **8. Appendix**

### App.1. Pearson correlation between variables in Jakarta Bay

Marked correlations are significant at  $p < .01$

N=90

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
silicate (1)	1.00																													
ammonium (2)	0.82	1.00																												
nitrate (3)	0.30	0.50	1.00																											
nitrite (4)	0.11	0.11	0.37	1.00																										
Phosphate (5)	0.47	0.75	0.73	0.14	1.00																									
Chl a (6)	0.35	0.45	0.51	0.22	0.48	1.00																								
Salinity (7)	-0.63	-0.81	-0.59	-0.25	-0.82	-0.54	1.00																							
Turbidity (8)	0.65	0.84	0.56	0.16	0.76	0.52	-0.77	1.00																						
Secchi depth (9)	-0.41	-0.54	-0.39	-0.22	-0.51	-0.52	0.55	-0.61	1.00																					
pH (10)	-0.50	-0.64	-0.57	-0.08	-0.72	-0.43	0.59	-0.64	0.40	1.00																				
%O2 sat.(11)	-0.54	-0.65	-0.43	-0.06	-0.62	-0.50	0.59	-0.73	0.39	0.52	1.00																			
temp.(12)	-0.03	0.18	0.20	0.19	0.13	0.11	-0.13	0.19	-0.12	0.05	-0.11	1.00																		
Phytoplankton (13)	0.38	0.31	0.28	0.14	0.26	0.75	-0.41	0.36	-0.44	-0.30	-0.34	0.01	1.00																	
Diatoms (14)	0.29	0.15	0.05	0.17	0.08	0.60	-0.21	0.20	-0.33	-0.16	-0.19	-0.04	0.90	1.00																
Dinophyceae (15)	0.17	0.29	0.26	0.00	0.28	0.19	-0.11	0.20	-0.33	-0.16	-0.30	0.21	0.12	0.04	1.00															
Cyanophyceae (16)	0.38	0.54	0.55	0.06	0.63	0.46	-0.70	0.48	-0.34	-0.39	-0.38	0.07	0.38	0.06	0.12	1.00														
Chlorophyceae (17)	0.16	0.10	0.27	-0.03	0.12	0.33	-0.16	0.28	-0.21	-0.09	-0.31	-0.11	0.30	0.17	0.07	0.14	1.00													
K (18)	0.67	0.81	0.56	0.10	0.75	0.53	-0.79	0.95	-0.61	-0.62	-0.70	0.11	0.38	0.16	0.14	0.64	0.30	1.00												
Z Eu (19)	-0.45	-0.60	-0.44	-0.23	-0.58	-0.57	0.61	-0.68	0.96	0.44	0.46	-0.14	-0.42	-0.30	-0.35	-0.38	-0.24	-0.68	1.00											
Zmix:Zeu (20)	-0.28	-0.25	-0.21	-0.25	-0.21	-0.43	0.34	-0.26	0.22	0.23	0.39	-0.15	-0.57	-0.55	-0.29	-0.17	-0.09	-0.21	0.23	1.00										
Z mix (21)	-0.43	-0.50	-0.38	-0.30	-0.46	-0.62	0.56	-0.56	0.79	0.40	0.46	-0.17	-0.64	-0.55	-0.40	-0.33	-0.19	-0.53	0.80	-0.03	1.00									
I average (22)	-0.27	-0.30	-0.11	0.12	-0.26	0.00	0.18	-0.35	-0.05	0.18	0.18	0.03	0.08	0.13	0.27	-0.15	-0.07	-0.36	-0.01	-0.53	-0.37	1.00								
N:P (23)	-0.18	-0.22	-0.16	-0.04	-0.23	-0.21	0.21	-0.23	0.33	0.26	0.19	-0.09	-0.08	-0.02	-0.08	-0.16	-0.09	-0.25	0.31	0.12	0.25	-0.04	1.00							
N:Si (24)	-0.15	-0.01	0.02	0.07	-0.01	-0.04	0.07	-0.01	-0.13	0.03	0.21	0.02	-0.16	-0.15	-0.06	-0.03	-0.06	0.01	-0.15	0.19	-0.01	0.03	0.07	1.00						
Chl c (25)	0.08	0.06	0.22	0.09	0.34	0.01	-0.19	0.19	-0.19	-0.39	-0.21	-0.04	0.00	-0.06	-0.03	0.22	-0.02	0.29	-0.22	-0.05	-0.17	-0.14	-0.09	-0.05	1.00					
lutein (26)	0.25	0.59	0.41	0.03	0.57	0.39	-0.69	0.56	-0.30	-0.37	-0.40	0.22	0.25	0.03	-0.02	0.63	0.06	0.57	-0.34	-0.13	-0.27	-0.24	-0.13	0.02	-0.02	1.00				
fucoxanthin (27)	0.01	0.05	0.24	0.52	0.05	0.53	-0.09	0.20	-0.27	-0.05	-0.19	0.31	0.35	0.35	0.04	-0.09	0.26	0.09	-0.29	-0.29	-0.37	0.11	-0.14	0.04	-0.08	0.05	1.00			
diadinoxanthin (28)	0.07	0.21	0.25	0.49	0.14	0.54	-0.24	0.31	-0.26	-0.13	-0.27	0.43	0.39	0.31	0.03	0.18	0.10	0.24	-0.29	-0.29	-0.37	-0.01	-0.14	0.05	-0.04	0.39	0.85	1.00		
Chl b (29)	0.18	0.48	0.43	0.00	0.45	0.39	-0.54	0.42	-0.24	-0.30	-0.31	0.22	0.29	0.07	0.00	0.69	0.08	0.48	-0.27	-0.11	-0.22	-0.18	-0.09	0.03	-0.04	0.85	0.06	0.40	1.00	
β carotene (30)	0.32	0.60	0.37	0.19	0.48	0.36	-0.62	0.62	-0.34	-0.39	-0.42	0.35	0.28	0.12	0.01	0.51	0.04	0.59	-0.38	-0.20	-0.35	-0.21	-0.14	0.05	-0.02	0.73	0.33	0.60	0.82	1.00

## App.2. Pearson correlation between variables in Lampung Bay

Marked correlations are significant at  $p < .01$

N=102

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
phosphate (1)	1.00																														
nitrite (2)	0.38	1.00																													
nitrate (3)	0.41	0.42	1.00																												
ammonium (4)	0.66	0.15	0.21	1.00																											
silicate (5)	0.53	0.18	0.13	0.73	1.00																										
Chl a (6)	0.80	0.23	0.57	0.57	0.39	1.00																									
salinity (7)	-0.73	-0.55	-0.51	-0.60	-0.71	-0.57	1.00																								
turbidity (8)	0.70	0.24	0.26	0.77	0.82	0.52	-0.85	1.00																							
secchi depth (9)	-0.49	-0.38	-0.33	-0.39	-0.57	-0.51	0.68	-0.63	1.00																						
pH (10)	-0.40	-0.29	-0.16	-0.36	-0.58	-0.24	0.56	-0.51	0.55	1.00																					
% O2 sat. (11)	-0.72	-0.44	-0.38	-0.56	-0.69	-0.52	0.88	-0.79	0.60	0.51	1.00																				
temp (12)	0.17	-0.04	-0.03	0.20	0.31	0.11	-0.13	0.23	-0.19	-0.49	-0.28	1.00																			
phytoplankton (13)	0.32	0.23	0.62	0.22	0.20	0.69	-0.42	0.33	-0.63	-0.14	-0.29	0.04	1.00																		
diatoms (14)	0.29	0.17	0.64	0.20	0.17	0.68	-0.39	0.30	-0.60	-0.11	-0.25	0.02	0.99	1.00																	
dinoflagellates (15)	0.67	0.20	0.14	0.41	0.41	0.56	-0.43	0.39	-0.46	-0.42	-0.47	0.26	0.22	0.19	1.00																
cyanophyceae (16)	0.23	0.49	0.12	0.12	0.19	0.25	-0.36	0.20	-0.39	-0.26	-0.32	0.06	0.40	0.28	0.17	1.00															
chlorophyceae (17)	0.14	0.12	0.02	0.64	0.48	0.24	-0.33	0.52	-0.38	-0.13	-0.22	0.10	0.35	0.32	0.08	0.33	1.00														
K (18)	0.65	0.38	0.49	0.71	0.81	0.55	-0.93	0.90	-0.66	-0.57	-0.83	0.20	0.42	0.40	0.45	0.25	0.43	1.00													
ZeU (19)	-0.59	-0.45	-0.39	-0.46	-0.65	-0.58	0.81	-0.74	0.96	0.58	0.72	-0.21	-0.66	-0.62	-0.48	-0.44	-0.42	-0.77	1.00												
Zmix : ZEu (20)	-0.31	-0.26	-0.23	-0.21	-0.40	-0.27	0.44	-0.36	0.42	0.28	0.38	-0.04	-0.35	-0.31	-0.16	-0.40	-0.20	-0.36	0.46	1.00											
Zmix (21)	-0.53	-0.42	-0.36	-0.40	-0.61	-0.53	0.73	-0.66	0.86	0.49	0.66	-0.15	-0.62	-0.59	-0.39	-0.46	-0.40	-0.68	0.90	0.10	1										
I Average (22)	0.02	-0.03	-0.10	-0.01	0.12	0.05	0.03	0.05	-0.11	0.07	-0.13	0.26	0.16	0.15	-0.01	0.15	0.11	-0.05	-0.14	-0.57	-0.35	1.00									
N:P ratio (23)	-0.12	-0.09	-0.06	-0.06	-0.13	-0.11	0.11	-0.12	0.12	0.42	0.18	-0.34	-0.03	-0.02	-0.12	-0.11	-0.06	-0.13	0.16	0.01	0.10	-0.14	1.00								
N:Si (24)	0.13	0.07	0.36	0.16	-0.14	0.24	-0.08	0.01	0.02	0.19	-0.04	-0.34	0.21	0.22	-0.04	0.02	-0.05	0.05	0.02	-0.14	-0.07	-0.11	0.14	1.00							
Chl c (25)	-0.01	-0.02	0.02	-0.01	0.00	0.20	-0.03	0.20	-0.28	0.09	-0.06	0.00	0.38	0.38	-0.01	0.09	0.39	0.12	-0.33	0.14	-0.25	0.00	-0.06	-0.05	1.00						
lutein (26)	0.67	0.07	0.59	0.72	0.32	0.80	-0.46	0.45	-0.21	-0.15	-0.45	0.06	0.39	0.40	0.37	0.00	-0.01	0.49	-0.29	-0.05	-0.23	-0.10	-0.08	0.27	0.12	1.00					
fucoxanthin (27)	0.08	0.02	0.07	0.08	0.06	0.24	-0.08	0.32	-0.30	0.03	-0.17	0.10	0.31	0.31	0.05	0.04	0.37	0.16	-0.34	0.06	-0.27	0.05	-0.07	-0.03	0.84	0.19	1.00				
diadinoxanthin (28)	0.78	0.09	0.47	0.85	0.41	0.90	-0.42	0.52	-0.32	-0.16	-0.47	0.14	0.42	0.42	0.61	0.06	0.09	0.51	-0.38	-0.09	-0.32	-0.03	-0.07	0.20	0.22	0.84	0.34	1.00			
Chl b (29)	0.65	0.12	0.69	0.70	0.26	0.86	-0.42	0.39	-0.24	-0.10	-0.38	0.06	0.50	0.52	0.31	0.02	0.00	0.45	-0.29	-0.10	-0.25	-0.08	0.00	0.29	0.04	0.89	0.14	0.85	1.00		
β carotene (30)	0.65	0.04	0.24	0.68	0.53	0.74	-0.49	0.56	-0.37	-0.29	-0.48	0.05	0.33	0.33	0.64	0.06	0.15	0.59	-0.45	-0.11	-0.38	-0.09	-0.09	0.08	0.20	0.71	0.25	0.75	0.54	1.00	

### App.3. Pearson correlation between variables in Semangka Bay

Marked correlations are significant at  $p < .01$

N=84

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
phosphate (1)	1																													
nitrite (2)	0.83	1																												
nitrate (3)	0.57	0.55	1																											
ammonium (4)	0.10	0.16	-0.02	1																										
silicate (5)	0.24	0.34	0.27	0.76	1																									
Chl a (6)	0.12	0.24	-0.04	0.61	0.57	1																								
salinity (7)	-0.72	-0.68	-0.75	-0.21	-0.43	0.00	1																							
turbidity (8)	0.59	0.53	0.66	0.05	0.28	0.02	-0.72	1																						
secchi depth (9)	-0.39	-0.44	-0.24	-0.36	-0.43	-0.36	0.43	-0.33	1																					
pH (10)	-0.17	-0.28	0.07	0.42	0.22	0.16	-0.04	-0.10	0.13	1																				
% O2 sat. (11)	0.12	0.15	-0.25	-0.20	-0.16	0.11	0.17	-0.23	0.06	-0.47	1																			
temp (12)	0.18	0.16	0.20	0.18	0.22	0.18	-0.16	0.27	-0.26	0.11	-0.13	1																		
phytoplankton (13)	0.08	0.18	-0.13	0.50	0.28	0.82	0.10	-0.06	-0.31	0.25	0.07	0.11	1																	
diatoms (14)	0.07	0.18	-0.13	0.49	0.27	0.82	0.11	-0.06	-0.28	0.24	0.07	0.10	1.00	1																
dinoflagellates (15)	0.02	0.06	-0.09	0.22	0.08	0.39	0.15	-0.08	-0.09	0.13	0.03	0.10	0.40	0.37	1															
cyanophyceae (16)	0.18	0.04	-0.02	0.16	0.22	0.23	-0.20	0.05	-0.37	0.14	0.11	0.25	0.18	0.12	0.21	1														
chlorophyceae (17)	0.10	0.11	0.00	0.35	0.28	0.09	-0.20	0.01	-0.31	0.17	-0.12	0.18	0.14	0.09	0.05	0.49	1													
K (18)	0.45	0.47	0.44	0.56	0.68	0.30	-0.75	0.61	-0.65	0.06	-0.19	0.30	0.14	0.12	0.01	0.31	0.31	1.00												
Zeu (19)	-0.20	-0.25	-0.18	-0.13	-0.18	-0.14	0.25	-0.18	0.27	0.09	0.04	-0.13	-0.11	-0.10	-0.10	-0.01	-0.14	-0.32	1.00											
Z mix (20)	-0.50	-0.61	-0.33	-0.43	-0.48	-0.50	0.58	-0.39	0.68	0.02	-0.02	-0.30	-0.40	-0.37	-0.26	-0.39	-0.30	-0.68	0.33	1.00										
Zmix:Zeu (21)	-0.24	-0.33	0.00	-0.24	-0.11	-0.32	0.16	-0.06	0.02	0.00	-0.16	-0.11	-0.27	-0.26	-0.26	-0.14	0.01	0.00	-0.13	0.51	1.00									
I Average (22)	0.45	0.59	0.21	0.45	0.38	0.61	-0.34	0.21	-0.44	0.05	0.08	0.40	0.56	0.54	0.50	0.31	0.22	0.45	-0.23	-0.81	-0.60	1.00								
N:P (23)	-0.18	-0.20	-0.11	0.49	0.21	0.08	-0.07	-0.06	-0.06	0.38	-0.15	-0.17	0.17	0.18	-0.05	-0.02	-0.05	0.25	-0.01	-0.03	-0.05	-0.04	1.00							
N:Si (24)	0.00	-0.02	0.47	-0.05	-0.20	-0.07	-0.05	0.00	0.24	0.32	-0.25	0.12	-0.03	-0.02	0.05	-0.16	-0.12	-0.13	-0.02	0.08	-0.07	0.06	0.06	1.00						
Chl c (25)	0.00	0.15	-0.08	0.48	0.57	0.81	0.07	0.01	-0.22	0.02	0.11	0.14	0.56	0.56	0.18	0.10	-0.04	0.26	-0.11	-0.32	-0.22	0.38	0.01	-0.09	1.00					
lutein (26)	-0.19	-0.19	-0.18	-0.14	-0.08	-0.04	0.24	-0.12	-0.02	-0.05	0.11	0.27	-0.08	-0.09	0.02	0.16	-0.06	-0.16	0.12	0.10	0.06	-0.10	-0.10	-0.18	0.02	1.00				
fucoxanthin (27)	-0.02	0.11	-0.14	0.22	0.19	0.63	0.12	-0.03	-0.21	-0.08	0.14	0.11	0.64	0.64	0.15	0.15	-0.07	0.10	-0.09	-0.30	-0.23	0.36	0.07	-0.09	0.76	0.08	1.00			
diadinoxanthin (28)	-0.06	0.04	-0.12	0.33	0.44	0.61	0.11	-0.03	-0.20	0.06	0.05	0.18	0.53	0.53	0.11	0.19	-0.03	0.13	-0.07	-0.20	-0.12	0.24	0.02	-0.16	0.73	0.05	0.80	1.00		
Chl b (29)	-0.12	-0.08	-0.04	-0.04	-0.04	0.02	-0.03	0.03	0.13	0.25	-0.13	-0.23	0.07	0.07	0.12	-0.06	0.09	0.02	0.00	0.10	0.27	-0.09	-0.01	-0.05	-0.11	-0.01	-0.07	-0.10	1.00	
β carotene (30)	-0.03	0.13	-0.15	0.18	0.25	0.60	0.14	-0.02	-0.22	-0.25	0.30	0.14	0.45	0.45	0.20	0.10	-0.13	0.12	-0.13	-0.28	-0.21	0.35	-0.04	-0.18	0.75	0.30	0.80	0.64	-0.14	1.00

#### App.4. Results of two-way Anova of Jakarta Bay

Variables	Source	SS	df	MS	F	p-value
salinity	stations	5381.34	14	384.3816349	39.03	1.90958E-27
	time	78.44	5	15.68791111	1.59	0.173435132
	residual	689.39	70	9.848434921		
	total	6149.17	89			
turbidity	stations	4481.84	14	320.1313773	32.07	6.82935E-25
	time	45.69	5	9.138487111	0.92	0.476169764
	residual	698.73	70	9.981896159		
	total	5226.26	89			
attenuation coefficient	stations	469.61	14	33.54338731	37.66	5.62112E-27
	time	5.55	5	1.109590004	1.25	0.0233356
	residual	62.34	70	0.890615757		
	total	537.50	89			
Secchi depth	stations	276.75	14	19.76758206	16.30	8.85396E-17
	time	33.86	5	6.772419778	5.59	0.000218
	residual	84.88	70	1.212537873		
	total	395.49	89			
Zmix:Zeu	stations	22.20	14	1.585914049	13.36	1.20E-14
	time	4.25	5	0.850042869	7.16	1.84E-05
	residual	8.31	70	0.118700597		
	total	34.76	89			
pH	stations	6.94	14	0.49599254	7.39	3.61938E-09
	time	1.01	5	0.201375111	3.00	0.016362076
	residual	4.70	70	0.06707654		
	Total	12.65	89			
O2 sat.	stations	59251.55	14	4232.25322	16.41	7.46735E-17
	time	7386.22	5	1477.243781	5.73	0.000173489
	residual	18051.17	70	257.8738714		
	Total	84688.93	89			
water temperature	stations	4.93	14	0.352253968	1.80	2.28226E-13
	time	22.02	5	4.403111111	22.47	0.056146111
	residual	13.72	70	0.195968254		
	Total	40.66	89			
phytoplank. abundance	stations	4.6683E+14	14	3.33448E+13	5.43	7.08182E-07
	time	1.9853E+14	5	3.97061E+13	6.46	5.42568E-05
	residual	4.3014E+14	70	6.14479E+12		
	total	1.0955E+15	89			

Variables	Source	SS	df	MS	F	p-value
phosphate	stations	9463.0	14	675.93	19.06	1.52707E-18
	time	289.1	5	57.81	1.63	0.163407065
	residual	2482.5	70	35.46		
	total	12234.6	89			
nitrite	stations	9.5	14	0.68	1.67	0.081651572
	time	4.1	5	0.83	2.03	0.084435105
	residual	28.4	70	0.41		
	total	42.1	89			
nitrate	stations	1084.2	14	77.44	3.94	6.11338E-05
	time	253.4	5	50.68	2.58	0.033789177
	residual	1376.7	70	19.67		
	total	2714.3	89			
ammonium	stations	77739.4	14	5552.82	19.75	5.94993E-19
	time	3474.5	5	694.89	2.47	0.040430898
	residual	19684.8	70	281.21		
	total	100898.7	89			
silicate	stations	402634.1	14	28759.58	6.67	2.33193E-08
	time	138055.1	5	27611.02	6.40	5.94038E-05
	residual	301811.3	70	4311.59		
	total	842500.4	89			
N:P	stations	182947.1	14	13067.65	1.24	0.270823938
	time	91465.5	5	18293.10	1.73	0.139297987
	residual	740585.8	70	10579.80		
	total	1014998.4	89			
N:Si	stations	23.4	14	1.67	0.96	0.503676711
	time	41.4	5	8.28	4.74	0.000873114
	residual	122.3	70	1.75		
	total	187.1	89			
chl a	stations	10333.2	14	738.09	6.00	1.40023E-07
	time	458.0	5	91.60	0.75	0.0082336
	residual	8604.5	70	122.92		
	total	19395.7	89			
daily PP	stations	4287900.1	2	2143950.0	18.05	0.000480762
	time	913524.3	5	182704.85	1.54	0.012353
	residual	1188087.6	10	118808.76		
	total	6389512.0	17			

### App.5. Results of two-way Anova of Lampung Bay

Variables	Source	SS	df	MS	F	p-value
salinity	stations	9125	16	570.3186	721.5126	1.94E-79
	time	28.14	5	5.628157	7.120207	1.49E-05
	residual	63.24	80	0.790449		
	total	9216	101			
turbidity	stations	1499	16	93.6877	17.38002	1.04E-19
	time	59.59	5	11.91847	2.210997	0.061171
	residual	431.2	80	5.39054		
	total	1990	101			
secchi depth	stations	2207	16	137.9434	34.29512	3.81E-29
	time	82.16	5	16.43266	4.085443	0.002356
	residual	321.8	80	4.022247		
	total	2611	101			
pH	stations	7.767	16	0.485446	23.45901	1.04E-23
	time	11.87	5	2.374309	114.7376	5.31E-35
	residual	1.655	80	0.020693		
	total	21.29	101			
O2 sat.	stations	42277	16	2642.311	44.93334	3.23E-33
	time	4500	5	899.9475	15.30389	1.55E-10
	residual	4704	80	58.80515		
	total	51481	101			
water temperature	stations	2.667	16	0.166667	2.432916	0.005223
	time	9.395	5	1.878922	27.42755	0.005251
	residual	5.48	80	0.068505		
	total	17.54	101			
Zmix:Zeu	stations	13.72	16	0.857698	21.69549	1.22E-22
	time	0.372	5	0.074326	1.880068	0.107018
	residual	3.163	80	0.039533		
	total	17.26	101			
attenuation coefficient	stations	133.4	16	8.340065	45.36902	2.3E-33
	time	1.87	5	0.373979	2.034403	0.046251
	residual	14.71	80	0.183827		
	total	150	101			
phytoplankton abundance	stations	1E+14	16	6.25E+12	5.301484	1.98E-07
	time	9E+12	5	1.71E+12	1.449629	0.01325
	residual	9E+13	80	1.18E+12		
	total	2E+14	101			

Variables	Source	SS	df	MS	F	p-value
phosphate	stations	3003.548197	16	187.7218	15.68384	2.07E-18
	time	69.9707414	5	13.99415	1.169187	0.331659
	residual	957.529822	80	11.96912		
	total	4031.04876	101			
nitrite	stations	188.7504936	16	11.79691	4.016788	1.57E-05
	time	32.09595593	5	6.419191	2.185703	0.06387
	residual	234.9520332	80	2.9369		
	total	455.7984828	101			
nitrate	stations	5556.30151	16	347.2688	2.157815	0.013088
	time	2300.192375	5	460.0385	2.858528	0.019973
	residual	12874.83407	80	160.9354		
	total	20731.32796	101			
ammonium	stations	80687.61536	16	5042.976	8.479712	1.61E-11
	time	4314.397803	5	862.8796	1.450923	0.023125
	residual	47576.86053	80	594.7108		
	total	20731.32796	101			
silicate	stations	459961.3232	16	28747.58	8.408422	1.95E-11
	time	95447.58991	5	19089.52	5.58352	0.000183
	residual	273512.2871	80	3418.904		
	total	828921.2002	101			
N:P	stations	106542.0241	16	6658.877	1.142166	0.05623
	time	343032.2669	5	68606.45	11.76774	1.53E-08
	residual	466403.4705	80	5830.043		
	total	915977.7614	101			
N:Si	stations	5.903875471	16	0.368992	1.403234	0.04526
	time	11.14523063	5	2.229046	8.476801	1.79E-06
	residual	21.03667403	80	0.262958		
	total	38.08578014	101			
chl a	stations	5346.304141	16	334.144	6.19444	1.15E-08
	time	277.7081712	5	55.54163	1.029644	0.01322
	residual	4315.405366	80	53.94257		
	total	9939.417678	101			
daily PP	stations	425914.5642	2	212957.3	20.90299	0.000268
	time	35511.83337	5	7102.367	0.697138	0.01213
	residual	101878.8773	10	10187.89		
	total	563305.2749	17			



### App.6. Results of two-way Anova of Semangka Bay

Variables	Source	SS	df	MS	F	p-value
salinity	stations	3883	13	298.6592	77.39149	2.44E-34
	time	194.5	5	38.89543	10.07897	3.57E-07
	residual	250.8	65	3.85907		
	total	4328	83			
turbidity	stations	3205	13	246.5415	3.46585	0.000422
	time	526.6	5	105.3163	1.480523	0.208337
	residual	4624	65	71.13451		
	total	8355	83			
secchi depth	stations	1891	13	145.4824	12.92132	2.04E-13
	time	329.1	5	65.82673	5.846537	0.000161
	residual	731.8	65	11.2591		
	total	2952	83			
pH	stations	0.111	13	0.008525	0.780132	0.677677
	time	7.218	5	1.443584	132.1039	0.12113
	residual	0.71	65	0.010928		
	total	8.039	83			
O2 sat.	stations	1978	13	152.1665	1.100883	0.374435
	time	5253	5	1050.596	7.600775	0.222321
	residual	8984	65	138.2222		
	total	16216	83			
water temperature	stations	3.112	13	0.239386	4.762434	1E-05
	time	5.008	5	1.001548	19.92512	5.47E-12
	residual	3.267	65	0.050266		
	total	11.39	83			
Z <sub>mix</sub> :Z <sub>eu</sub>	stations	215.8	13	16.60221	16.65455	6.13E-16
	time	6.462	5	1.292376	1.29645	0.276383
	residual	64.8	65	0.996857		
	total	287.1	83			
attenuation coefficient	stations	11.4	13	0.876632	22.7891	2.59E-19
	time	0.55	5	0.110046	2.860778	0.021408
	residual	2.5	65	0.038467		
	total	14.45	83			
phytoplankton abundance	stations	3E+12	13	2.17E+11	6.839575	4.55E-08
	time	7E+11	5	1.43E+11	4.502031	0.001386
	residual	2E+12	65	3.17E+10		
	total	6E+12	83			

Variables	Source	SS	df	MS	F	p-value
phosphate	stations	33.96403597	13	2.612618	4.850176	7.87E-06
	time	6.697422204	5	1.339484	2.486676	0.040171
	residual	35.01320139	65	0.538665		
	total	75.67465956	83			
nitrite	stations	0.80942955	13	0.062264	8.095026	2.45E-09
	time	0.179932995	5	0.035987	4.67868	0.001039
	residual	0.499954852	65	0.007692		
	total	1.489317398	83			
nitrate	stations	482.7063527	13	37.13126	6.300627	1.72E-07
	time	448.1812186	5	89.63624	15.20995	7.05E-10
	residual	383.0621349	65	5.893264		
	total	1313.949706	83			
ammonium	stations	111.1372	13	8.549015	3.851086	0.000135
	time	116.2862187	5	23.25724	10.47672	2.11E-07
	residual	144.2933117	65	2.219897		
	total	371.7167305	83			
silicate	stations	82286.51401	13	6329.732	3.699311	0.000211
	time	26137.74701	5	5227.549	3.055158	0.015429
	residual	111218.6988	65	1711.057		
	total	219642.9599	83			
N:P	stations	887481.638	13	68267.82	0.955523	0.503371
	time	3743520.443	5	748704.1	10.47937	2.1E-07
	residual	4643957.79	65	71445.5		
	total	9274959.87	83			
N:Si	stations	0.338554459	13	0.026043	1.920764	0.043655
	time	1.457203364	5	0.291441	21.49507	1.25E-12
	residual	0.881301716	65	0.013558		
	total	2.677059538	83			
chl a	stations	61.92872717	13	4.763748	7.653067	6.66E-09
	time	8.767309798	5	1.753462	2.816976	0.023048
	residual	40.46006947	65	0.622463		
	total	111.1561064	83			
daily PP	stations	12668.93375	2	6334.467	5.745338	0.021815
	time	9177.104415	5	1835.421	1.66472	0.230283
	residual	11025.40404	10	1102.54		
	total	32871.44221	17			

**App.7. Results of two-way Anova of the comparison of each parameter between bays.**

Variable	Source	SS	df	MS	F	p-value	F-crit.	Variables	Source	SS	df	MS	F	p-value	F-crit.	
salinity	stations	18610.4	45	413.5647	78.99	1.55E-114	1.426	nitrite	stations	210.8	45	4.68	3.69	5.37089E-11	1.647	
	time	126.54	5	25.30809	4.83	0.0003217	2.254		time	14.6	5	2.91	2.30	0.046328682	3.100	
	residual	1177.98	225	5.23548					residual	285.7	225	1.27				
	total	19914.9	275						total	511.1	275					
turbidity	stations	9587.79	45	213.0619	7.77	1.665E-26	1.426	ammonium	stations	168711.3	45	3749.14	12.12	1.8603E-39	1.647	
	time	212.067	5	42.41337	1.55	0.1766342	2.254		time	5724.7	5	1144.94	3.70	0.003067071	3.100	
	residual	6173.52	225	27.43786					residual	69586.4	225	309.27				
	total	15973.4	275						total	244022.4	275					
Secchi de	stations	6708.03	45	149.0673	23.83	1.772E-63	1.426	silicate	stations	956872.4	45	21263.83	6.56	2.74491E-22	1.647	
	time	175.932	5	35.1865	5.62	6.611E-05	2.254		time	216571.4	5	43314.27	13.36	2.08702E-11	3.100	
	residual	1407.73	225	6.256557					residual	729611.3	225	3242.72				
	total	8291.69	275						total	1903055.1	275					
pH	stations	17.6555	45	0.392345	5.76	2.579E-19	1.426	phosphate	stations	13467.0	45	299.27	18.33	1.32514E-53	1.647	
	time	11.8224	5	2.364473	34.69	3.185E-26	2.254		time	166.6	5	33.31	2.04	0.074079185	3.100	
	residual	15.3351	225	0.068156					residual	3674.2	225	16.33				
	total	44.813	275						total	17307.8	275					
oxygen sa	stations	111344	45	2474.311	14.23	1.002E-44	1.426	N:P ratio	stations	1762969.9	45	39177.11	1.01	0.464680116	1.426	
	time	9101.47	5	1820.294	10.47	4.768E-09	2.254		time	1289727.0	5	257945.41	6.64	8.64745E-06	2.254	
	residual	39117.7	225	173.8567					residual	8739238.2	225	38841.06				
	total	159563	275						total	11791935.1	275					
water temperatu	stations	14.2943	45	0.317652	1.45	0.0411532	1.426	N:Si ratio	stations	51.4	45	1.14	1.54	0.021965241	1.426	
	time	9.75159	5	1.950319	8.93	9.367E-08	2.254		time	29.3	5	5.86	7.91	6.91883E-07	2.254	
	residual	49.1317	225	0.218363					residual	166.7	225	0.74				
	total	73.1777	275						total	247.5	275					
attenuatio	stations	689.715	45	15.32699	41.68	2.555E-86	1.426	Chl a	stations	23000.1	45	511.11	8.60	3.10081E-29	1.647	
	time	4.78318	5	0.956635	2.60	0.0260487	2.254		time	328.5	5	65.70	1.11	0.358469846	3.100	
	residual	82.7345	225	0.367709					residual	13376.4	225	59.45				
	total	777.232	275						total	36705.0	275					
Zmix:Z	stations	379.757	45	8.439049	22.43	3.702E-61	1.426	phytoplankton	stations	1.44001E+15	45	3.20003E+13	10.66	1.85487E-35	1.647	
	time	2.71028	5	0.542055	1.44	0.2105214	2.254		time	5.89268E+13	5	1.17854E+13	3.93	0.001967616	3.100	
	residual	84.6409	225	0.376182					residual	6.75394E+14	225	3.00175E+12				
	total	467.108	275						total	2.17434E+15	275					
nitrate	stations	7316.27	45	162.5837	2.38	1.73E-05	1.647	daily PP	stations	7148740.2	8	893592.53	18.31	3.78006E-11	2.180	
	time	2242.34	5	448.4674	6.55	1.027E-05	3.100		time	307582.5	5	61516.49	1.26	0.299673663	2.449	
	residual	15394	225	68.418					residual	1951622.7	40	48790.57				
	total	24952.7	275						total	9407945.3	53					

**App.8. List of phytoplankton species and their abundances (cells l<sup>-1</sup>) during December 2000 sampling in Jakarta Bay.**

Phytoplankton	stations												Marunda	Priok	Angke	
	1	2	3	4	5	6	7	8	9	10	11	12				
<b>BACILLARYOPHYCEAE</b>																
<i>Bacteriastrum furcatum</i>	2857	0	5143	571	10857	4571	1143	2857	0	0	0	0	0	0	0	0
<i>Bacteriastrum delicatulum</i>	0	571	0	0	0	0	4571	0	0	0	0	0	0	0	0	0
<i>Coscinodiscus concinnus</i>	2857	4000	32571	1714	7429	21143	0	6286	15429	30857	43429	6857	1143	6286	571	
<i>Coscinodiscus radiatus</i>	0	0	0	0	37115	0	0	0	0	0	0	0	0	0	0	0
<i>Chaetoceros debilis</i>	41200	477600	238800	12000	121600	164000	16800	127800	107200	225600	1836000	1641600	2134400	144018	10400	
<i>Chaetoceros decipiens</i>	11771	68229	170438	3429	34743	46857	9600	24343	30629	64457	87429	1993372	76229	183429	2971	
<i>Chaetoceros danicus</i>	5886	68229	34114	1714	17371	23429	800	12171	15314	32229	43714	1016229	38114	286	1486	
<i>Cyclotella spp.</i>	0	10849	18272	25124	11991	0	16559	30834	25124	23411	0	25695	50248	41112	0	
<i>Ditylum brightwellii</i>	0	0	0	0	1143	0	0	0	0	0	0	0	0	0	0	0
<i>Diatoma spp.</i>	0	0	0	0	571	0	0	0	0	1714	0	0	0	0	0	0
<i>Diploneis spp.</i>	571	0	0	0	0	0	0	0	0	2857	3429	1143	0	1143	0	0
<i>Eucampia cylindricornis</i>	0	0	5143	2286	571	4000	0	0	2857	0	4571	0	14857	0	3429	0
<i>Fragilaria spp.</i>	0	0	0	0	2286	571	0	0	0	0	0	0	0	0	0	0
<i>Guinardia delicatula</i>	0	571	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Guinardia flaccida</i>	0	0	0	0	18843	0	0	0	0	0	0	0	0	0	0	0
<i>Hemialus spp.</i>	571	0	25143	0	5714	0	0	571	4000	4571	0	0	0	0	0	0
<i>Lauderia spp.</i>	0	12571	0	4000	0	0	2857	6857	0	0	571	6857	1714	5714	0	0
<i>Leptocylindrus spp.</i>	2286	0	8571	0	16571	94857	16571	6857	87429	132000	64000	0	17714	0	9143	0
<i>Melosira spp.</i>	0	571	0	0	37115	0	0	0	0	0	571	0	0	0	0	0
<i>Navicula delicatula</i>	0	571	4571	571	1714	1714	571	1143	2857	4000	2857	10286	8571	5714	1714	0
<i>Nitzschia seriata</i>	5714	40543	38857	5714	26857	22286	5143	13714	15429	18286	18286	120571	214286	2124000	14857	0
<i>Odontella sinensis</i>	0	0	571	0	2286	1714	0	0	0	0	0	0	0	0	0	0
<i>Pseudonitzschia spp.</i>	0	0	588000	0	28571	62834	0	4000	5143	3429	24571	1302857	2201143	13143	0	0
<i>Pleurosigma indica</i>	1714	0	571	1143	2857	1714	0	0	571	571	1143	0	9143	0	571	0
<i>Rhizosolenia setigera</i>	5714	37714	16571	1143	132571	2857	0	571	0	3429	12000	571	43429	0	0	0
<i>Rhizosolenia delicatula</i>	0	0	0	0	11991	0	0	0	0	0	0	0	0	0	0	0
<i>Stephanophysis spp.</i>	0	0	7429	1143	0	82286	0	12571	84000	132000	0	0	1143	0	0	0
<i>Skeletonema costatum</i>	166286	569287	2288572	245143	644857	549143	205714	378286	575771	2128143	3197143	2142286	2308714	653224	1910857	0
<i>Thalassiosira decipiens</i>	5714	14857	26286	1714	21714	0	2286	571	7429	5143	270286	70286	13143	0	212571	0
<i>Thalassionema nitzschioides</i>	0	0	9714	0	0	0	1714	2286	0	12000	10857	0	9143	0	0	0
<i>Thalassiothrix spp.</i>	0	0	0	2286	571	0	0	0	1143	2857	0	0	12571	0	0	0
<i>Triceratium spp.</i>	571	0	571	0	0	0	0	0	0	0	571	0	571	0	0	0
Sub Total	253714	1306165	3519910	309695	1197912	1083976	284330	631720	980324	2827554	5621429	7060324	6257991	5366069	2181714	0
<b>DYNOPHYCEAE</b>																
<i>Ceratium longipes</i>	0	28575	22860	571	1143	44577	1143	0	48006	75438	49149	100584	113157	40005	96012	0
<i>Ceratium furca</i>	0	1143	36576	571	0	6858	0	0	10287	13716	69723	38862	138303	12573	108585	0
<i>Ceratium tripos</i>	0	0	0	0	571	0	0	571	0	0	0	0	0	0	0	0
<i>Ceratium fusus</i>	0	24003	33147	0	0	37719	0	0	13716	35433	25146	30861	30861	37719	50292	0
<i>Gymnodinium spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	13143	0	0	0
<i>Protoperidinium claudicans</i>	2286	571	6281	0	3426	34831	0	0	3426	34831	337461	126191	37686	97641	45109	0
<i>Dinophysis caudata</i>	0	0	17701	0	6281	0	0	0	0	0	0	0	18272	0	0	0
<i>Protocentrum micans</i>	0	5139	2855	0	571	6281	0	0	6281	6281	12562	6281	0	0	0	0
<i>cf. Alexandrium spp.</i>	0	571	571	0	1713	0	0	0	0	0	0	0	0	0	0	0
Sub Total	2286	60002	119991	1142	13705	130266	1143	571	81716	165699	494041	302779	351422	187938	299998	0
<b>CYANOPHYCEAE</b>																
<i>Trichodesmium spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	214286	0	0
<i>Spirulina spp.</i>	0	0	5143	0	0	21143	0	0	0	0	71375	980571	25695	5028572	0	0
Sub Total	0	0	5143	0	0	21143	0	0	0	0	71375	980571	25695	5242857	0	0
<b>CHLOROPHYCEAE</b>																
<i>Scenedesmus spp.</i>	0	0	0	0	0	0	0	0	0	0	0	16000	2271438	489918	0	0
<i>Netrium spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	311766	0	0
Sub Total	0	0	0	0	0	0	0	0	0	0	0	16000	2271438	801684	0	0
<b>TOTAL</b>	<b>256000</b>	<b>1366167</b>	<b>3645044</b>	<b>310837</b>	<b>1211617</b>	<b>1235385</b>	<b>285473</b>	<b>632291</b>	<b>1062040</b>	<b>2993253</b>	<b>6186845</b>	<b>8359674</b>	<b>8906546</b>	<b>11598548</b>	<b>2481712</b>	<b>0</b>

**App.9. List of phytoplankton species and their abundances (cells l<sup>-1</sup>) during February 2001 sampling in Jakarta Bay.**

Phytoplankton	stations												Marunda	Priok	Angke		
	1	2	3	4	5	6	7	8	9	10	11	12					
<b>BACILLARIOPHYCEAE</b>																	
<i>Asterionella</i> spp.	6286	49143	59429	0	45714	73714	72571	125714	323429	345714	60571	0	22857	0	0	0	
<i>Bacteriastrum furcatum</i>	4571	9143	14857	145714	16000	8571	13714	10286	13714	36571	4571	0	0	0	0	0	
<i>Cerataulina</i> spp.	571	0	0	0	571	0	0	0	0	0	0	0	0	0	0	0	
<i>Coscinodiscus wailesii</i>	571	2286	9143	5139	571	5714	571	1143	19429	21714	12571	9714	9143	5714	3429		
<i>Chaetoceros debilis</i>	533714	1121143	532571	203429	979429	1877714	188714	723429	866286	972000	2310857	114286	342857	603429	19200		
<i>Chaetoceros decipiens</i>	106743	224229	106514	30514	195886	375543	37743	144686	173257	194400	462171	22857	68571	120686	3840		
<i>Chaetoceros danicus</i>	53371	112114	53257	61029	97943	18777	1887	72343	86629	97200	231086	11429	34286	60343	1920		
<i>Corethron</i> spp.	0	0	0	0	0	0	0	0	0	571	0	0	0	0	0	0	
<i>Cyclotella</i> spp.	0	0	0	12562	0	0	0	0	0	571	0	0	0	0	0	0	
<i>Ditylum brightwellii</i>	0	0	0	0	0	0	0	0	0	0	571	0	0	0	0	0	
<i>Eucampia cylindricornis</i>	0	1143	0	2857	0	0	0	0	0	0	2857	0	0	0	0	0	
<i>Fragilaria</i> spp.	0	0	0	0	0	0	0	0	0	24000	571	0	0	0	0	0	
<i>Guinardia delicatula</i>	0	0	0	13133	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Guinardia flaccida</i>	32000	232571	112000	16571	134286	207429	224571	245714	81143	138857	88571	6857	4571	0	6857		
<i>Hemialus</i> spp.	1714	16000	21714	1713	8571	6857	21143	6857	29714	10857	0	0	0	0	0	0	
<i>Lauderia</i> spp.	0	12571	65143	0	0	13714	8000	46857	24000	36000	0	18286	41143	0	13714		
<i>Leptocylindrus</i>	4571	42286	34286	6286	0	305143	6857	125714	98286	21714	35429	37143	45714	11429	30857		
<i>Navicula delicatula</i>	0	2286	2857	0	1714	0	3429	1143	0	3429	2857	0	0	0	1143		
<i>Nitzschia</i> spp.	46286	87429	76571	21714	122857	101714	89714	115429	70857	106286	46857	68000	18286	44571	9143		
<i>Odontella sinensis</i>	0	5714	4000	5143	0	571	4000	6857	3429	571	2286	24571	2286	0	0	0	
<i>Odontella aurita</i>	0	0	0	2855	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Pseudonitzschia</i>	0	0	0	3426	0	4571	17714	0	24000	0	0	0	0	0	0	0	
<i>Pleurosigma normanii</i>	1143	0	1143	2857	0	0	0	0	0	6857	0	0	0	0	4571		
<i>Rhizosolenia setigera</i>	0	0	0	1142	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Rhizosolenia indica</i>	10857	18286	12000	17143	6286	6857	18857	13714	46857	57714	4571	9714	9143	5714	2286		
<i>Skeletonema costatum</i>	466857	710571	1E+06	356571	53143	1947429	538286	1960000	2428572	2166286	1531714	3197714	3997143	1414286	2E+06		
<i>Thalassiosira decipiens</i>	4571	25714	58286	4571	20000	28000	20571	28571	0	42286	102857	18857	25143	0	24000		
<i>Thalassionema nitzschioides</i>	3429	16000	41714	4571	42857	28000	22857	2286	0	4000	5143	0	0	0	0		
<i>Thalassiothrix</i> spp.	1143	9143	12571	571	3429	29714	6857	4571	28571	3429	9143	0	29714	0	0		
<i>Triceratium</i> spp.	0	0	0	571	0	0	0	0	0	0	0	0	0	0	0	0	
Sub Total	1278400	2697772	2699886	920083	1729257	5040035	1298058	3635314	4318172	4284172	4922115	3539429	4650857	2266172	2289532		
<b>DYNOPHYCEAE</b>																	
<i>Ceratium longipes</i>	1713	24553	0	0	1713	0	571	0	0	150876	128016	0	18272	17701	13133		
<i>Ceratium furca</i>	571	37686	6852	13133	1713	1143	571	0	0	0	50248	0	0	0	0		
<i>Ceratium tripos</i>	571	1	0	0	0	0	1713	1713	0	0	571	36544	5710	12562	37686		
<i>Ceratium fusus</i>	0	0	0	0	0	0	0	0	0	0	0	22269	1142	0	1142		
<i>Scripsiella trochoidea</i>	0	0	0	0	0	0	0	0	0	0	0	1142	571	0	0		
<i>Gymnodinium</i> spp.	0	0	0	0	0	571	0	0	571	571	2855	37686	1142	56529	0		
<i>Noctiluca scintillans</i>	0	0	0	0	0	0	1142	1142	1142	1142	1142	0	1142	1142	1142		
<i>Protoperdinium claudicans</i>	0	0	0	3426	0	1714	0	0	0	571	2284	0	0	0	0		
<i>Dinophysis caudata</i>	0	0	0	0	0	0	0	41683	3429	6857	2284	5139	73659	52532	10849		
<i>Protocentrum micans</i>	0	0	571	571	0	0	0	1143	0	571	23982	0	0	0	0		
<i>cf. Alexandrium</i> spp.	0	0	0	0	0	0	0	0	0	571	2284	0	0	0	0		
Sub Total	2855	62240	7423	17130	3426	3429	3997	45681	5142	161160	213666	102780	101638	140466	63952		
<b>CYANOPHYCEAE</b>																	
<i>Trichodesmium erythraeum</i>	1143	0	0	0	0	0	1714	0	0	0	0	0	0	0	0		
<i>Spirulina</i> spp.	0	0	0	0	0	91429	0	0	0	0	0	434286	75429	3457143	5710		
<i>Oscillatoria</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Sub Total	1143	0	0	0	0	91429	1714	0	0	0	0	434286	75429	3457143	5710		
<b>CHLOROPHYCEAE</b>																	
<i>Scenedesmus</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	5714	0		
<i>Netrium</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1143	0		
Sub Total	0	0	0	0	0	0	0	0	0	0	0	0	0	6856.9	0		
<b>TOTAL</b>	1282398	2760012	2707309	937214	1732683	5134892	1303769	3680995	4323313	4445332	5135781	4076494	4827924	5870637	2359194		

**App.10. List of phytoplankton species and their abundances (cells l<sup>-1</sup>) during April 2001 sampling in Jakarta Bay.**

Phytoplankton	stations														
	1	2	3	4	5	6	7	8	9	10	11	12	Marunda	Priok	Angke
<i>Asterionella</i> spp.	0	0	0	0	571	0	0	2286	0	0	0	0	1143	0	2286
<i>Bacteriastrum furcatum</i>	0	1143	14846	15988	2286	2286	0	0	2286	1143	18272	12562	0	0	0
<i>Bacteriastrum hyalinum</i>	0	0	40541	0	0	0	0	0	0	0	3426	2284	118768	0	0
<i>Cerataulina</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Coscinodiscus radiatus</i>	8052	11991	18272	7994	17701	12562	5139	11991	12562	24553	21127	26266	14846	14846	0
<i>Coscinodiscus concinnus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	6852	0
<i>Chaetoceros debilis</i>	41600	721600	1162133	104000	161700	64400	12000	100800	772800	50001	86400	42825	282074	2E+06	653224
<i>Chaetoceros decipiens</i>	23771	824686	664076	89143	68571	73600	3429	28800	441600	28571	24686	59384	0	0	24229
<i>Chaetoceros danicus</i>	11886	412343	332038	44571	34286	36800	1714	14400	220800	14286	12343	7423	0	326612	12114
<i>Cyclotella</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	560722	0	0
<i>Ditylum brightwellii</i>	50248	0	56529	371150	0	18272	18272	37686	22269	34831	46822	0	0	0	14846
<i>Diatoma</i> spp.	51961	0	0	178152	0	0	0	0	0	0	0	0	0	0	0
<i>Diploneis</i> spp.	69091	23411	29692	0	0	0	0	0	0	0	0	0	0	0	0
<i>Eucampia cylindricornis</i>	0	0	0	0	0	0	0	0	0	18843	0	0	0	0	0
<i>Fragilaria cylindrus</i>	0	12562	0	2286	3429	0	0	0	0	0	0	102857	460226	0	0
<i>Guinardia delicatula</i>	0	0	0	0	0	0	0	0	0	0	0	0	133614	0	0
<i>Guinardia flaccida</i>	50819	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lauderia</i>	1143	0	4571	571	0	8000	0	3429	3429	11429	12571	0	2286	0	89076
<i>Meuniera membranacea</i>	0	0	0	0	0	0	0	12562	0	0	0	0	89076	25124	14846
<i>Navicula delicatula</i>	0	0	0	0	0	0	23982	0	1143	0	0	0	237536	0	0
<i>Nitzschia</i> spp.	0	17701	23982	9707	11991	0	18272	33689	0	0	0	0	311766	653224	44538
<i>Odontella sinensis</i>	0	12562	23411	0	2286	1714	0	0	0	0	0	0	0	0	0
<i>Pseudonitzschia</i> spp.	237536	979836	816530	96571	134571	816530	126857	965714	376000	1766286	1400000	91714	237536	816530	653224
<i>Pleurosigma indica</i>	0	0	0	0	3429	2286	1143	0	0	0	0	5143	14846	0	0
<i>Rhizosolenia setigera</i>	5714	8000	9143	2286	4000	5714	29714	2286	1143	4571	4571	3429	178152	0	41143
<i>Skeletonema costatum</i>	54857	353143	2370286	8000	60000	836571	222857	803713	577143	31405	2586000	801429	507048	255808	1205952
<i>Thalassiosira decipiens</i>	0	0	0	0	0	0	0	0	0	0	0	0	2E+06	0	0
<i>Thalassionema nitzschioides</i>	0	414857	5714	2857	0	25143	1143	6857	4571	17143	28571	0	74230	0	1380678
<i>Thalassiothrix</i> spp.	1143	4571	0	0	0	6857	12571	20571	10286	18286	0	0	2286	0	0
<i>Triceratium</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub Total	607821	3798406	5571765	933277	504821	1910735	477093	2044784	2446031	2021347	4244790	1155315	4734165	4058668	4136155
<b>DYNOPHYCEAE</b>															
<i>Ceratium longipes</i>	14846	13133	14846	50248	0	51961	0	0	0	0	29692	44538	0	0	44538
<i>Ceratium furca</i>	0	29692	22269	18272	29692	18272	7423	44538	29692	905606	59384	0	18843	15988	50248
<i>Ceratium tripos</i>	6852	0	0	46251	0	0	7994	0	0	0	0	0	0	0	0
<i>Ceratium fusus</i>	0	10849	0	0	0	0	0	0	0	0	0	0	14846	11991	0
<i>Gymnodinium</i> spp.	0	0	0	0	0	0	0	0	0	1143	0	0	0	0	0
<i>Noctiluca scintillans</i>	0	0	0	0	0	1143	0	0	0	0	0	0	0	0	0
<i>Protoperdinium claudica</i>	0	0	0	0	0	0	0	0	10278	6852	6857	16559	0	18272	12562
<i>Dinophysis caudata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	59384
<i>Protocentrum micans</i>	0	0	0	0	0	0	0	0	5143	9143	0	0	1714	14275	12562
<i>Alexandrium</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub Total	21698	53674	37115	114771	29692	71376	15417	44538	45113	922744	95933	61097	35403	60526	179294
<b>CYANOPHYCEAE</b>															
<i>Trichodesmium</i> spp.	0	0	0	0	0	0	0	0	0	0	0	127429	0	203429	0
<i>Spirulina</i> spp.	0	0	0	0	0	68568	0	5714	72000	0	0	2274286	45714	5120000	57143
Sub Total	0	0	0	0	0	68568	0	5714	72000	0	0	2401714	45714	5323429	57143
<b>CHLOROPHYCEAE</b>															
<i>Scenedesmus</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	311766	5714	0
<i>Netrium</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1143	0
Sub Total	0	0	0	0	0	0	0	0	0	0	0	0	311766	6857	0
<b>TOTAL</b>	<b>607936</b>	<b>3798521</b>	<b>5571880</b>	<b>933392</b>	<b>504936</b>	<b>1979418</b>	<b>477208</b>	<b>2050613</b>	<b>2518146</b>	<b>2021462</b>	<b>4244905</b>	<b>3557145</b>	<b>5091761</b>	<b>9389069</b>	<b>4193413</b>

**App.11. List of phytoplankton species and their abundances (cells l<sup>-1</sup>) during July 2001 sampling in Jakarta Bay.**

Phytoplankton	stations												Marunda	Priok	Angke
	1	2	3	4	5	6	7	8	9	10	11	12			
<i>Asterionella</i> spp.	0	0	0	0	0	100571	0	0	0	0	0	2286	0	0	0
<i>Bacteriastrum furcatum</i>	0	0	1143	0	6857	99429	114286	52571	684657	18286	1143	0	9143	0	0
<i>Bacteriastrum delicatulum</i>	0	571	571	0	0	0	0	0	571	571	571	3426	571	571	3429
<i>Cerataulina</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Coscinodiscus radiatus</i>	11429	3429	0	5714	8000	30857	5714	34286	77714	32000	4571	12571	14846	30857	4571
<i>Coscinodiscus concinnus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Chaetoceros debilis</i>	15200	1600	17600	26400	19200	330400	21600	158400	842400	1630400	64000	15200	51200	437935	392151
<i>Chaetoceros decipiens</i>	4343	457	5029	7543	5486	94400	6171	45257	240686	465829	18286	4343	14629	125124	112043
<i>Chaetoceros danicus</i>	2171	571	2514	3771	2743	47200	3086	22629	120343	232914	9143	2171	7314	62562	56022
<i>Corethron</i> spp.	0	1143	6857	0	4571	0	1143	0	2286	0	0	0	0	1143	1143
<i>Cyclotella</i> spp.	0	9136	12562	0	0	0	0	0	50292	14275	10849	7994	14846	10849	11991
<i>Ditylum brightwellii</i>	571	0	0	1143	0	0	0	4571	24003	6852	11991	7994	571	1142	1142
<i>Diatoma</i> spp.	0	0	0	1143	0	0	0	4571	0	0	0	0	0	0	0
<i>Eucampia cylindricornis</i>	0	0	0	0	0	1143	0	2286	0	0	0	0	0	0	0
<i>Fragilaria</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Guinardia delicatula</i>	2286	11429	13714	0	1143	3429	0	5714	21714	38857	54857	5714	0	0	0
<i>Guinardia flaccida</i>	1143	1143	0	0	571	0	0	571	36576	11991	6852	14846	10278	6281	11991
<i>Hemialus</i> spp.	0	38857	13714	0	0	0	0	2286	0	5714	0	0	0	0	6857
<i>Lauderia</i> spp.	0	11429	0	0	0	144000	0	30857	28571	0	22857	0	105143	185143	2286
<i>Leptocylindrus</i> spp.	21714	0	0	285714	971429	124571	3429	84571	105143	93714	123429	113143	0	0	0
<i>Melosira</i> spp.	3429	13714	19429	0	0	3429	0	196571	1143	48000	98286	0	294857	69714	0
<i>Meuniera membranaceae</i>	571	2286	24003	0	571	0	0	571	28575	5139	11991	1713	0	571	0
<i>Navicula delicatula</i>	0	36571	52571	0	1143	3429	0	2286	0	2286	88000	75429	86857	0	0
<i>Nitzschia</i> spp.	2286	2286	5714	22857	8000	57143	0	74286	101714	80000	2286	112000	125714	13714	1143
<i>Odontella sinensis</i>	0	1143	0	0	2286	6857	1143	24000	0	6857	1143	5714	0	0	0
<i>Odontella aurita</i>	571	571	0	571	571	571	0	0	0	0	0	571	0	0	0
<i>Planktoniella</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	57143	0
<i>Pseudonitzschia</i> spp.	0	0	0	0	0	141714	0	53714	109714	338286	4571	26286	745143	34286	0
<i>Pleurosigma indica</i>	1143	0	0	4571	0	0	0	1143	5714	5715	0	2286	0	16000	4571
<i>Rhizosolenia setigera</i>	5714	4571	8000	2286	10286	99429	9143	118857	82286	228571	11429	0	112000	8000	0
<i>Rhizosolenia indica</i>	571	571	1143	0	0	1143	0	1143	571	571	1143	571	1143	1143	571
<i>Streptothecca</i> spp.	18286	0	0	1143	0	2286	3429	1143	3429	0	0	0	0	0	0
<i>Stephanophysis</i> spp.	0	0	0	0	0	170286	4571	0	27429	91429	5714	36571	68571	62857	0
<i>Skeletonema costatum</i>	61143	926895	1416857	171433	270476	689714	428571	1162667	1046400	697600	1113143	880000	130286	84571	1966476
<i>Thalassiosira decipiens</i>	0	1049143	1053143	2286	2286	0	0	0	80000	82286	58286	49143	653224	9143	3683429
<i>Thalassionema nitzschioides</i>	1143	0	0	0	0	0	0	21714	250317	9143	0	0	0	0	0
<i>Thalassiothrix</i> spp.	1143	0	0	0	0	0	0	21714	8000	9143	0	0	0	0	0
<i>Triceratium</i> spp.	0	0	0	0	0	0	0	1143	0	36571	1143	0	0	0	0
Sub Total	154855	2117516	2654565	536576	1315618	2152000	605714	2131809	3985963	4181570	1727968	1377686	2462336	1207321	6256387
<b>DYNOPHYCEAE</b>															
<i>Ceratium longipes</i>	2286	0	3429	0	0	0	1143	0	1143	0	4571	0	0	0	0
<i>Ceratium furca</i>	1143	571	5715	0	571	571	11428	0	58293	0	1143	1143	1143	1143	571
<i>Ceratium tripos</i>	0	571	571	0	1143	571	571	0	4572	0	0	0	0	0	0
<i>Ceratium fusus</i>	0	0	0	0	0	571	1143	571	0	571	0	0	0	0	571
<i>Gymnodinium</i> spp.	0	0	3429	0	1143	0	0	0	3429	2286	1143	0	0	0	0
<i>Goniaulax</i> spp.	571	0	0	0	0	0	0	0	5715	0	0	0	0	0	0
<i>Noctiluca scintillans</i>	1143	24000	1224000	0	2286	0	0	0	252603	482286	299429	486857	1446857	898286	486857
<i>Protoperidinium claudicans</i>	0	0	1143	0	0	0	0	0	148571	0	0	0	0	0	0
<i>Dinophysis caudata</i>	0	0	0	0	0	1143	0	0	36576	0	0	0	0	0	0
<i>Protocentrum micans</i>	0	10286	9143	0	0	1143	0	0	37719	2286	4571	0	0	0	0
Sub Total	5143	35428	1247429	0	5143	3999	14285	571	548621	487428	310857	488000	1448000	899429	487999
<b>CYANOPHYCEAE</b>															
<i>Trichodesmium</i> spp.	0	0	0	0	0	1143	0	0	0	0	0	210286	0	2149714	0
<i>Spirulina</i> spp.	0	0	0	0	0	0	0	0	0	0	0	9143	27429	21714	2286
<i>Oscillatoria</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	1202526	0	0
Sub Total	0	0	0	0	0	1143	0	0	0	0	0	219429	1229955	2171429	2286
<b>CHLOROPHYCEAE</b>															
<i>Halosphaeria</i> spp.	0	0	0	0	0	0	0	0	1143	0	0	0	0	0	0
<i>Scenedesmus</i> spp.	0	0	0	0	0	0	0	0	0	0	0	4571	0	3429	0
Sub Total	0	0	0	0	0	0	0	0	1143	0	0	4571	0	3429	0
<b>TOTAL</b>	<b>159998</b>	<b>2152944</b>	<b>3901994</b>	<b>536576</b>	<b>1320760</b>	<b>2157141</b>	<b>619999</b>	<b>2132380</b>	<b>4535727</b>	<b>4668999</b>	<b>2038826</b>	<b>2089687</b>	<b>5140291</b>	<b>4281607</b>	<b>6746671</b>

**App.12. List of phytoplankton species and their abundances (cells l<sup>-1</sup>) during September 2001 sampling in Jakarta Bay.**

	stations													Marunda	Priok	Angke
Phytoplankton	1	2	3	4	5	6	7	8	9	10	11	12	Marunda	Priok	Angke	
<b>BACILLARIOPHYCEAE</b>																
<i>Bacteriastrum furcatum</i>	0	89076	44538	1143	0	296920	1143	186309	1143	2286	0	0	0	0	0	
<i>Bacteriastrum delicatulu</i>	0	0	0	0	0	0	0	25146	0	59436	0	0	0	0	0	
<i>Cerataulina spp.</i>	48000	0	4571	0	0	0	0	0	0	0	0	2286	0	1143	0	
<i>Coscinodiscus wailesii</i>	4571	1143	0	6857	10286	0	8000	36576	2286	19431	0	9143	43429	8000	22857	
<i>Coscinodiscus radiatus</i>		89076	44538			30834				9144						
<i>Chaetoceros debilis</i>	0	2701972	3295812	0	0	3064710	0	366903	0	1123569	0	1306448	0	0	0	
<i>Chaetoceros decipiens</i>	0	29692	44538	0	0	11991	0	141732	0	252603	0	0	0	0	0	
<i>Chaetoceros danicus</i>	0	237536	0	0	0	760095	0	59436	0	75438	0	0	0	0	0	
<i>Corethron spp.</i>	0	0	0	0	0	0	1143	0	0	0	0	2286	0	0	6857	
<i>Cyclotella spp.</i>	0	59384	44538	0	0	14846	0	0	0	0	0	0	0	0	0	
<i>Ditylum spp.</i>	0	192998	14846	0	0	0	0	0	0	2286	0	0	0	0	0	
<i>Diatoma spp.</i>	0	0	0	1143	0	0	0	0	0	0	0	0	0	0	0	
<i>Eucampia cylindricornis</i>	1143	207844	17143	0	0	18272	0	0	0	0	36571	0	0	0	0	
<i>Fragilaria spp.</i>	0	0	0	0	0	0	0	0	1143	0	0	0	0	0	0	
<i>Guinardia delicatula</i>	5714	237536	89076	0	11429	5714	0	0	0	10287	0	0	0	0	0	
<i>Guinardia flaccida</i>		59384	29692			14846	0	0	0	5715	0	0	0	0	0	
<i>Hemialus spp.</i>	0	28571	44538	0	0	11991	0	0	0	9144	6857	5714	0	1143	0	
<i>Hyalodiscus spp.</i>	3429	1143	0	0	0	0	0	0	0	0	0	0	1143	0	34286	
<i>Isthmia spp.</i>	0	0	0	0	0	0	0	1143	0	0	0	0	0	0	0	
<i>Lauderia spp.</i>	14857	0	0	0	201143	0	0	2286	0	0	6857	0	0	0	8000	
<i>Leptocylindrus spp.</i>	0	0	0	0	0	0	11429	29714	29714	0	0	0	0	0	0	
<i>Melosira spp.</i>	11429	0	0	0	0	6857	9143	2286	0	0	22857	0	26286	0	2286	
<i>Meuniera membranacea</i>	0	44538	59384			18272	0	0	0	32004	0	0	0	0	0	
<i>Navicula delicatula</i>	18286	0	29692	0	0	12562	0	3429	0	12573	10286	4571	0	2286	0	
<i>Nitzschia spp.</i>	1143	59384	59384	6857	6857	0	1143	30857	10286	0	0	112000	297143	62857	2286	
<i>Odontella sinensis</i>	0	0	0	0	0	0	0	2286	2286	0	0	0	3429	0	1143	
<i>Planktoniella spp.</i>	0	0	0	0	0	13133	0	0	0	0	90286	0	0	0	0	
<i>Pseudonitzschia spp.</i>	3429	89076	178152	0	1143	4571	0	882396	14857	1092708	4571	8000	21714	6857	9143	
<i>Pleurosigma normanii</i>	0	2286	0	0	1143	0	0	1143	0	0	1143	0	0	1143	0	
<i>Rhizosolenia setigera</i>	2286	0	29692	2286	3429	10278	3429	4571	9143	6858	2286	10286	28571	18286	2286	
<i>Rhizosolenia indica</i>	0	44538	74230	0	0	0	0	0	0	10287	0	0	0	0	0	
<i>Rhabdonema spp.</i>	0	0	0	0	0	0	0	1143	0	0	0	0	0	0	0	
<i>Streptothea spp.</i>	4571	0	0	0	0	10849	0	0	0	0	0	0	0	0	0	
<i>Stephanophysis spp.</i>	18286	0	0	0	10286	0	0	0	0	5714	0	0	0	4571	0	
<i>Skeletonema costatum</i>	1914921	4424108	4839796	282286	694857	2411730	137143	0	0	91440	8720000	7451429	1068571	2137143	11265306	
<i>Thalassiosira decipiens</i>	11429	99429	189714	0	0	59384	0	6857	3429	1143	520000	86857	9143	6857	272000	
<i>Thalassionema nitzschic</i>	0	0	133614	0	0	0	0	0	0	60579	0	0	0	0	0	
<i>Thalassionema frauenfe</i>	0	0	0	0	0	0	0	3429	3429	2286	1143	0	8000	84571	0	
<i>Triceratium spp.</i>	0	0	14846	0	0	14846	0	2286	0	0	0	0	0	0	0	
Sub Total	2063492	8698713	9282335	300571	940571	6792702	178286	1789927	74286	2884931	9420571	9002448	1505143	2334857	11625306	
<b>DYNOPHYCEAE</b>																
<i>Alexandrium spp.</i>	0	0	0	0	1143	7994	1143	0	0	0	0	0	0	1143	0	
<i>Ceratium longipes</i>	0	0	0	0	0	0	0	0	0	5710	5710	5710	0	5710	1143	
<i>Ceratium furca</i>	1143	89076	29692	5714	1143	12562	5710	3429	5710	10287	1143	9143	5710	5710	5710	
<i>Ceratium tripos</i>	0	0	5714	5714	1143	0	1143	0	1143	2286	5710	5710	1143	1143	5710	
<i>Ceratium fusus</i>	1143	29692	1143	0	1143	0	1143	1143	0	1143	0	0	0	0	1143	
<i>Sciepsiella trochoidea</i>	3429	0	0	0	0	13714	5710	0	0	2286	0	0	1143	0	0	
<i>Gymnodinium spp.</i>	0	5714	5714	0	0	1143	1143	4571	1143	0	2286	3429	0	2286	13714	
<i>Noctiluca scintillans</i>	0	29692	59384	1143	2286	29692	0	6858	0	598932	0	0	0	0	2286	
<i>Protoperdinium claudica</i>	0	59384	34286	1143	0	14846	0	1143	2286	3429	0	0	0	0	12571	
<i>Peridinium spp.</i>	0	44538	44538		571	13133	571	0	0	0	571	571	1143	1143	1143	
<i>Dinophysis caudata</i>	0	14846	14846	2286	0	5710	0	1143	0	1143	0	0	0	0	0	
<i>Prorocentrum micans</i>	0	44538	0	0	5710	9136	0	1143	0	6858	9143	0	1143	0	0	
<i>Prorocentrum lima</i>	0	29692	1143	0	0	6852	571	1143	1143	2286	1143	1143	1143	0	1143	
<i>Prorocentrum tristinum</i>	0	0	0	0	0	0	0	0	0	3429	0	0	0	0	0	
Sub Total	5714	347172	196460	15999	13139	114782	17134	20573	17135	637789	25706	19996	11996	11425	44563	
<b>CYANOPHYCEAE</b>																
<i>Trichodesmium spp.</i>	0	13716	0	6857	9143	0	1143	0	0	0	0	24000	114286	457143	0	
<i>Spirulina spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	133614	
<i>Oscillatoria spp.</i>	0	0	0	0	0	118768	0	0	0	0	0	0	0	0	0	
Sub Total	0	13716	0	6857	9143	118768	1143	0	0	0	0	24000	114286	457143	133614	
<b>CHLOROPHYCEAE</b>																
<i>Halosphaeria spp.</i>	0	0	8000	1143	0	0	0	0	0	0	0	0	2286	0	0	
<i>Netrium spp.</i>	0	0	0	0	0	63952	0	0	0	0	0	0	1143	0	0	
<i>Closteridium spp.</i>	0	0	0	0	0	0	0	0	0	0	0	3429	6857	3429	0	
Sub Total	0	0	8000	1143	0	63952	0	0	0	0	0	3429	10286	3429	0	
<b>TOTAL</b>	2069207	9059602	9486794	324571	962853	7090204	196563	1810500	91420	3522720	9446277	9049872	1641710	2806853	11803483	

**App.13. List of phytoplankton species and their abundances (cells l<sup>-1</sup>) during November 2001 sampling in Jakarta Bay.**

Phytoplankton	station												Marunda	Priok	Angke		
	1	2	3	4	5	6	7	8	9	10	11	12					
<b>BACILLARYOPHYCEAE</b>																	
<i>Asterionella</i> spp.	0	0	0	1143	0	0	0	9143	0	1143	0	1143	0	0	0	0	0
<i>Bacteriastrium furcatum</i>	0	0	0	6857	0	0	4571	0	0	0	0	0	0	0	0	0	0
<i>Bacteriastrium delicatulum</i>	0	0	0	14859	0	0	19431	0	0	0	0	0	0	0	0	0	0
<i>Coscinodiscus radiatus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	638378
<i>Coscinodiscus concinnus</i>	0	12573	0	0	0	0	14859	0	0	0	0	0	0	3429	2286	430534	
<i>Coscinodiscus radiatus</i>	0	4571	44538	0	0	0	20571	5714	13714	2286	9143	24000	3429	16000	105143		
<i>Chaetoceros debilis</i>	1143	100571	133614	10286	0	0	13714	0	0	0	59436	365714	0	0	0	0	0
<i>Cyclotella</i>	0	0	178152	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ditylum brightwellii</i>	0	20571	0	13714	1143	4571	0	0	0	0	0	0	0	0	0	0	0
<i>Eucampia cylindricornis</i>	1143	1143	125714	6857	13714	38857	0	3429	9143	4571	203429	86857	0	0	0	253714	
<i>Guinardia delicatula</i>	0	0	2286	10286	3429	6857	13714	0	8000	0	0	0	0	0	0	0	0
<i>Hemialus</i> spp.	0	0	9143	0	0	0	0	41143	0	0	6858	0	0	0	0	0	0
<i>Lauderia</i> spp.	0	6857	0	6857	0	0	0	0	2286	2286	0	0	4571	0	0	0	0
<i>Leptocylindrus</i> spp.	0	73143	0	18286	0	0	0	0	9143	0	0	0	0	0	2286	0	0
<i>Melosira</i> spp.	6857	0	221714	0	69714	0	0	34286	0	0	96000	0	0	0	0	0	0
<i>Meuniera membranaceae</i>	0	0	0	0	0	0	0	0	0	0	2286	0	0	0	0	0	0
<i>Navicula delicatula</i>	0	0	0	0	0	0	54857	115429	12571	35429	0	0	0	0	0	796545	
<i>Nitzschia seriata</i>	3429	0	0	2286	2286	38857	49143	0	1143	0	4571	4571	5714	233143	2286		
<i>Odontella sinensis</i>	0	0	16000	0	2286	4571	0	0	0	0	0	0	0	0	0	0	0
<i>Odontella aurita</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Planktoniella</i> spp.	0	0	0	24000	0	0	0	0	0	12571	333714	86857	12571	0	571429		
<i>Pseudonitzschia</i> spp.	0	292571	1855750	20571	80000	506286	258286	13714	26286	1306448	22857	13714	0	1143142	1440062		
<i>Pleurosigma indica</i>	0	0	0	0	0	0	0	0	0	0	1143	0	3429	0	0	0	0
<i>Rhizosolenia setigera</i>	9143	4571	831376	9143	11429	36571	51429	4571	8000	0	6857	10286	0	2286	0	0	0
<i>Skeletonema costatum</i>	678857	2428571	8773986	1163429	4805714	3931810	1484143	6477061	6860571	11270204	8292000	9051429	4205714	1984000	5952000		
<i>Thalassiosira decipiens</i>	3429	0	226286	6857	16000	51429	60571	34286	161143	73143	189714	86857	0	475072	41143		
<i>Thalassionema nitzschioides</i>	3429	0	9143	44571	10286	3429	0	0	9143	0	36576	0	0	0	0	0	0
<i>Triceratium</i> spp.	0	0	0	1143	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub Total	707429	2945144	12427702	1361145	5016000	4623238	2045290	6738776	7121143	12708081	9264585	9731429	4238857	3858214	10231233		
<b>DYNOPHYCEAE</b>																	
<i>Ceratium longipes</i>	0	0	0	0	0	0	5715	0	27432	24003	0	0	0	0	0	36576	
<i>Ceratium furca</i>	9143	12571	12571	5714	20571	27432	1143	14857	20572	3429	4571	3429	0	6857	5143		
<i>Ceratium tripos</i>	0	0	3429	0	0	0	0	0	0	0	0	17145	24003	44538	0	0	0
<i>Ceratium fusus</i>	0	2286	0	0	0	24003	0	0	0	0	0	0	0	14846	0	0	0
<i>Sciepsiella trochoidea</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gymnodinium</i> spp.	0	0	2286	0	0	0	0	2286	10286	42254	6857	3429	23982	56529	54245		
<i>Goniaulax</i> spp.	0	0	0	0	0	0	0	0	0	18272	10849	0	0	0	0	0	0
<i>Noctiluca scintillans</i>	0	0	2286	0	25143	10287	0	1143	0	14846	0	0	1143	0	0	0	0
<i>Protoperidinium claudicans</i>	0	1143	1143	0	0	0	0	0	14859	18286	3429	12573	1143	1143	24553		
<i>Dinophysis caudata</i>	0	571	571	0	0	0	0	0	21717	0	1143	0	571	10849	571		
<i>Protocentrum micans</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Prorocentrum lima</i>	0	0	0	0	0	0	0	0	0	0	1143	0	0	0	0	0	0
<i>Prorocentrum tristrinum</i>	0	0	0	0	0	0	0	0	0	0	1143	0	0	0	0	0	0
Sub Total	9143	16571	22285	5714	45714	61722	6858	18286	94866	121089	29136	36575	50842	134762	121088		
<b>CYANOPHYCEAE</b>																	
<i>Trichodesmium</i> spp.	0	0	0	0	0	0	2286	0	0	0	0	0	0	0	0	0	0
<i>Spirulina</i> spp.	0	0	0	0	0	0	0	0	0	445714	0	262857	297143	3497143	12562		
Sub Total	0	0	0	0	0	0	2286	0	0	445714	0	262857	297143	3497143	12562		
<b>CHLOROPHYCEAE</b>																	
<i>Scenedesmus</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	638378	
Sub Total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	638378	
<b>TOTAL</b>	<b>716571</b>	<b>2961715</b>	<b>12449987</b>	<b>1366859</b>	<b>5061714</b>	<b>4684960</b>	<b>2054434</b>	<b>6757061</b>	<b>7216008</b>	<b>13274884</b>	<b>9293720</b>	<b>10030861</b>	<b>4586842</b>	<b>7490119</b>	<b>11003261</b>		



**App.14. List of phytoplankton species and their abundances (cells l<sup>-1</sup>) during January 2001 sampling in Lampung Bay.**

Phytoplankton	stations																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	KK	WL	
<b>BACILLARYOPHYCEAE</b>																		
<i>Achnantes</i> spp.	0	0	0	571	571	571	0	0	571	0	0	1142	1142	11420	41112	13133	17130	
<i>Amphora libyca</i>	0	0	0	0	0	0	571	0	0	571	0	1142	5710	12562	62810	0	0	
<i>Asterionelopsis glacialis</i>	1142	1142	0	1142	0	571	0	571	2284	1142	571	0	5710	0	0	571	0	
<i>Bacillaria</i> spp.	0	0	0	0	0	0	0	0	0	1142	0	0	0	0	0	0	0	
<i>Bacteriastrium furcatum</i>	0	1713	0	2855	0	0	0	1142	571	286	0	1142	0	0	36544	0	0	
<i>Bacteriastrium hyalinum</i>	286	0	0	3426	0	0	0	571	1142	0	286	1142	0	0	10278	0	0	
<i>Brockmanniella</i> spp.	0	0	0	1142	0	0	0	0	1142	0	0	0	0	0	0	0	0	
<i>Chaetoceros decipiens</i>	767424	400842	243124	981179	43872	216161	571	29692	54816	5710	5710	141037	16559	14846	894186	1306448	282645	
<i>Chaetoceros danicus</i>	92502	123336	6852	6398	37686	74230	41112	3997	42825	5710	0	133614	0	3426	328896	15417	9136	
<i>Chaetocheros debilis</i>	0	178152	38286	17714	99429	1143	17714	159429	37686	1142	15417	43396	0	6852	41112	0	0	
<i>Cocconeis</i> spp.	0	0	0	0	0	0	0	0	0	0	0	1142	0	0	0	0	0	
<i>Corethron</i> spp.	0	0	0	0	0	0	0	0	0	0	0	1142	0	0	0	0	0	
<i>Coscinodiscus radiatus</i>	29692	2286	2286	571	571	571	571	571	571	2855	0	29692	571	0	5139	0	0	
<i>Coscosira</i> spp.	0	0	0	10511	0	0	0	0	0	0	0	0	0	0	0	18843	30834	
<i>Cylindrotheca closterium</i>	0	0	0	80432	0	0	44538	0	0	0	0	0	0	0	0	0	0	
<i>Cyclotella</i> spp.	0	0	0	0	0	0	0	0	571	0	0	0	0	0	0	0	0	
<i>Dityota</i> spp.	0	0	0	0	0	0	0	0	0	286	0	0	0	0	0	0	0	
<i>Ditylum brightwellii</i>	0	571	571	0	0	0	0	286	1142	0	286	0	571	571	13704	571	571	
<i>Dactylosolen fragillismus</i>	0	0	0	0	0	0	5714	0	1713	286	5139	1142	0	0	0	0	0	
<i>Diploneis elliptica</i>	0	286	0	0	0	0	0	0	0	0	0	0	0	0	571	0	0	
<i>Eucampia zodiacus</i>	0	0	0	0	0	0	0	0	1142	0	0	0	0	0	4568	0	0	
<i>Fragilaria</i> spp.	0	0	0	0	0	0	0	0	0	0	571	286	0	0	0	571	1142	
<i>Guinardia flaccida</i>	1142	4113	42044	5941	7769	63066	1713	13000	11991	3426	1142	571	5710	5710	27408	11991	54816	
<i>Guinardia striata</i>	1142	571	0	0	400	10278	571	0	2284	0	0	0	0	0	5139	0	0	
<i>Guinardia delicatula</i>	0	133614	66285.5	81714	129143	5714	90286	198286	6281	286	74230	5710	0	0	27408	0	0	
<i>Gyrosigma</i> spp.	571	0	0	0	0	0	0	0	0	571	0	5710	0	0	0	0	0	
<i>Hemiaulus sinensis</i>	0	0	0	0	0	0	1143	0	0	0	0	0	0	0	0	0	0	
<i>Leptocylindrus danicus</i>	9143	96571	6852	226857	147715	3810	102857	400842	16559	286	59384	29692	5139	13704	1142	3426	5715	
<i>Mestoglia</i> spp.	0	0	0	0	0	0	0	0	0	286	0	0	7423	571	0	0	0	
<i>Melosira</i> spp.	0	0	0	0	0	0	0	0	0	0	571	0	5710	0	0	0	0	
<i>Navicula delicatula</i>	1714	0	0	0	0	0	0	0	3426	286	1142	286	0	0	0	0	0	
<i>Nitzschia seriata</i>	5714	29692	44538	238857	281143	5333	70857	482286	6852	2284	89076	11420	0	0	0	0	0	
<i>Nitzschia longissima</i>	571	571	571	2742	457	914	16400	1142	571	0	0	0	0	0	571	5139	17130	452232
<i>Odontella sinensis</i>	0	0	0	457	0	457	0	1142	3426	0	0	0	0	0	15417	13704	10278	
<i>Odontella regia</i>	0	0	0	0	0	0	0	1142	0	0	0	0	0	0	4568	0	0	
<i>Odontella aurita</i>	0	571	0	0	0	0	0	0	0	0	0	0	0	286	0	5139	15417	
<i>Pelagothrix</i> spp.	0	0	0	0	0	0	0	0	0	0	0	5710	2855	2855	5710	0	0	
<i>Pleurosigma</i> spp.	0	0	0	0	0	0	0	0	0	2284	0	0	571	0	0	0	0	
<i>Pseudonitzschia pungens</i>	133614	14846	192998	121143	56000	0	24571	98286	44538	0	12562	5139	0	0	0	0	0	
<i>Rhabdonema</i> spp.	0	0	0	0	0	0	200	0	0	571	0	0	0	0	0	0	0	
<i>Rhizosolenia indica</i>	1142	6852	53012	162692	7312	55297	3800	22400	16559	9136	7423	5139	16559	15988	17366	162692	51390	
<i>Rhizosolenia setigera</i>	0	22269	122857	8000	45143	1524	14286	94857	4568	2855	25124	11420	0	0	0	1142	1142	
<i>Rhizosolenia pungens</i>	0	286	200	200	800	600	1400	0	286	571	571	571	0	0	0	0	0	
<i>Skeletonema costatum</i>	3429	26286	3429	14286	45143	4952	1714	118768	571	5710	17701	0	4568	0	61668	41112	56529	
<i>Stephanopyxis</i> spp.	0	0	0	0	0	0	0	3429	0	571	1142	0	0	0	0	0	0	
<i>Thalassiosira punctigera</i>	0	0	0	0	0	0	2286	17143	9136	0	0	0	0	0	27979	1713	4568	
<i>Thalassionema nitzschioides</i>	0	0	5710	0	4000	0	2857	0	14846	286	0	0	0	0	105064	0	0	
<i>Thalassiotrix</i> spp.	0	0	0	0	0	0	1143	0	286	571	0	0	0	0	0	0	0	
<i>Triceratium</i> spp.	286	0	571	0	1371	457	200	571	1142	1142	571	0	571	571	571	1142	571	
<i>sub total</i>	1051228	1044570	831899.5	1968830	908524.5	445649	447075	1736409	294351	49967	319761	437387	79369	91361	1743499	1614745	1006107	
<b>DINOPHYCEAE</b>																		
<i>Ceratium furca</i>	571	571	0	571	1143	571	457	571	286	286	286	286	571	571	4568	5139	0	
<i>Ceratium fusus</i>	0	571	0	0	914	0	914	0	286	286	286	286	0	571	2855	5139	14846	
<i>Ceratium trichoceros</i>	286	1142	571	571	0	571	1371	0	1142	0	0	0	0	571	5139	0	571	
<i>Dinophysis caudata</i>	0	0	0	0	0	0	0	0	1142	0	0	0	571	0	0	3426	0	
<i>Dinophysis</i> spp.	0	0	0	0	0	0	0	0	286	286	0	0	0	0	15417	571	0	
<i>Gonyolax</i> spp.	0	0	0	0	0	0	200	0	0	0	0	0	0	0	0	0	0	
<i>Gymnodinium</i> spp.	571	571	0	0	0	0	0	571	0	0	0	286	0	0	0	0	0	
<i>Gyrodinium</i> spp.	0	0	0	0	0	0	0	0	0	1142	0	0	0	0	0	0	0	
<i>Scrippsiella trochoidea</i>	1713	3426	0	0	0	0	400	0	571	0	0	0	0	0	2284	0	0	
<i>Noctiluca scintillans</i>	0	0	0	0	0	0	0	0	286	0	0	0	0	0	5139	0	0	
<i>Protoperdinium claudicans</i>	0	0	0	0	0	0	571	0	286	286	571	286	0	0	0	0	0	
<i>Protoperdinium</i> spp.	571	0	0	0	0	0	0	0	1142	1142	0	0	0	0	0	0	0	
<i>Peridinium</i> spp.	571	286	571	457	5484	0	400	5710	0	1142	0	0	571	571	571	571	0	
<i>Pyrocystis</i> spp.	0	0	0	0	0	0	1714	0	0	0	0	200	0	0	0	0	0	
<i>Prorocentrum micans</i>	0	0	0	0	0	5710	571	1142	0	0	381	0	0	0	0	0	0	
<i>Prorocentrum lima</i>	571	571	0	0	0	0	400	571	1600	1200	400	0	457	400	400	0	3199	
<i>sub total</i>	4854	7138	1142	1599	7541	6852	6998	8565	7027	5770	1924	1344	2170	2684	36373	14846	18616	
<b>CYANOPHYCEAE</b>																		
<i>Spirulina</i> spp.	11420	0	0	69662	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Trichodesmium</i> spp.	0	5710	0	0	0	0	1142	29692	504764	0	0	5710	0	0	690910	376860	1092894	
<i>sub total</i>	11420	5710	0	73088	0	286	1142	30834	504764	0	0	5710	0	0	690910	376860	1092894	
<b>CHLOROPHYCEAE</b>																		
<i>Scenedesmus</i> spp.	0	0	0	19985	0	0	0	0	0	0	0	0	0	0	0	0	1828	
<i>sub total</i>	0	0	0	19985	0	0	0	0	0	0	0	0	0	0	0	0	2742	
<b>Grand total</b>	1067502	1057418	833042	2063502	916066	452787	455215	1775808	806142	55737	321685	444441	81539	94045	2470782	2006451	2120359	

**App.15. List of phytoplankton species and their abundances (cells l<sup>-1</sup>) during February 2001 sampling in Lampung Bay.**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	KK	WL
Phytoplankton																	
<b>BACILLARYOPHYCEAE</b>																	
<i>Amphora</i> spp.	0	0	0	571	0	0	0	0	0	0	0	0	0	0	11991	0	22857
<i>Bacteriastrum hyalinum</i>	2571	1142	1142	0	6286	3429	1143	3429	2286	6571	7143	1143	571	0	0	857	0
<i>Bacteriastrum furcatum</i>	0	1142	1142	571	7714	1143	6571	0	0	0	571	0	0	0	0	0	0
<i>Chaetoceros decipiens</i>	74230	30834	89076	0	118768	296920	178152	222690	237536	118768	178152	148460	205560	1142	0	8286	0
<i>Chaetoceros danicus</i>	0	29692	178152	102870	0	0	0	44538	59384	29692	0	0	571	571	21717	37719	89154
<i>Chaetoceros debilis</i>	0	0	169587	61722	0	0	0	0	0	0	0	0	571	571	75438	329184	54864
<i>Chaetoceros</i> spp.	0	1142	0	9144	0	0	0	0	0	0	0	0	0	571	10287	102870	177165
<i>Coscinodiscus radiatus</i>	286	571	0	2286	0	1142	1142	3429	3429	1143	1143	0	0	286	1142	0	1142
<i>Coscinodiscus</i> spp.	0	571	571	0	0	0	1142	0	0	0	0	0	0	0	0	0	0
<i>Corethron</i> spp.	1714	0	0	0	3429	0	1142	0	0	0	0	0	0	0	0	0	0
<i>Cyclotella atomus</i>	571	571	571	2286	0	0	0	0	0	0	0	0	0	286	13716	150876	25146
<i>Diploëis elliptica</i>	0	0	0	1143	0	0	0	0	0	0	0	0	0	0	1142	1142	571
<i>Ditylum brightwellii</i>	0	1142	34260	571	0	0	0	0	0	0	0	0	0	286	0	0	571
<i>Cerataulina</i> spp.	0	0	0	0	1143	1142	1142	1714	1714	571	0	0	286	0	0	0	0
<i>Eucampia zodiacus</i>	0	0	0	2286	0	0	0	0	0	0	0	0	0	0	1142	1142	571
<i>Guinardia flaccida</i>	6857	3429	4857	4571	14846	108572	237536	94857	29692	3143	178152	3429	256950	1142	3426	4857	571
<i>Guinardia delicatula</i>	0	571	0	0	0	0	0	0	0	0	0	0	0	0	0	571	571
<i>Guinardia striata</i>	0	27408	0	1143	0	0	0	0	0	0	0	0	0	0	571	571	0
<i>Hemiaulus sinensis</i>	1714	1143	0	1143	571	1714	0	0	857	571	226	571	0	571	0	571	0
<i>Lauderia</i> spp.	0	2286	0	0	1143	1143	0	3429	1143	571	286	0	0	0	0	0	0
<i>Licmophora</i> spp.	0	0	0	0	0	0	0	0	0	0	0	226	286	0	0	0	0
<i>Leptocylindrus danicus</i>	74230	207844	3714	17714	148460	296920	74230	5	133614	45429	10571	5029	31976	571	14846	178152	44538
<i>Melosira</i> spp.	571	0	0	9144	0	0	0	0	0	0	0	0	0	0	12562	0	0
<i>Nitzschia seriata</i>	4286	25143	4287	53143	26857	25714	44538	14846	18857	1429	2571	1371	41112	148460	356304	534456	296920
<i>Nitzschia closterium</i>	0	0	0	13716	0	0	0	286	0	0	0	0	0	571	13133	0	0
<i>Nitzschia longiceps</i>	0	0	0	1143	0	0	14846	286	0	0	0	0	0	571	5710	0	0
<i>Navicula delicatula</i>	0	1143	0	1714	571	0	571	0	0	286	1429	226	1142	0	0	6000	14286
<i>Navicula</i> spp.	0	571	13704	0	0	0	0	0	0	0	0	0	1142	0	0	0	0
<i>Odontella sinensis</i>	0	571	0	0	0	571	0	0	0	0	0	0	0	0	0	0	0
<i>Odontella regia</i>	0	0	0	6858	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Odontella mobilensis</i>	0	0	0	5715	0	0	0	0	0	0	0	0	0	0	2286	0	0
<i>Planktoniella</i> spp.	0	571	1429	1143	4000	0	0	0	0	0	571	226	1142	571	0	0	0
<i>Pleurosigma</i> spp.	0	0	286	1143	1143	0	286	0	0	286	0	0	13133	5139	1143	2286	2286
<i>Pseudonitzschia pungens</i>	1143	4571	0	226314	13143	28571	571	16571	30286	5143	571	0	0	5139	125730	571	0
<i>Rhabdonema</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	571	1429	4000
<i>Rhizosolenia indica</i> spp.	2286	5139	2000	5714	14857	39429	4857	14286	34857	6000	4000	1829	9136	9136	1142	2857	2286
<i>Rhizosolenia setigera</i>	571	20566	457	1143	1143	571	571	571	5027	5027	1143	0	571	0	1142	0	0
<i>Rhizosolenia pungens</i>	0	0	0	0	0	0	0	1142	0	0	0	0	0	0	571	0	0
<i>Rhizosolenia robusta</i>	0	0	0	20574	0	0	0	0	0	0	0	0	0	0	10287	0	0
<i>Skeletonema costatum</i>	14846	102286	89076	445380	29692	29692	11420	29692	59384	44538	27714	5710	37686	61668	178152	181142	89076
<i>Striatella</i> spp.	1142	1142	286	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Stephanophysis</i> spp.	0	1142	1714	0	112571	0	0	0	0	0	0	457	0	0	0	0	0
<i>Thalassiosira delicatula</i>	1143	3429	3714	6858	13143	79429	857	12000	5714	0	0	0	0	0	4572	6000	4000
<i>Thalassionema nitzschioideum</i>	1714	6281	3143	10287	1714	5143	2857	1143	9714	4000	2857	914	0	286	4572	0	0
<i>Thalassiothrix</i> spp.	0	0	5143	0	9714	3429	0	0	0	4000	1714	457	0	1142	0	0	0
<i>Triceratium</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1714
sub total	189875	482033	608311	1018010	530908	924674	583574	464914	632637	277454	418588	170274	602406	238109	873866	1551254	832860
<b>DINOPHYCEAE</b>																	
<i>Ceratium furca</i>	571	571	571	571	571	1142	5710	571	571	0	571	226	571	0	9136	20556	20556
<i>Ceratium tripos</i>	571	0	571	1143	1142	6852	0	0	1142	0	0	571	0	571	14846	41112	27408
<i>Ceratium fusus</i>	0	1142	571	3429	1142	571	571	5710	1142	0	1142	1142	0	571	0	0	0
<i>Ceratium trichoceros</i>	0	0	0	571	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Dinophysis acuminata</i>	0	0	0	571	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Scrippsiella trochoidea</i>	0	6852	0	6858	0	1142	0	0	0	0	0	0	0	0	0	0	0
<i>Gonyaulax</i> spp.	285	0	0	13716	0	1142	0	0	0	0	0	0	0	0	0	0	0
<i>Dinophycis caudata</i>	0	0	0	571	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gymnodinium</i> spp.	0	0	0	571	0	0	0	0	0	0	0	0	0	0	3426	5139	9136
<i>Gyrodinium</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3426	6281	12562
<i>Noctiluca scintillans</i>	0	0	0	1143	0	0	0	571	571	571	571	2284	2855	3426	5710	5710	1142
<i>Protoperdinium spec.</i>	0	3426	0	2286	0	1142	1142	571	1142	1142	571	0	0	0	0	0	0
<i>Protoperdinium claudicans</i>	0	571	0	3429	0	0	1142	0	0	571	0	0	0	0	0	0	0
<i>Prorocentrum micans</i>	0	0	0	4572	1143	0	0	571	0	0	0	0	0	0	0	0	0
<i>Prorocentrum lima</i>	0	0	0	1143	0	0	0	0	0	0	0	0	0	0	0	0	0
sub total	1427	12562	1713	40574	3998	11991	8565	7994	4568	2284	2855	4223	3426	4568	36544	78798	70804
<b>CYANOPHYCEAE</b>																	
<i>Spirulina</i> spp.	7200	0	0	69662	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Trichodesmium</i> spp.	0	0	0	226314	0	0	0	0	0	0	0	0	0	0	0	0	0
sub total	7200	0	0	295976	0	1142	0	0	0	571	0	0	0	0	0	0	0
<b>CHLOROPHYCEAE</b>																	
<i>Scenedesmus</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5714
<i>Closteridium</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10286
sub total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16000
Total	198502	494595	610024	1354560	534906	937807	592139	472908	637205	280309	421443	174497	605832	242677	910410	1630052	919664

KK. Kota Karang River ; WL : Way Lunik River

**App.16. List of phytoplankton species and their abundances (cells l<sup>-1</sup>) during May 2001 sampling in Lampung Bay.**

Phytoplankton	stations																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	KK	WL
<b>BACILLARYOPHYCEAE</b>																	
<i>Achnanthes</i> spp.	0	800	0	0	500	0	0	0	0	0	0	0	0	0	0	0	0
<i>Amphiprora</i> spp.	0	0	0	457	0	100	100	0	0	0	0	2742	2285	457	2742	1122849	
<i>Asterionellopsis glacialis</i>	0	0	0	457	0	600	0	0	0	0	0	0	0	0	457	457	2742
<i>Bacteriastrium furcatum</i>	900	1800	300	8382	2500	1300	2300	500	1600	1500	3900	3800	457	2742	30162	11049	35646
<i>Bacteriastrium hyalinum</i>	0	0	0	3429	0	0	0	0	0	0	0	0	0	0	4113	8382	7312
<i>Bacillaria</i> spp.	0	0	0	6096	0	0	0	0	0	0	0	1400	5484	16452	7312	12573	8683
<i>Chaetoceros decipiens</i>	2300	6400	2300	6858	12700	12400	12300	16700	10100	11900	20500	20100	13710	21936	8226	11049	13253
<i>Chaetoceros danius</i>	0	0	0	48006	0	18200	0	0	0	0	0	0	0	457	57582	64008	86373
<i>Chaetoceros debilis</i>	0	0	0	33528	0	0	0	0	0	0	0	0	0	0	60324	75438	80432
<i>Chaetoceros spec.</i>	0	0	0	3429	0	0	0	0	0	0	0	0	0	0	8226	6096	16452
<i>Coscinodiscus radiatus</i>	0	0	0	2286	0	300	0	100	800	700	300	0	2285	3199	8226	3048	24678
<i>Coscinodiscus</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	457	0	2285
<i>Cocconeis</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	457
<i>Cerataulina</i> spp.	0	0	0	0	100	800	0	0	0	0	0	0	0	0	0	0	0
<i>Corethron</i> spp.	200	0	0	0	0	1300	0	0	300	700	900	2800	3656	3199	0	0	0
<i>Dactylosolen fragillissimus</i>	0	800	0	1143	300	0	400	300	200	0	400	700	457	457	5484	1143	10988
<i>Diploneis elliptica</i>	0	0	0	2286	0	0	0	0	100	200	200	0	457	0	25135	3048	26963
<i>Dytilium brightwellii</i>	0	0	0	3429	0	0	0	0	300	100	0	0	0	0	914	5334	8226
<i>Eucampia zodiacus</i>	0	0	400	1143	0	300	0	200	0	0	200	200	0	0	5484	1143	21936
<i>Fragilaria</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Guinardia delicatula</i>	1500	1700	600	33528	1500	1500	700	2900	1600	900	3100	5800	457	4570	60324	67056	90486
<i>Guinardia striata</i>	0	0	0	67056	0	2700	0	0	0	0	0	0	0	0	10054	33528	160864
<i>Guinardia flaccida</i>	0	0	0	16002	0	0	0	0	0	0	0	0	0	0	80432	64008	291566
<i>Gyrosigma</i> spp.	0	0	0	381	0	0	0	0	0	0	0	100	3656	7312	2742	2742	18737
<i>Hemiaulus sinensis</i>	300	0	0	0	300	0	300	0	500	100	0	700	1371	4113	30162	0	27877
<i>Lauderia</i> spp.	0	0	0	0	0	200	0	0	0	0	0	0	0	0	0	0	0
<i>Leptocylindrus danicus</i>	700	5100	2400	4000	3100	2800	800	4900	400	200	2000	6700	3656	14624	30162	2742	45243
<i>Meuniera membranacea</i>	0	0	0	0	0	600	0	0	0	0	0	0	457	457	0	0	0
<i>Navicula delicatula</i>	800	300	500	1714	400	300	300	200	500	400	400	700	1371	2742	10054	2742	5027
<i>Nitzschia closterium</i>	300	900	2700	4380000	900	1300	600	2400	1500	2600	1400	2400	1371	2742	3956706	4170582	4610216
<i>Nitzschia seriata</i>	0	0	0	2286	0	600	0	0	0	0	0	0	0	0	3656	1905	5027
<i>Odontella sinensis</i>	0	1700	0	1143	0	0	0	0	0	0	0	200	0	0	5484	1143	60324
<i>Odontella regia</i>	0	0	0	1143	0	600	0	0	0	0	0	0	0	0	10054	1143	5027
<i>Odontella aurita</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pleurosigma</i> spp.	0	0	0	2857	0	0	0	0	0	0	200	400	0	0	20108	4113	231242
<i>Pseudonitzschia pungens</i>	600	2700	1000	3429	1000	42500	200	2600	700	1000	1000	2000	457	457	2742	3656	3656
<i>Planktoniella</i> spp.	300	100	300	1143	200	0	200	0	0	100	300	0	1371	4113	2742	0	7312
<i>Rabdonema</i> spp.	0	0	0	0	0	200	0	0	0	0	0	0	2742	10968	0	0	0
<i>Rhizosolenia indica</i>	200	1100	2400	5714	400	400	1300	1300	300	1600	2800	5600	2742	5484	30162	0	316701
<i>Rhizosolenia setigera</i>	0	0	0	11428	0	1200	0	0	0	0	0	0	0	0	0	34284	0
<i>Rhizosolenia pungens</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Suriella</i> spp.	0	0	0	0	200	0	0	100	300	0	0	0	0	0	0	0	0
<i>Striatella</i> spp.	0	0	0	0	0	0	0	0	0	300	100	0	0	0	0	0	0
<i>Streptothecca</i> spp.	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0
<i>Skeletonema costatum</i>	5400	600	5000	193714	600	36600	0	2200	0	700	0	0	8226	16452	663564	142584	512754
<i>Stephanophysis</i> spp.	0	200	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0
<i>Thalassionema nitzschioides</i>	700	500	400	10854	200	600	2000	1000	600	1300	600	500	0	0	0	4113	0
<i>Thalassiothrix</i> spp.	200	0	300	1714	500	300	1100	2600	1200	1100	2300	3300	0	0	1714	7312	1714
<i>Thalassiosira punctigera</i>	0	0	0	172000	0	2200	1100	0	0	0	0	0	2742	8226	30162	250893	60324
<i>Thalassiosira delicatula</i>	0	0	0	1143	0	0	0	0	0	0	0	0	0	0	30162	457	316701
Sub Total	14400	24700	18600	5032178	25400	129900	23700	38000	21000	25400	40700	57500	59867	132987	5203745	5000513	8240053
<b>DINOPHYCEAE</b>																	
<i>Ceratium furca</i>	0	0	0	1143	200	0	285.5	100	300	200	100	200	0	0	25135	2742	5484
<i>Ceratium fusus</i>	0	0	0	5715	0	1200	0	0	0	0	0	0	0	0	8226	7312	2742
<i>Ceratium trichoceros</i>	0	0	0	0	0	800	0	0	0	0	0	0	0	0	8226	8226	457
<i>Ceratium macroceros</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2742
<i>Dinophysis caudata</i>	0	0	0	1143	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gymnodinium</i> spp.	200	0	600	571	0	0	0	500	0	0	900	100	0	0	0	2742	13710
<i>Gyrodinium</i> spp.	0	0	0	0	0	0	0	100	100	100	0	0	0	0	0	0	0
<i>Peridinium</i> spp.	0	600	600	1143	0	0	100	0	400	200	400	100	0	0	0	0	0
<i>Prorocentrum</i> spp.	100	0	300	0	0	0	100	0	100	0	0	0	0	0	0	0	0
<i>Protoperdinium</i> spp.	0	0	0	2286	0	600	0	0	0	0	0	0	0	0	13710	4113	3656
<i>Protoperdinium claudicans</i>	0	0	0	1143	0	300	0	0	0	0	0	0	0	0	0	0	457
<i>Prorocentrum micans</i>	0	0	100	0	0	300	0	0	0	0	0	0	0	0	0	0	0
<i>Scrippsiella trochoidea</i>	100	100	0	0	0	300	0	0	0	0	0	0	0	0	0	0	0
Sub Total	400	1200	1600	13144	200	3500	485.5	700	900	500	1400	400	0	0	55297	25135	29248
<b>CYANOPHYCEAE</b>																	
<i>Trichodesmium</i> spp.	0	0	0	178308	20000	0	0	0	0	0	0	0	0	0	0	0	90486
<i>Oscillatoria</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	214790	120648	0
<i>Spirulina</i> spp.	7200	0	0	69662	0	0	0	0	0	0	0	0	0	0	0	0	12796
Sub Total	7200	0	0	247970	20000	0	0	0	0	0	0	0	0	0	214790	133444	90486
<b>CHLOROPHYCEAE</b>																	
<i>Scenedesmus</i> spp.	0	0	0	19985	0	0	0	0	0	0	0	0	0	0	1828	1828	0
<i>Closterium</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	914	914	0
Sub Total	0	0	0	19985	0	0	0	0	0	0	0	0	0	0	2742	2742	0
Total	22000	25900	20200	5313277	45600	133400	24185.5	38700	21900	25900	42100	57900	59867	132987	5476574	5161834	8359787

KK. Kota Karang River ; WL : Way Lunik River

**App.17. List of phytoplankton species and their abundances (cells l<sup>-1</sup>) during July 2001 sampling in Lampung Bay.**

Phytoplankton	stations																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	KK	WL
<b>BACILLARYOPHYCEAE</b>																	
<i>Asterionellopsis glacialis</i>	0	0	0	0	0	0	0	0	0	1371	0	0	0	0	0	0	1524
<i>Bacillaria</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	457	457	0	0	30162
<i>Bacteriastrium furcatum</i>	457	2742	2286	38095	12190	7619	2285	2742	16452	2285	10054	5941	457	0	60324	3810	80432
<i>Bacteriastrium hyalinum</i>	457	457	0	4113	0	40216	457	457	0	0	0	0	457	0	5484	0	0
<i>Odontella sinensis</i>	4113	0	4571	0	10667	20571	4113	4113	3199	2285	5027	4570	10054	9597	457	0	0
<i>Brockmanniella</i> spp.	0	0	0	0	0	15238	0	0	0	0	0	0	0	457	0	0	0
<i>Cerataulina</i> spp.	0	0	0	0	0	0	457	457	1371	0	0	0	0	0	0	0	0
<i>Chaetoceros decipiens</i>	2742	8683	1055238	2826667	170667	695619	39759	81346	86373	11425	13253	21479	15081	20108	1176318	110476	120648
<i>Chaetoceros danicus</i>	0	124304	0	0	0	0	0	0	0	0	0	0	457	457	10054	45243	281512
<i>Chaetoceros debilis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	457	120648	58496
<i>Chaetoceros</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	65808
<i>Coscinodiscus radiatus</i>	457	1828	2286	5333	2286	3810	0	457	1371	0	0	457	1371	2742	5027	0	0
<i>Coscinodiscus</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	2742	3656	457	0	0
<i>Ditylum brightwellii</i>	0	0	0	0	0	0	0	0	2742	0	0	0	0	457	0	0	0
<i>Eucampia zodiacus</i>	0	2285	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Fragillaria</i> spp.	2285	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Guinardia delicatula</i>	0	6855	35810	3048	0	13714	3656	3199	5484	0	1371	2742	3656	2285	60324	0	0
<i>Guinardia striata</i>	0	1828	0	0	0	0	0	0	0	0	0	0	0	1828	457	0	0
<i>Guinardia flaccida</i>	0	11882	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Hemiaulus sinensis</i>	0	1828	762	0	0	0	0	0	0	914	0	0	0	0	0	0	0
<i>Leptocylindrus danicus</i>	13253	144412	2140952	1443048	496762	2121905	31076	138928	45243	2742	9597	26506	5484	1828	1449804	140190	0
<i>Navicula delicatula</i>	3656	1828	0	3048	9143	6857	3199	5484	4113	0	4113	2742	13710	8226	10054	3810	96000
<i>Nitzschia seriata</i>	4570	6855	9143	7619	25905	13714	15081	16909	24678	8226	3656	6398	4570	3656	10968	37333	26667
<i>Paralia</i> spp.	4570	11425	6095	0	22095	0	5027	6855	1828	0	0	0	14624	10968	0	8381	0
<i>Pleurosigma</i> spp.	2742	5941	1524	0	3048	0	914	4570	1371	914	3199	1371	5027	4113	0	9143	16762
<i>Pseudonitzschia</i> spp.	914	130702	1524	28190	3048	0	0	0	2285	1828	1828	2742	8226	5027	30162	3048	0
<i>Rhizosolenia indica</i>	10054	5941	6095	25143	22857	41143	6855	12796	11882	1371	3656	10054	4570	6855	25135	28190	17524
<i>Rhizosolenia setigera</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	457	0	0
<i>Rhizosolenia pungens</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Skeletonema costatum</i>	8226	15081	9905	338286	65524	11429	20565	24678	21936	9597	5484	19651	2742	4570	653510	34286	7619
<i>Stephanophysis</i> spp.	0	0	0	1524	0	0	0	0	0	0	0	0	457	0	457	0	0
<i>Synedra capitata</i>	0	261404	0	0	0	0	0	0	0	0	0	0	457	0	457	0	0
<i>Thalassiosira punctigera</i>	4570	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Thalassionema nitzschioides</i>	0	8683	0	7619	0	0	6398	3656	5484	2285	1828	4570	0	0	0	0	0
<i>Thalassiothrix</i> spp.	0	0	0	0	0	0	914	2285	2285	0	0	0	0	8226	4113	0	762
<i>Triceratium</i> spp.	0	0	0	0	697905	0	1828	0	914	0	457	457	457	0	0	0	0
sub total	63066	754964	3276190	4731732	1542095	2991835	142584	308932	239011	45243	63523	109680	95056	95513	3504276	544558	803915
<b>DINOPHYCEAE</b>																	
<i>Ceratium furca</i>	0	1371	457	457	762	0	457	457	457	457	0	457	457	457	8226	5027	1524
<i>Ceratium fusus</i>	0	457	1371	1828	0	457	914	0	457	457	457	457	457	457	8683	7312	5027
<i>Ceratium tripos</i>	0	0	0	0	0	914	0	457	0	914	914	0	914	1828	5027	8226	6398
<i>Dinophysis caudata</i>	1371	0	1524	0	0	0	0	914	457	0	0	0	0	0	8226	5027	0
<i>Dinophysis acuminata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	457	0	0
<i>Gonyaulax</i> spp.	0	1371	0	0	0	0	0	0	0	0	0	0	0	0	0	1524	0
<i>Gymnodinium</i> spp.	914	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gyrodinium</i> spp.	2285	457	0	762	762	0	0	0	914	0	0	0	0	0	0	0	0
<i>Protoperidinium</i> spp.	0	2742	762	0	4572	0	457	457	457	457	0	0	0	0	2286	0	0
<i>Protoperidinium claudicans</i>	0	457	0	0	0	0	0	0	0	0	0	0	0	0	762	0	0
<i>Noctiluca scintillans</i>	0	914	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19810
<i>Prorocentrum micans</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9905
<i>Prorocentrum lima</i>	0	0	457	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Scrippsiella trochoidea</i>	0	457	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sub total	4570	8226	4571	3047	6096	1371	1828	2285	2285	2285	1371	457	1828	2742	33667	27116	42663
<b>CYANOPHYCEAE</b>																	
<i>Oscillatoria</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34286	0
<i>Spirulina</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	64000
<i>Trichodesmium</i> spp.	1828	0	762	0	0	0	0	0	0	0	0	0	0	0	904860	0	0
sub total	1828	0	762	0	0	0	0	0	0	0	0	0	0	0	904860	34286	64000
<b>CHLOROPHYCEAE</b>																	
<i>Netrium</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11429
<i>Closterium</i> spp.	0	0	0	30162	0	10054	0	0	0	0	0	0	0	0	60324	762	1524
<i>Scenedesmus</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sub total	0	0	0	30162	0	10054	0	0	0	0	0	0	0	0	60324	762	12952
Grand total	69464	763190	3281523	4764941	1548191	3003260	144412	311217	241296	47528	64894	110137	96884	98255	4503127	611293	943340

KK: Kota Karang River ; WL : Way Lunik River

**App.18. List of phytoplankton species and their abundances (cells l<sup>-1</sup>) during September 2001 sampling in Lampung Bay.**

Phytoplankton	stations																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	KK	WL
<b>BACILLARIOPHYCEAE</b>																	
<i>Amphora</i> spp.	0	0	0	0	0	0	0	0	0	0	0	600	600	600	571	1371	914
<i>Asterionellopsis glacialis</i>	800	1142	0	0	0	571	0	600	1571	800	0	0	0	0	571	0	0
<i>Asterococcus</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10968	0
<i>Bacillaria</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Bacteriastrium furcatum</i>	0	14600	27420	28334	5027	34275	0	4286	4600	1000	0	2860	2860	2860	14846	0	0
<i>Bacteriastrium hyalinum</i>	286	0	0	0	0	0	0	0	0	0	286	0	0	0	0	0	0
<i>Odontella sinensis</i>	800	600	0	0	3199	0	0	3286	0	1571	800	800	800	800	0	0	0
<i>Brockmanniella</i> spp.	0	0	0	0	0	0	0	0	1000	0	0	0	0	0	0	0	0
<i>Cerataulina</i> spp.	0	0	6398	0	0	0	0	0	1600	0	0	0	0	0	0	0	0
<i>Chaetoceros decipiens</i>	0	68571	243124	490590	43872	216161	571	82600	104600	5286	8800	10000	10000	10000	1306448	0	0
<i>Chaetoceros danicus</i>	2600	5710	6852	6398	12562	0	6571	8571	12571	5286	0	0	0	0	0	0	0
<i>Chaetoceros debilis</i>	0	0	0	18272	0	0	0	12600	8571	4286	0	0	0	0	0	0	0
<i>Corethron</i> spp.	571	1600	2742	5484	0	914	286	1000	0	0	0	571	571	571	13133	0	0
<i>Coscinodiscus radiatus</i>	800	571	1828	0	0	571	571	1000	286	0	3000	1000	1000	1000	0	0	0
<i>Coscosira</i> spp.	0	0	0	10511	0	0	0	0	0	0	0	0	0	0	18843	3199	0
<i>Cylindrotheca closterium</i>								32600									
<i>Dictyocha</i> spp.	0	0	0	0	0	0	0	571	0	0	571	0	0	0	571	0	0
<i>Ditylum brightwellii</i>	0	0	571	0	0	0	0	286	800	0	0	0	0	0	571	0	0
<i>Dactylosolen fragilissimu</i>	571	0	1371	0	914	8683	0	3286	1600	1286	571	0	0	0	0	0	0
<i>Eucampia zodiacus</i>	0	1000	1828	0	0	6855	0	0	0	0	0	0	0	0	6855	0	0
<i>Fragilaria</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	571	1828	5484
<i>Guinardia flaccida</i>	571	9286	42044	5941	7769	63066	1571	13000	9571	1571	1800	2860	2860	2860	11991	0	0
<i>Guinardia striata</i>	286	286	0	0	571	0	571	0	0	0	0	800	800	800	0	0	0
<i>Guinardia delicatula</i>	24286	7000	0	14167	78147	15538	6000	12860	11600	8600	20600	0	0	0	0	0	0
<i>Gyrosigma</i> spp.	0	0	0	7769	0	0	0	0	0	0	286	571	571	571	37686	2742	914
<i>Hemiaulus sinensis</i>	0	1000	1828	9140	571	4113	0	571	2571	0	0	800	800	800	29121	0	0
<i>Hemidiscus</i> spp.	0	0	1371	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lauderia</i> spp.	571	1000	914	914	1371	1828	0	0	0	0	0	0	0	0	0	914	0
<i>Skeletonema costatum</i>	67800	92000	548400	745824	84088	23993	73600	232000	131440	14284	14284	20000	4568	118768	994432	8226	95928
<i>Melosira</i> spp.	6571	600	0	16452	0	1828	0	5710	2600	0	0	600	600	600	16452	0	0
<i>Navicula delicatula</i>	6600	1000	7312	11882	1371	5484	3286	5000	5600	4286	1800	1600	1600	1600	11882	420897	930452
<i>Nitzschia seriata</i>	22286	3000	34732	276028	10968	32447	1571	13286	15571	1000	2286	2571	2571	2571	276028	12796	9140
<i>Nitzschia longissima</i>								16571									
<i>Pelagothrix</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pleurosigma</i> spp.	800	286	2742	10968	1828	914	286	1000	1571	0	1600	1000	1000	1000	10968	0	0
<i>Pseudonitzschia</i> spp.	37800	17400	130245	263689	12339	93228	397800	46713	38400	1286	0	14400	4800	4800	527378	0	0
<i>Rhabdonema</i> spp.	0	0	0	0	0	0	286	0	0	600	0	0	0	0	0	0	9597
<i>Rhizosolenia indica</i>	2571	16571	53012	162692	7312	55297	3800	22571	25600	7800	4286	4600	4600	4600	162692	10054	1828
<i>Rhizosolenia setigera</i>	286	600	571	286	800	0	600	600	571	286	0	0	0	0	286	0	0
<i>Rhizosolenia pungens</i>	0	286	286	286	800	600	1571	0	286	600	800	0	0	0	286	0	0
<i>Stephanophysis</i> spp.	0	0	0	56211	0	7769	0	0	8571	1286	0	0	0	0	56211	0	1371
<i>Suriella</i> spp.	0	0	0	0	0	0	571	0	0	0	0	0	0	0	0	0	6398
<i>Thalassiosira punctigera</i>	46800	2860	8226	22393	2285	914	18600	2571	7600	1800	4571	1000	1000	1000	22393	9140	12796
<i>Thalassionema nitzschioi</i>	0	0	3199	914	914	3656	1600	1571	1000	600	0	0	0	0	914	0	0
<i>Thalassiothrix</i> spp.	0	1800	9140	6398	0	0	0	1000	0	800	0	0	0	0	6398	0	0
<i>Triceratium</i> spp.	286	0	914	0	1371	571	286	571	1000	800	0	0	0	0	0	0	3656
sub total	223942	248769	1137070	2171543	278079	579276	569740	476539	400751	65685	65770	66633	41601	155801	3521243	482135	1078478
<b>DINOPHYCEAE</b>																	
<i>Ceratium furca</i>	571	571	571	571	0	571	571	571	0	0	0	0	0	0	0	0	0
<i>Ceratium fusus</i>	0	571	0	571	914	0	0	0	286	286	0	0	0	0	0	0	9597
<i>Ceratium tripos</i>	286	0	0	0	0	0	0	0	571	0	0	0	0	0	0	0	0
<i>Dinophysis caudata</i>	286	0	0	914	0	571	0	286	0	0	0	0	0	0	914	0	0
<i>Gonyolax</i> spp.	0	0	0	0	0	0	571	0	0	0	0	0	0	0	0	0	0
<i>Gymnodinium</i> spp.	0	0	0	0	1828	0	571	571	0	0	0	0	0	0	0	0	571
<i>Gyrodinium</i> spp.	0	0	0	0	0	0	286	0	286	0	800	0	0	0	0	0	0
<i>Scrippsiella trochoidea</i>	0	0	0	0	0	0	286	0	0	0	0	0	0	0	0	0	3656
<i>Noctiluca scintillans</i>	286	0	0	0	0	914	571	0	800	571	0	0	0	0	0	3199	30619
<i>Protoperdinium</i> spp.	0	0	0	0	0	0	1600	0	0	0	0	0	0	0	0	3656	94599
<i>Peridinium</i> spp.	1000	286	571	571	5484	0	571	1800	0	2286	600	571	571	571	571	0	914
<i>Podolomphas</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7769	3199
<i>Prorocentrum micans</i>	800	286	0	914	0	914	0	600	0	286	0	0	0	914	20565	115164	
<i>Prorocentrum lima</i>	571	800	0	0	0	6855	571	600	0	1286	0	571	571	571	0	3199	6855
sub total	3800	2514	1142	3541	8226	9825	5598	4428	1943	4429	1686	1142	1142	1142	2399	47985	255577
<b>CYANOPHYCEAE</b>																	
<i>Halosphaera</i> spp.	0	0	0	3426	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Oscillatoria</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	214790	120648
<i>Spirulina</i> spp.	7286	0	0	69662	0	0	0	0	0	0	0	0	0	0	0	0	12796
sub total	7286	0	0	73088	0	0	0	0	0	0	0	0	0	0	0	214790	133444
<b>CHLOROPHYCEAE</b>																	
<i>Scenedesmus</i> spp.	0	0	0	19985	0	0	0	0	0	0	0	0	0	0	0	1828	1828
<i>Closterium</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	914	914
sub total	0	0	0	19985	0	0	0	0	0	0	0	0	0	0	0	2742	2742
Grand total	235028	251283	1138212	2268157	286305	589101	575338	480967	402694	70114	67456	67775	42743	156943	3523642	747652	1470241

KK: Kota Karang River ; WL : Way Lunik River

**App.19. List of phytoplankton species and their abundances (cells l<sup>-1</sup>) during November 2001 sampling in Lampung Bay.**

Phytoplankton	stations																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	KK	WL
<b>BACILLARIOPHYCEAE</b>																	
<i>Amphora</i> spp.	0	0	0	571	0	0	0	0	0	0	0	0	0	0	457	1371	10968
<i>Asterionella kariana</i>	0	400	0	1713	0	457	0	0	400	0	0	800	2855	0	3997	0	7312
<i>Bacillaria</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1828	457
<i>Bacteriastrium hyalinum</i>	7400	6400	2285	10849	12796	28791	7000	27800	2000	13800	3600	4600	1142	2855	10849	0	0
<i>Bacteriastrium furcatum</i>	200	0	457	914	914	1828	0	0	0	0	0	0	0	0	0	0	0
<i>Odontella sinensis</i>	0	200	0	0	0	0	0	0	0	2000	0	2600	3426	3426	0	914	457
<i>Ceratulina</i> spp.	0	0	0	0	0	3656	2000	0	1200	3200	2000	200	571	457	0	0	0
<i>Chaetoceros decipiens</i>	38800	56600	551599	103282	426838	4113	88600	76000	91400	85000	64300	20800	11991	16452	15988	0	0
<i>Chaetoceros danicus</i>	1200	18843	0	14846	0	7312	0	0	0	0	0	0	0	7312	16559	0	0
<i>Chaetoceros debilis</i>	0	0	0	0	0	331782	0	0	0	0	0	0	0	0	0	0	0
<i>Chaetoceros</i> spp.	0	0	0	0	0	7769	0	0	0	0	0	0	0	0	0	0	0
<i>Corethron</i> spp.	0	2400	0	0	2742	3199	1400	800	0	1800	1000	600	457	457	0	457	457
<i>Coscinodiscus radiatus</i>	2200	571	1828	571	2742	2742	0	600	400	3000	0	1400	457	457	0	0	457
<i>Coscosira</i> spp.	0	0	0	0	0	0	0	0	0	0	0	457	1142	0	127503	200992	
<i>Cyclotella</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	457	457	86373
<i>Dactylosolen</i> spp.	457	457	457	0	0	457	0	0	0	0	0	0	0	0	0	0	457
<i>Ditylum brighwellii</i>	0	0	1371	0	914	457	400	0	2000	0	200	0	0	0	0	0	0
<i>Diploneis</i> spp.	0	1200	15538	11425	11882	11425	1800	0	800	2400	0	0	0	0	10278	3199	0
<i>Eucampia zodiacus</i>	0	0	0	0	0	0	0	0	400	200	0	200	571	1142	0	0	0
<i>Guinardia flaccida</i>	1000	27000	19651	1828	23764	79518	21000	20200	21400	3400	1800	1200	1142	2284	3997	0	0
<i>Guinardia delicatula</i>	89300	70200	385996	638378	354175	435978	322800	145700	847600	16400	15400	25200	1713	457	621819	7769	0
<i>Guinardia striata</i>	0	0	1713	1713	0	1828	0	0	0	0	0	0	0	0	4568	0	0
<i>Gyrosigma</i> spp.	0	800	1371	0	457	4570	400	600	200	1000	400	0	0	0	3426	914	0
<i>Hemiaulus sinensis</i>	2000	600	4113	0	0	914	0	1200	600	1800	0	1000	571	1713	0	0	0
<i>Hemidiscus</i> spp.	0	0	457	0	1828	15538	0	0	0	400	0	0	0	0	0	0	457
<i>Leptocylindrus danicus</i>	4113	187200	10054	45243	0	4113	0	0	0	0	0	0	0	0	0	0	0
<i>Melosira</i> spp.	8200	2600	4113	11425	6855	2742	3800	400	400	2200	0	2000	571	1142	11991	0	0
<i>Navicula delicatula</i>	600	1600	4570	8226	3199	5941	200	1200	400	2000	400	2800	0	0	5139	193768	475072
<i>Nitzschia seriata</i>	1000	4800	20108	979836	5027	14167	4200	4400	3000	13200	4000	3400	0	0	430534	76776	311766
<i>Paralia sulcata</i>	0	12000	0	0	31990	23307	80800	9000	48000	23000	0	6000	6852	3426	0	0	0
<i>Pleurosigma</i> spp.	0	400	914	0	914	2285	0	800	0	1000	200	600	571	1713	3997	0	8226
<i>Pseudonitzschia pungens</i>	571	25000	95970	24221	35189	84088	6400	15200	16600	5800	4000	1200	1713	1713	571	0	0
<i>Rhabdonema</i> spp.	0	0	0	0	0	0	0	0	0	400	800	0	571	0	0	0	0
<i>Rhizosolenia indica</i>	571	0	0	3656	0	0	457	3656	0	0	0	0	0	0	0	0	0
<i>Rhizosolenia setigera</i>	0	0	0	0	0	914	0	0	0	0	0	0	0	0	0	0	0
<i>Rhizosolenia pungens</i>	3800	32000	42273	267228	62152	86602	21000	32100	26800	8100	7200	13800	5139	4568	178152	223930	263232
<i>Rhizosolenia robusta</i>	571	571	571	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Skeletonema costatum</i>	43560	21400	35418	28334	24678	62838	47500	20750	7100	2400	23800	32800	8565	2285	118768	0	0
<i>Stephanophysis</i> spp.	19400	0	0	3656	0	0	0	400	0	0	0	1000	0	0	0	457	0
<i>Suirirella</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4113	0
<i>Thalassiosira punctigera</i>	1200	4000	0	5027	37017	12796	1600	0	2400	1200	800	1600	11991	0	10849	0	0
<i>Thalassionema nitzschio</i>	600	600	13710	0	3656	0	400	0	0	0	1000	400	571	0	0	0	0
<i>Thalassiothrix</i> spp.	0	800	6398	3199	2742	914	0	0	4200	600	800	0	0	0	0	0	0
<i>Triceratium</i> spp.	800	600	2285	0	457	3199	0	400	200	1000	0	400	0	0	0	0	0
Sub Total	227543	479242	1223219	2166141	1052928	1246239	611757	361206	1077500	195300	131700	124600	61897	53001	1452396	643456	1366683
<b>DINOPHYCEAE</b>																	
<i>Ceratium furca</i>	0	0	0	0	0	457	0	0	0	457	0	1371	0	0	0	0	0
<i>Ceratium tripos</i>	0	0	0	457	0	3656	200	0	400	0	400	914	571	457	571	0	2285
<i>Ceratium fusus</i>	0	0	0	0	0	3656	0	0	0	0	0	0	0	3656	4568	1828	0
<i>Ceratium trichoceros</i>	3656	4113	7312	28791	21936	7769	28791	20565	3656	457	9597	457	0	0	0	0	0
<i>Scrippsiella trochoidea</i>	0	0	0	0	0	1828	0	0	400	0	0	0	0	0	2284	0	5027
<i>Gonyaulax</i> spp.	0	200	457	0	0	79061	0	0	0	400	400	0	0	0	0	0	0
<i>Dinophycis caudata</i>	0	0	914	0	0	0	0	400	0	0	0	0	0	0	0	0	0
<i>Dinophysis acuminata</i>	0	0	0	0	0	0	0	0	0	0	0	457	0	0	0	0	0
<i>Gymnodinium</i> spp.	0	5200	2285	0	41130	8683	200	200	0	0	0	0	0	457	571	0	1371
<i>Gyrodinium</i> spp.	0	0	0	0	0	457	200	0	0	400	0	0	0	0	0	1828	0
<i>Noctiluca scintillans</i>	0	200	914	0	2285	914	200	400	0	0	0	400	457	400	3426	914	914
<i>Protoperidinium</i> spp.	400	1200	457	3656	2285	7312	2200	1800	0	5000	200	4200	4200	0	0	6855	3199
<i>Protoperidinium claudica</i>	0	457	457	457	457	457	0	457	0	457	0	0	4200	0	0	0	0
<i>Prorocentrum micans</i>	0	0	0	0	0	1371	0	0	0	0	0	0	0	0	0	0	1828
<i>Prorocentrum lima</i>	600	4400	4570	5941	21936	200	800	0	3400	600	1400	1400	1713	0	1828	2285	0
Sub Total	4656	15770	17366	33818	74034	137557	31991	24622	4456	10571	11197	9199	11285	6797	10849	13253	16909
<b>CYANOPHYCEAE</b>																	
<i>Halosphaera</i> spp.	0	0	0	0	0	0	0	0	0	400	0	0	0	0	0	0	0
<i>Oscillatoria</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4570	13710
<i>Spirulina</i> spp.	0	0	13710	0	0	0	6000	0	0	0	0	0	0	0	44538	8683	118768
<i>Trichodesmium</i> spp.	457	457	4113	176859	2285	4570	0	0	0	0	0	0	0	0	0	0	0
Sub Total	457	457	17823	176859	2285	4570	6000	0	0	400	0	0	0	0	44538	13253	132478
<b>CHLOROPHYCEAE</b>																	
<i>Scenedesmus</i> spp.	0	0	0	15995	0	0	0	0	0	0	0	0	0	0	0	0	89076
Sub Total	0	0	0	15995	0	0	0	0	0	0	0	0	0	0	0	0	89076
<b>TOTAL</b>	232656	495469	1258408	2392813	1129247	1388366	649748	385828	1081956	206271	142897	133799	73182	59798	1507783	669962	1605146

KK. Kota Karang River ; WL : Way Lunik River

**App.20. List of phytoplankton species and their abundances (cells l<sup>-1</sup>) during January 2001 sampling in Semangka Bay.**

Phytoplankton	stations													River
	1	2	3	4	5	6	7	8	9	10	11	12	13	
<b>BACILLARYOPHYCEAE</b>														
<i>Asterionelopsis glacialis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	457
<i>Bacterastrum furcatum</i>	914	914	2286	2286	5943	3657	1829	914	10971	13257	5486	3657	1829	914
<i>Bacterastrum hyalinum</i>	229	914	0	914	0	0	914	0	914	0	0	0	0	0
<i>Bacillaria spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Chaetoceros decipiens</i>	25143	10286	27657	22400	35429	17371	32457	5257	15771	17371	19886	25600	45029	21022
<i>Chaetoceros danicus</i>	1374	4122	5496	5496	6870	10992	1320	7312	4113	7312	20565	2742	8226	914
<i>Chaetoceros debilis</i>	0	0	0	229	0	0	0	0	3656	0	0	0	7312	914
<i>Chaetoceros spp.</i>	0	914	0	0	914	0	7312	0	0	0	914	0	7312	0
<i>Chaetoceros spp.</i>	0	0	0	0	0	0	0	0	0	0	0	457	914	0
<i>Coscinodiscus radiatus</i>	8686	5486	9600	5486	12800	4114	5943	3657	2743	5029	2743	2286	7771	1829
<i>Corethron spp.</i>	0	0	457	0	1829	0	0	0	0	914	0	0	914	0
<i>Cerataulina spp.</i>	0	914	457	0	0	0	0	1371	0	0	0	0	0	2286
<i>Dactylosolen fragillimus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Diploneis spec. 1</i>	0	457	0	0	0	0	0	914	0	0	0	0	4114	914
<i>Eucampia zoodiacus</i>	1371	0	1829	457	914	1371	0	914	1829	914	1829	914	3656	914
<i>Flagillaria spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	5486	3200
<i>Guinardia flaccida</i>	0	0	0	0	0	0	0	0	0	0	0	0	457	0
<i>Guinardia striata</i>	0	0	0	0	0	0	0	0	0	0	0	0	914	0
<i>Guinardia delicatula</i>	0	0	2286	1371	2286	1371	1371	914	3657	0	0	914	457	914
<i>Hemiaulus sinensis</i>	0	0	0	0	457	0	0	0	0	0	0	914	457	914
<i>Melosira spp.</i>	0	914	2743	1829	2286	0	0	0	0	0	0	4114	26971	0
<i>Navicula delicatula</i>	4114	1371	8686	9600	5486	3657	4114	3657	1829	8229	3200	8229	51200	17371
<i>Navicula spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Nitzschia longiceps</i>	3657	3200	2743	6400	14171	9600	2743	4114	25143	11886	3657	2743	14629	3657
<i>Nitzschia closterium</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	7312
<i>Odontella sinensis</i>	0	457	0	0	914	0	2286	457	0	914	0	0	457	0
<i>Odontella regia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pleurosigma spp.</i>	0	0	457	0	457	0	0	0	0	914	0	0	457	0
<i>Pseudonitzschia pungens</i>	0	0	0	0	0	14629	0	5486	15543	8229	2286	7771	7312	0
<i>Rhabdonema spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rhizosolenia delicatula</i>	3200	3657	4114	2286	6857	5486	2286	2743	9600	8686	5029	8686	11429	1829
<i>Rhizosolenia setigera</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rhizosolenia indica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Skeletonema costatum</i>	0	9600	5943	8686	1829	20571	2743	15543	30629	34743	15086	16914	2743	1829
<i>Striatella spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	14171
<i>Thalassionema nitzschioides</i>	2286	914	4114	2743	2743	2743	4570	3657	1371	1829	1829	0	17371	2743
<i>Thalassiothrix spp.</i>	0	0	5029	5486	3657	5486	0	1371	0	2286	0	1829	914	0
<i>Thalassiosira spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	3657
<i>Thalassiosira punctigera</i>	0	0	914	0	914	0	4570	0	0	0	0	0	3656	0
<i>Triceratium spp.</i>	457	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Surirella spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	12343
Sub Total	51431	44121	84810	75668	106755	101049	74457	58283	127769	122512	82508	87770	231987	100104
<b>DINOPHYCEAE</b>														
<i>Ceratium furca</i>	457	5484	5484	229	457	457	457	0	457	229	0	0	5484	457
<i>Ceratium fusus</i>	457	914	457	229	914	457	229	457	0	0	457	0	7312	229
<i>Ceratium trichoceros</i>	914	0	229	0	914	914	229	0	0	457	457	0	0	0
<i>Ceratium tripos</i>	0	0	0	0	0	0	229	0	0	0	0	0	0	0
<i>Dinophysis spp.</i>	0	0	914	914	914	914	0	0	0	0	0	0	914	0
<i>Noctiluca scintillans</i>	1829	914	914	914	1371	457	1371	914	914	914	229	1371	1371	914
<i>Protoperdinium spp.</i>	1371	914	914	914	457	0	0	1371	914	914	914	914	1371	914
Sub Total	5028	8227	8913	3201	5028	3199	2515	2743	2286	2515	2057	2286	16453	2515
<b>CYANOPHYCEAE</b>														
<i>Oscillatoria spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Trichodesmium spp.</i>	9140	0	32904	0	28791	0	7312	5484	0	0	5484	0	43872	49356
<i>Spirulina spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub Total	9140	0	32904	0	28791	0	7312	5484	0	0	5484	0	43872	49356
Grand Total	65599	52348	126627	78868	140573	104248	84285	66510	130054	125027	90049	90056	292312	151974

**App.21. List of phytoplankton species and their abundances (cells l<sup>-1</sup>) during March 2001 sampling in Semangka Bay.**

Phytoplankton	stations													River
	1	2	3	4	5	6	7	8	9	10	11	12	13	
<b>BACILLARYOPHYCEAE</b>														
<i>Bacterastrum furcatum</i>	914	914	229	914	9143	686	686	857	514	0	0	343	2572	514
<i>Bacterastrum hyalinum</i>	0	457	457	0	0	0	0	0	0	0	0	0	0	0
<i>Chaetoceros decipiens</i>	30162	10054	28791	30162	244343	7086	7143	9943	5657	2743	3600	6514	1071929	0
<i>Chaetoceros danicus</i>	20108	9597	14624	7312	24678	8226	30162	0	914	914	914	914	30162	0
<i>Chaetoceros debilis</i>	0	914	0	914	0	1371	914	914	0	457	0	0	457	0
<i>Chaetoceros affinis</i>	5027	2742	4113	0	914	2742	0	0	0	0	0	4113	0	0
<i>Chaetoceros lorenzianus</i>	914	0	0	0	0	4113	0	0	0	0	0	914	914	0
<i>Coscinodiscus radiatus</i>	914	457	1143	914	457	1371	114	4570	343	171	0	343	9000	343
<i>Corethron spp.</i>	0	0	0	0	0	1371	0	0	0	0	0	0	0	0
<i>Cerataulina spp.</i>	0	0	0	457	457	457	0	0	0	0	0	0	0	0
<i>Diploneis spp.</i>	914	0	0	0	0	0	0	0	0	0	0	0	914	0
<i>Ditylum brightwellii</i>	457	0	914	0	0	0	0	0	0	10968	8226	171	10054	0
<i>Eucampia zoodiacus</i>	457	0	0	0	0	2285	0	914	0	0	0	0	914	0
<i>Flagellaria spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	343
<i>Guinardia flaccida</i>	2742	0	0	0	0	914	914	5484	8226	5484	457	0	457	0
<i>Guinardia striata</i>	4113	1828	0	2742	2742	8226	914	914	914	914	8226	457	914	0
<i>Guinardia delicatula</i>	0	0	229	914	914	914	7312	7312	5484	171	0	0	914	0
<i>Gyrosigma spp.</i>	457	229	0	0	0	0	0	0	0	0	0	0	0	0
<i>Hemiaulus sinensis</i>	0	0	0	0	0	0	0	914	914	0	0	914	914	0
<i>Lauderia spp.</i>	0	0	0	0	0	0	0	0	0	0	857	0	0	0
<i>Leptocylindrus spp.</i>	3200	1143	8914	1600	10286	457	2743	1714	1714	1200	857	1543	5572	1029
<i>Melosira spp.</i>	0	0	0	0	0	0	0	0	343	0	0	0	8143	1714
<i>Navicula delicatula</i>	1143	914	1829	3200	4343	914	1143	2057	1714	343	857	1886	19286	5027
<i>Navicula spp.</i>	0	0	0	0	0	457	0	0	0	0	0	914	0	0
<i>Nitzschia longiceps</i>	3200	3429	4571	6857	15314	1371	5943	2229	1886	514	0	686	9000	4113
<i>Nitzschia closterium</i>	0	0	0	457	0	0	0	0	0	0	0	0	0	0
<i>Odontella sinensis</i>	0	0	0	0	0	0	0	171	171	171	171	0	428	0
<i>Paralia spp.</i>	0	0	0	0	0	914	0	0	0	0	0	0	0	0
<i>Pleurosigma spp.</i>	229	0	0	686	0	0	457	0	0	0	0	0	857	1543
<i>Pseudonitzschia pungens</i>	914	0	457	2286	16452	2285	0	457	457	457	914	1828	8226	514
<i>Rhabdonema spp.</i>	229	0	0	0	0	0	0	0	0	0	0	0	0	171
<i>Rhizosolenia delicatula</i>	2057	2743	2514	5943	2743	1371	2857	1886	1200	1200	1886	514	6428	2743
<i>Rhizosolenia setigera</i>	457	0	0	0	0	8226	0	0	0	0	0	2285	0	0
<i>Rhizosolenia indica</i>	457	5027	8226	10968	9140	2742	0	0	0	0	0	914	0	0
<i>Streptothecca spp.</i>	0	229	0	229	229	0	0	0	0	0	0	0	0	0
<i>Striatella spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	8571
<i>Thalassionema nitzschioides</i>	3656	457	9597	5486	7086	5484	2286	0	3429	514	0	3656	4113	6000
<i>Thalassiothrix spp.</i>	0	1371	0	914	3429	457	457	857	2229	0	686	1543	4286	0
<i>Thalassiosira spp.</i>	0	0	0	0	0	914	457	0	0	0	0	0	0	0
<i>Thalassiosira punctigera</i>	0	0	0	0	0	4113	0	0	0	0	0	0	0	2571
<i>Triceratium spp.</i>	0	0	0	0	457	0	0	0	0	0	0	0	0	0
<i>Suriella spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1714
Sub Total	82720	42504	86607	82954	353125	69468	64501	41193	36109	26223	27651	30452	1196453	36911
<b>DINOPHYCEAE</b>														
<i>Ceratium furca</i>	457	229	457	457	457	0	457	114	0	457	114	2285	4113	0
<i>Ceratium fusus</i>	457	0	457	914	0	1371	457	457	457	0	114	457	3656	0
<i>Ceratium macroceros</i>	0	0	914	0	0	914	0	0	914	0	457	0	457	0
<i>Ceratium tripos</i>	0	0	0	0	0	914	0	0	0	914	0	0	0	0
<i>Dinophysis spp.</i>	686	0	0	0	0	0	0	0	0	0	0	0	457	0
<i>Dinophysis caudata</i>	0	0	0	914	0	0	0	0	0	0	0	0	0	0
<i>Gonyaulax spp.</i>	457	457	914	914	914	914	0	914	0	0	0	457	0	0
<i>Gimnodinium spp.</i>	914	0	0	0	0	0	0	0	0	0	0	914	428	0
<i>Scropsiella spp.</i>	0	0	457	457	0	0	0	0	0	0	0	0	0	0
<i>Noctiluca scintillans</i>	0	914	0	0	686	2057	0	514	686	514	343	114	0	343
<i>Protoperidinium spp.</i>	0	0	0	457	457	914	114	0	0	0	0	914	2143	0
<i>Protoperidinium claudicans</i>	457	914	914	457	0	0	0	0	0	0	0	0	0	0
<i>Prorocentrum compressum</i>	914	914	0	457	0	0	0	0	0	0	0	0	0	0
Sub Total	4342	3428	4113	5027	2514	7084	1028	1999	2057	1885	1028	5141	11254	343
<b>CYANOPHYCEAE</b>														
<i>Trichodesmium spp.</i>	4570	2742	4113	10054	0	7312	0	2742	0	5484	0	12339	21936	686
Sub Total	4570	2742	4113	10054	0	7312	0	2742	0	5484	0	12339	21936	686
<b>CHLOROPHYCEAE</b>														
<i>Scenedesmus spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	457
Sub Total	0	0	0	0	0	0	0	0	0	0	0	0	0	457
<b>Grand Total</b>	<b>91632</b>	<b>48674</b>	<b>94833</b>	<b>98035</b>	<b>355639</b>	<b>83864</b>	<b>65530</b>	<b>45935</b>	<b>38166</b>	<b>33592</b>	<b>28679</b>	<b>47932</b>	<b>1229643</b>	<b>38397</b>



**App.22. List of phytoplankton species and their abundances (cells l<sup>-1</sup>) during May 2001 sampling in Semangka Bay.**

Phytoplankton	stations													River
	1	2	3	4	5	6	7	8	9	10	11	12	13	
<b>BACILLARYOPHYCEAE</b>														
<i>Amphiphora</i> spp.	0	229	0	0	0	0	0	0	0	0	0	0	0	0
<i>Asterionelopsis glacialis</i>	0	0	0	0	0	0	0	0	0	0	0	0	1829	0
<i>Bacteiastrum furcatum</i>	0	229	457	114	686	457	4113	1371	1829	1371	2743	1371	1371	0
<i>Bacteriastrum hyalinum</i>	0	0	914	0	0	0	0	0	0	0	0	0	0	0
<i>Chaetoceros decipiens</i>	5486	13714	34971	8226	112914	5486	194743	5484	51200	16452	46629	23764	149486	0
<i>Chaetoceros danicus</i>	2742	914	10054	2742	8226	3656	8226	4570	4113	914	1371	2285	49356	0
<i>Chaetoceros debilis</i>	4113	2742	5027	2285	0	0	21936	4570	4113	914	914	0	7312	0
<i>Chaetoceros</i> spp.	0	0	0	0	8226	0	0	0	0	0	0	16452	0	0
<i>Chaetoceros</i> spp.	0	0	0	0	0	3656	0	0	0	0	0	0	24678	0
<i>Coscinodiscus radiatus</i>	343	457	457	914	457	229	1371	3200	2286	2742	2743	4571	3657	4114
<i>Corethron</i> spp.	0	0	0	0	0	0	0	457	914	457	457	457	4113	457
<i>Cerataulina</i> spp.	0	0	457	457	0	0	0	0	0	0	457	914	7312	0
<i>Dactyliosolen fragillissimus</i>	457	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Diploneis</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	1829	0
<i>Eucampia zoodiacus</i>	0	0	0	0	1828	0	914	457	0	457	0	0	457	0
<i>Flagellaria</i> spp.	0	0	0	0	343	0	914	457	457	457	914	0	2743	4570
<i>Guinardia flaccida</i>	457	914	914	914	457	914	914	914	0	0	457	0	0	0
<i>Guinardia striata</i>	0	914	914	0	914	914	1371	0	0	0	0	0	0	0
<i>Guinardia delicatula</i>	0	0	0	0	457	0	457	0	0	0	0	0	0	0
<i>Gyrosigma</i> spp.	0	0	0	0	0	0	457	0	0	0	0	0	0	0
<i>Hemiaulus sinensis</i>	0	0	0	914	0	0	457	0	0	0	0	914	914	0
<i>Melosira</i> spp.	0	686	229	0	457	343	457	0	0	0	0	0	0	0
<i>Navicula delicatula</i>	1371	2057	2629	686	1029	1029	3657	4571	5943	914	10514	5029	10514	8226
<i>Navicula</i> spp.	0	0	457	0	0	0	0	0	0	0	0	914	0	0
<i>Nitzschia longiceps</i>	229	343	800	457	2629	4113	15543	4113	5029	914	3657	4114	30629	0
<i>Nitzschia closterium</i>	0	0	914	0	0	914	0	0	914	914	0	0	0	0
<i>Odontella sinensis</i>	0	0	0	914	0	0	0	0	0	0	457	0	2286	0
<i>Odontella regia</i>	457	0	0	0	0	914	0	0	0	0	0	0	0	0
<i>Pleurosigma</i> spp.	0	0	0	0	114	0	0	0	0	0	0	0	0	0
<i>Pseudonitzschia pungens</i>	2742	0	13710	0	41130	914	49356	8226	0	914	914	7312	16452	0
<i>Rhabdonema</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rhizosolenia delicatula</i>	1029	114	0	914	1143	800	5943	2742	1829	914	3200	1371	5029	8226
<i>Rhizosolenia setigera</i>	0	0	914	0	0	0	0	0	0	0	0	914	0	0
<i>Rhizosolenia indica</i>	0	0	0	0	0	0	914	0	0	0	0	914	0	0
<i>Skeletonema costatum</i>	457	343	8226	3656	1029	3656	4113	5943	457	457	457	457	4113	4114
<i>Streptothecca</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	3200
<i>Striatella</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	914
<i>Thalassionema nitzschioides</i>	0	800	2171	2742	5943	3656	8686	3657	4571	457	914	1829	4571	0
<i>Thalassiothrix</i> spp.	0	0	0	114	0	0	0	0	0	914	0	0	914	457
<i>Thalassiosira</i> spp.	0	0	914	0	0	0	0	0	0	0	0	0	0	457
<i>Thalassiosira punctigera</i>	914	0	914	0	914	0	2742	0	0	0	0	0	914	0
<i>Triceratium</i> spp.	457	0	0	0	0	0	0	0	0	0	0	0	0	457
<i>Surirella</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	914
<b>Sub Total</b>	<b>21253</b>	<b>24456</b>	<b>86043</b>	<b>26049</b>	<b>188895</b>	<b>31650</b>	<b>327284</b>	<b>50732</b>	<b>83654</b>	<b>30163</b>	<b>76798</b>	<b>73583</b>	<b>330479</b>	<b>36107</b>
<b>DINOPHYCEAE</b>														
<i>Ceratium furca</i>	0	2742	914	457	4113	914	2742	457	914	457	457	2742	8226	0
<i>Ceratium fusus</i>	0	457	914	0	2742	914	3656	457	0	914	457	0	457	457
<i>Ceratium trichoceros</i>	0	457	0	0	0	0	3656	0	0	457	0	0	914	0
<i>Ceratium tripos</i>	0	0	457	0	0	0	0	0	0	0	0	0	0	0
<i>Dinophysis</i> spp.	0	457	0	0	457	457	0	3200	457	0	457	457	914	0
<i>Dinophysis caudata</i>	4113	0	457	0	0	0	0	0	0	0	0	0	0	0
<i>Gonyaulax</i> spp.	0	0	457	0	0	0	457	0	457	457	0	0	0	0
<i>Gimnodinium</i> spp.	0	0	0	0	0	0	457	0	0	0	0	0	457	457
<i>Noctiluca scintillans</i>	114	0	343	457	457	0	914	0	0	0	457	0	457	457
<i>Protoperidinium</i> spp.	457	229	114	114	457	114	457	1371	914	457	914	1371	3200	457
<i>Protoperidinium claudicans</i>	0	0	457	0	0	0	0	0	0	0	0	0	0	0
<i>Prorocentrum micans</i>	0	0	914	0	914	0	0	0	0	0	0	0	0	0
<i>Prorocentrum lima</i>	0	0	457	0	0	0	0	0	0	0	0	0	0	0
<b>Sub Total</b>	<b>4684</b>	<b>4342</b>	<b>5484</b>	<b>1028</b>	<b>9140</b>	<b>2399</b>	<b>12339</b>	<b>5485</b>	<b>2742</b>	<b>2742</b>	<b>2743</b>	<b>4571</b>	<b>14625</b>	<b>1828</b>
<b>CYANOPHYCEAE</b>														
<i>Trichodesmium</i> spp.	10054	4113	7312	3656	2285	0	8226	914	4570	4113	4570	4570	21936	5486
<b>Sub Total</b>	<b>10054</b>	<b>4113</b>	<b>7312</b>	<b>3656</b>	<b>2285</b>	<b>0</b>	<b>8226</b>	<b>914</b>	<b>4570</b>	<b>4113</b>	<b>4570</b>	<b>4570</b>	<b>21936</b>	<b>5486</b>
<b>CHLOROPHYCEAE</b>														
<i>Scenedesmus</i> spp.	914	0	0	0	0	0	0	0	0	0	0	0	3656	914
<b>Sub Total</b>	<b>914</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>3656</b>	<b>914</b>
<b>Grand Total</b>	<b>36906</b>	<b>32911</b>	<b>98839</b>	<b>30734</b>	<b>200320</b>	<b>34049</b>	<b>347849</b>	<b>57132</b>	<b>90966</b>	<b>37018</b>	<b>84111</b>	<b>82723</b>	<b>370696</b>	<b>44335</b>

**App.23. List of phytoplankton species and their abundances (cells l<sup>-1</sup>) during July 2001 sampling in Semangka Bay.**

Phytoplankton	stations													River
	1	2	3	4	5	6	7	8	9	10	11	12	13	
<b>BACILLARYOPHYCEAE</b>														
<i>Asterionolopsis glacialis</i>	0	0	0	0	0	457	0	0	0	0	0	0	0	0
<i>Bacteastrum furcatum</i>	457	0	2743	3657	6400	4114	2286	15543	27886	25600	6857	4114	2286	457
<i>Chaetoceros decipiens</i>	105600	16457	47543	66286	75886	16452	22857	20108	197486	71292	42057	55771	543543	47543
<i>Chaetoceros danicus</i>	3656	0	12339	0	10054	6855	914	914	58496	4113	4113	0	16452	0
<i>Chaetoceros debilis</i>	0	8226	914	8226	16452	8226	7312	3656	4113	4113	4113	1371	37017	0
<i>Chaetoceros spp.</i>	0	0	0	0	0	0	457	0	4113	0	0	1371	7312	0
<i>Coscinodiscus spp.</i>	0	0	0	0	0	457	0	0	0	0	0	0	914	0
<i>Coscinodiscus radiatus</i>	9600	8229	13257	6857	10971	5029	7771	4114	1829	4571	3200	2743	7771	1371
<i>Corethron spp.</i>	0	0	457	0	914	0	0	0	0	914	0	0	0	0
<i>Cerataulina spp.</i>	0	0	0	0	0	0	0	914	0	0	0	0	0	914
<i>Dactyliosolen fragillismus</i>	0	0	0	0	0	0	4571	0	0	0	0	0	0	0
<i>Diploneis spp.</i>	0	0	0	0	0	0	0	457	0	0	0	0	4114	0
<i>Ditylum brightwellii</i>	1829	0	0	0	0	457	4571	0	0	0	0	0	0	0
<i>Eucampia zoodiacus</i>	1829	0	1829	457	0	914	0	1371	914	1371	914	457	0	0
<i>Eucampia spp.</i>	0	0	0	0	0	914	0	0	0	0	0	0	0	0
<i>Flagellaria spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	5029	2286
<i>Guinardia flaccida</i>	0	0	914	914	914	2742	4571	0	914	0	457	0	7312	0
<i>Guinardia striata</i>	0	0	0	0	0	4570	0	0	0	0	0	0	0	0
<i>Guinardia delicatula</i>	0	0	3200	914	3657	914	1371	1371	2743	0	0	914	0	0
<i>Gyrosigma spp.</i>	1829	0	0	0	0	0	0	0	0	0	0	0	457	0
<i>Hemiaulus sinensis</i>	0	0	0	0	0	4113	0	0	457	0	0	457	914	0
<i>Melosira spp.</i>	0	0	4571	1829	2286	0	0	0	0	0	0	5029	23771	0
<i>Meuniera membranaceae</i>	0	0	0	0	0	914	0	0	0	0	0	0	0	0
<i>Navicula delicatula</i>	5486	1371	9143	8686	5943	2743	3200	5029	2286	6400	4114	5029	53486	14171
<i>Navicula spp.</i>	0	0	0	0	0	914	0	0	0	0	0	0	0	0
<i>Nitzschia longiceps</i>	3657	1371	2286	7314	13714	10514	1371	19200	29714	13714	3200	4114	10971	1829
<i>Nitzschia closterium</i>	0	0	0	0	0	914	0	0	0	0	0	0	0	0
<i>Odontella sinensis</i>	0	457	0	0	914	0	914	457	0	457	0	0	457	0
<i>Odontella regia</i>	0	0	0	0	0	0	0	0	0	0	0	457	0	0
<i>Pleurosigma spp.</i>	0	0	0	0	457	0	0	0	0	457	0	0	457	0
<i>Pseudonitzschia pungens</i>	0	0	7312	0	21936	30162	29248	22400	19200	7314	1371	5486	32904	914
<i>Rhizosolenia delicatula</i>	2286	2743	5029	3200	4571	4571	2286	39314	10971	9143	5943	5943	13257	1371
<i>Rhizosolenia setigera</i>	0	0	0	0	0	1828	0	0	0	0	0	0	0	0
<i>Rhizosolenia indica</i>	0	0	0	0	0	914	0	0	0	0	0	0	0	0
<i>Streptotheca spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Striatella spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	17371
<i>Thalassionema nitzschioides</i>	914	914	2743	4114	3200	3657	0	3657	914	0	914	0	14171	1371
<i>Thalassiothrix spp.</i>	0	0	914	0	0	457	0	1371	914	2743	0	914	0	0
<i>Thalassiosira spp.</i>	0	0	0	0	0	914	0	0	914	0	0	4570	4570	4114
<i>Thalassiosira punctigera</i>	0	0	0	0	0	4113	0	0	21936	0	0	0	4570	0
<i>Triceratium spp.</i>	457	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Surirella spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	13714
Sub Total	137599	44797	122508	122969	180099	149002	97817	175524	507400	191518	94626	117027	794936	110628
<b>DINOPHYCEAE</b>														
<i>Ceratium furca</i>	914	914	457	914	2742	5941	914	457	1371	914	1371	0	14624	457
<i>Ceratium fusus</i>	0	0	914	7312	10968	9597	10968	914	914	914	0	457	4113	0
<i>Ceratium trichoceros</i>	0	914	0	0	914	2742	914	0	0	0	0	0	914	0
<i>Ceratium tripos</i>	0	0	0	0	0	457	0	0	0	0	0	0	0	0
<i>Dinophysis spp.</i>	457	0	457	457	457	457	0	914	457	0	457	457	2742	0
<i>Dinophysis caudata</i>	0	0	0	0	0	0	0	0	0	0	0	0	914	0
<i>Gonyaulax spp.</i>	0	0	457	457	914	457	0	0	0	0	0	0	0	0
<i>Scropsiella spp.</i>	0	0	0	0	0	457	0	0	0	0	0	0	0	0
<i>Noctiluca scintillans</i>	1371	914	1371	914	1828	914	914	457	1371	1371	914	914	1371	914
<i>Protoperidinium spp.</i>	914	914	914	914	914	457	0	914	457	1829	2286	914	457	0
<i>Protoperidinium claudicans</i>	0	0	0	0	0	457	0	0	0	0	0	0	0	0
<i>Prorocentrum micans</i>	0	457	457	0	0	914	0	0	0	0	0	0	457	0
Sub Total	3657	4114	5028	10969	18737	22850	13710	3657	4571	5028	5028	2743	25592	1371
<b>CYANOPHYCEAE</b>														
<i>Trichodesmium spp.</i>	2742	2285	4113	4570	12339	10054	8226	10968	2742	914	2742	0	24678	3656
Sub Total	2742	2285	4113	4570	12339	10054	8226	10968	2742	914	2742	0	24678	3656
<b>CHLOROPHYCEAE</b>														
<i>Scenedesmus spp.</i>	8226	0	24678	0	0	0	0	0	0	0	0	0	914	10968
Sub Total	8226	0	24678	0	0	0	0	0	0	0	0	0	914	10968
Grand Total	152224	51196	156326	138507	211175	181906	119753	190149	514712	197460	102396	119770	846120	126624

**App.24. List of phytoplankton species and their abundances (cells l<sup>-1</sup>) during October 2001 sampling in Semangka Bay.**

	stations													River	
	1	2	3	4	5	6	7	8	9	10	11	12	13		
Phytoplankton															
<b>BACILLARIOPHYCEAE</b>															
<i>Amphiphora</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	457	0
<i>Asterionolopsis glacialis</i>	0	0	457	0	457	0	457	0	0	0	0	0	0	914	0
<i>Bacterastrum furcatum</i>	0	1371	1829	1829	914	0	457	0	1829	914	457	914	2286	914	914
<i>Bacterastrum hyalinum</i>	0	0	0	0	457	0	0	0	0	0	0	0	914	914	0
<i>Chaetoceros affinis</i>	0	0	12339	0	24678	0	0	0	5484	20108	0	0	0	0	0
<i>Chaetoceros decipiens</i>	119771	194743	242286	95543	81371	197943	6857	150857	92343	11429	3657	4114	831740	37017	0
<i>Chaetoceros danicus</i>	0	7312	37017	14624	8226	0	914	0	457	8226	0	5484	74034	10968	0
<i>Chaetoceros debilis</i>	0	0	0	24678	10968	20565	18280	457	0	914	0	3656	41130	914	0
<i>Chaetoceros didymus</i>	0	0	0	0	914	0	0	0	914	0	0	0	7312	0	0
<i>Coscinodiscus</i> spp.	0	0	0	0	914	457	457	0	0	0	0	0	0	0	0
<i>Coscinodiscus radiatus</i>	0	0	457	914	0	457	0	457	4113	914	0	914	3657	914	0
<i>Corethron</i> spp.	0	1371	1371	0	914	0	0	457	3657	914	1829	457	1371	457	0
<i>Cerataulina</i> spp.	0	7314	1371	3656	1829	0	15086	1829	6400	3200	6857	2743	9600	6857	0
<i>Diploneis</i> spp.	0	0	457	0	0	0	0	0	0	0	0	914	0	0	0
<i>Ditylum brightwellii</i>	457	0	0	457	457	457	0	457	0	0	914	0	0	0	457
<i>Flagillaria</i> spp.	457	0	0	0	0	0	0	0	0	0	1371	0	2743	0	0
<i>Guinardia striata</i>	0	0	0	0	0	0	0	0	2742	0	0	0	0	0	0
<i>Guinardia delicatula</i>	0	1371	3657	914	3200	0	1829	457	3200	2286	0	0	0	0	2286
<i>Hemiaulus sinensis</i>	0	457	0	0	7314	0	0	0	914	914	457	3657	9600	0	0
<i>Lauderia</i> spp.	0	0	0	0	914	457	457	0	457	457	0	0	2743	1829	0
<i>Leptocylindrus danicus</i>	0	0	0	0	0	0	0	0	914	914	0	0	0	0	0
<i>Melosira</i> spp.	1829	0	0	0	0	0	0	457	0	0	0	0	2286	0	0
<i>Navicula delicatula</i>	2743	4114	1371	3657	2743	2286	2286	914	5029	1829	4571	2286	4114	914	0
<i>Navicula</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Nitzschia longiceps</i>	7771	5486	190112	5486	6400	914	5943	914	8686	3200	4114	5943	11429	37017	0
<i>Nitzschia closterium</i>	0	0	914	914	0	0	0	0	914	0	0	0	0	0	0
<i>Odontella sinensis</i>	0	0	0	0	0	0	0	914	0	0	0	457	914	457	0
<i>Odontella regia</i>	0	0	914	914	0	0	0	0	0	457	0	0	457	0	0
<i>Odontella aurita</i>	0	0	914	914	0	0	0	0	0	0	0	0	0	0	0
<i>Pleurosigma</i> spp.	0	0	0	0	914	0	457	0	1371	0	457	0	0	914	0
<i>Pseudonitzschia pungens</i>	914	0	2286	37017	0	914	914	0	16452	914	0	11882	9600	0	0
<i>Rhizosolenia delicatula</i>	2286	5943	13257	11429	20114	3200	6400	2743	18286	7314	1829	3657	5029	6400	0
<i>Rhizosolenia setigera</i>	0	0	0	0	0	0	0	0	4570	0	0	0	0	0	0
<i>Rhizosolenia indica</i>	0	0	0	0	0	0	0	0	914	4570	0	2742	0	0	0
<i>Streptothea</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	9600	0	0
<i>Striatella</i> spp.	0	0	0	0	0	0	0	0	0	0	0	5486	0	0	0
<i>Thalassionema nitzschioides</i>	0	0	3657	21936	0	2743	0	0	0	0	914	3656	12339	0	0
<i>Thalassiothrix</i> spp.	0	0	0	0	0	914	914	0	0	0	0	0	0	0	0
<i>Thalassiosira</i> spp.	0	0	0	0	0	0	0	0	3656	1371	0	0	0	0	0
<i>Thalassiosira punctigera</i>	0	457	5486	5029	2286	0	914	1371	4571	1829	3657	914	4114	1829	0
<i>Triceratium</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	457	0	0
<i>Surirella</i> spp.	0	0	914	914	0	0	4571	457	914	0	0	0	0	0	0
Sub Total	141257	247312	540724	296632	183757	242736	74051	166400	208901	79073	39771	64905	1070783	119284	0
<b>DINOPHYCEAE</b>															
<i>Ceratium furca</i>	457	0	914	457	457	457	0	0	457	914	0	4113	7312	457	0
<i>Ceratium fusus</i>	0	0	0	0	0	914	914	457	914	457	457	0	457	457	0
<i>Ceratium trichoceros</i>	0	0	0	914	914	0	0	0	0	457	0	4113	0	0	0
<i>Dinophysis punctata</i>	0	0	0	0	0	0	0	0	457	0	0	457	914	0	0
<i>Dinophysis</i> spp.	457	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Dinophysis caudata</i>	0	0	0	0	0	0	0	0	457	0	0	0	0	0	0
<i>Gonyaulax</i> spp.	0	0	0	0	0	0	0	0	0	0	0	1828	0	0	0
<i>Gimnodinium</i> spp.	0	0	914	457	0	0	457	914	457	0	0	0	6400	0	0
<i>Scripsiella</i> spp.	0	0	0	0	0	0	0	0	0	914	0	0	0	0	0
<i>Noctiluca scintillans</i>	0	457	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Protoperidinium</i> spp.	457	457	914	914	1371	457	0	914	914	2285	914	2285	6857	457	0
<i>Protoperidinium claudicans</i>	0	0	0	0	0	0	0	0	914	4570	0	0	0	0	0
<i>Prorocentrum micans</i>	0	457	0	0	0	0	0	0	0	8226	0	4113	0	914	0
<i>Prorocentrum compressum</i>	0	0	0	0	457	0	457	0	12796	0	0	0	914	914	0
Sub Total	1371	1371	2743	2742	3199	1828	1828	2285	17367	17823	1371	16452	22397	4113	0
<b>CYANOPHYCEAE</b>															
<i>Trichodesmium</i> spp.	74034	8226	8226	24678	28791	4570	914	24678	8226	30162	3656	8683	3656	49356	0
Sub Total	74034	8226	8226	24678	28791	4570	914	24678	8226	30162	3656	8683	3656	49356	0
<b>CHLOROPHYCEAE</b>															
<i>Scenedesmus</i> spp.	38388	0	0	457	914	0	457	914	0	2742	914	914	20565	25592	0
Sub Total	38388	0	0	457	914	0	457	914	0	2742	914	914	20565	25592	0
Grand Total	255050	256909	551693	324509	216661	249134	77250	194277	234494	129800	45713	90954	1117401	198345	0

**App.25. List of phytoplankton species and their abundances (cells l<sup>-1</sup>) during December 2001 sampling in Semangka Bay.**

Phytoplankton	stations													River
	1	2	3	4	5	6	7	8	9	10	11	12	13	
<b>BACILLARYOPHYCEAE</b>														
<i>Bacteiastrium furcatum</i>	3200	914	0	2286	3200	457	1829	457	10971	0	0	1371	914	457
<i>Chaetoceros decipiens</i>	108343	9597	261404	11429	427752	23764	925425	267429	575086	4571	1829	140367	491001	11425
<i>Chaetoceros danicus</i>	7312	20108	7312	2742	30162	13253	10968	5484	7312	8226	0	47528	71292	4113
<i>Chaetoceros debilis</i>	914	8226	2742	10968	8226	7312	24678	9597	10968	0	1828	30162	23764	3656
<i>Chaetoceros spp.</i>	0	0	0	0	0	0	0	0	0	914	0	8226	9140	0
<i>Chaetoceros spp.</i>	0	0	0	0	16452	0	914	914	0	0	0	0	10054	0
<i>Coscinodiscus spec.</i>	0	0	0	0	0	0	0	0	0	0	0	0	914	0
<i>Coscinodiscus radiatus</i>	457	457	914	457	457	1371	457	457	457	457	0	457	457	457
<i>Corethron spp.</i>	0	457	0	0	2286	0	0	0	2286	0	457	0	0	0
<i>Cerataulina spp.</i>	0	0	0	457	0	457	457	3200	1829	1371	457	0	914	914
<i>Dactyliosolen fragillismus</i>	0	457	0	0	0	0	0	0	0	0	0	0	914	0
<i>Diploneis spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	5027	0
<i>Ditylum brightwellii</i>	0	0	0	0	0	457	0	0	0	0	457	0	0	0
<i>Eucampia zodiacus</i>	0	914	0	0	0	0	0	0	0	0	0	0	0	0
<i>Flagellaria spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	1829	914
<i>Guinardia flaccida</i>	0	2742	457	457	914	457	914	457	457	457	457	914	3656	457
<i>Guinardia striata</i>	0	3656	0	0	914	457	0	0	0	0	0	0	7312	0
<i>Guinardia delicatula</i>	0	1829	1371	914	0	914	1371	0	914	914	0	1371	1371	0
<i>Hemiaulus sinensis</i>	0	0	0	0	914	0	2743	0	0	0	914	1828	2286	0
<i>Leptocylindrus danicus</i>	0	35646	0	0	0	0	0	0	0	0	0	0	9597	0
<i>Melosira spp.</i>	457	0	914	0	9600	0	0	457	0	0	0	0	0	0
<i>Meuniera membranaceae</i>	0	0	0	0	0	0	0	0	0	0	0	1828	0	0
<i>Navicula delicatula</i>	4114	1829	2286	914	914	1829	914	1829	914	914	457	2286	8229	5029
<i>Navicula spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	914	0
<i>Nitzschia longiceps</i>	1371	4571	6400	3200	4571	3200	5029	5486	6857	914	1371	2286	16457	1371
<i>Odontella regia</i>	0	0	457	457	0	457	0	457	0	457	0	0	1371	0
<i>Odontella aurita</i>	0	457	0	0	0	0	0	0	0	0	0	0	2742	0
<i>Paralia spp.</i>	0	0	0	0	3200	457	1371	0	6857	0	0	0	0	0
<i>Pleurosigma spp.</i>	0	914	0	457	0	0	0	0	0	0	0	0	914	0
<i>Pseudonitzschia pungens</i>	8229	11882	5943	0	7771	914	3657	914	4114	0	914	2742	9143	3656
<i>Rhabdonema spp.</i>	0	0	457	0	0	0	0	0	0	0	0	0	0	0
<i>Rhizosolenia delicatula</i>	1829	2286	4114	4571	3657	4114	5486	2743	1829	1829	4571	1829	6857	2286
<i>Rhizosolenia setigera</i>	0	2742	0	0	0	0	0	0	0	0	0	0	2742	0
<i>Rhizosolenia indica</i>	0	4113	0	0	0	0	0	0	0	0	0	2742	11882	0
<i>Rhizosolenia robusta</i>	0	0	0	0	0	0	0	0	0	0	0	0	914	0
<i>Thalassionema nitzschioides</i>	0	1371	0	0	0	0	0	0	914	0	0	914	12796	914
<i>Thalassiothrix spp.</i>	0	0	914	0	0	0	2743	0	0	0	0	0	914	0
<i>Thalassiosira spp.</i>	914	0	1371	457	914	457	0	1371	3657	4114	0	1829	0	914
<i>Thalassiosira punctigera</i>	0	0	0	0	0	0	0	0	0	0	0	4113	1828	914
<i>Triceratium spp.</i>	0	457	1829	0	0	0	0	0	0	0	0	457	0	0
<i>Suriella spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	914
Sub Total	157712	118368	308486	60795	744464	69014	1129711	333699	737365	38397	22399	260107	923339	41592
<b>DINOPHYCEAE</b>														
<i>Ceratium furca</i>	0	914	457	457	914	914	914	914	457	457	457	2285	914	914
<i>Ceratium fusus</i>	0	914	0	0	457	914	3656	0	914	457	0	914	2742	0
<i>Ceratium trichoceros</i>	457	2285	914	457	0	0	457	457	0	0	0	914	3656	457
<i>Dinophysis spp.</i>	457	914	457	457	457	457	457	457	457	0	0	0	3656	0
<i>Dinophysis caudata</i>	0	0	0	0	0	0	0	0	0	0	0	457	0	0
<i>Gimnodinium spp.</i>	0	0	0	0	0	0	0	0	0	0	0	457	0	0
<i>Scrapsiella spp.</i>	0	914	0	0	0	0	0	0	0	0	0	0	0	0
<i>Noctiluca scintillans</i>	0	0	914	0	0	0	0	0	0	457	0	914	0	914
<i>Protoperdinium spp.</i>	0	1371	0	457	457	1371	914	914	914	1371	914	457	914	0
<i>Protoperdinium claudicans</i>	0	2285	0	0	0	0	0	0	0	0	0	0	0	0
<i>Prorocentrum micans</i>	0	1371	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pyrocystis spp.</i>	457	457	457	0	0	0	0	0	0	0	457	0	457	0
Sub Total	1371	11426	3199	1828	2285	3656	6398	2742	2742	2743	1828	6398	12339	2285
<b>CYANOPHYCEAE</b>														
<i>Trichodesmium spp.</i>	1371	10054	4113	8226	12339	10968	8226	10968	7312	12339	5484	7312	13253	10054
Sub Total	1371	10054	4113	8226	12339	10968	8226	10968	7312	12339	5484	7312	13253	10054
<b>CHLOROPHYCEAE</b>														
<i>Scenedesmus spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	914	1828
Sub Total	0	0	0	0	0	0	0	0	0	0	0	0	914	1828
Grand Total	160454	139847	315799	70850	759088	83639	1144336	347409	747420	53479	29712	273817	949845	55760

**App.26. Eigenvalues of each principle component analysis of Biplot PCA, calculated from 30-34 variables.**

		Factors	Eigenvalue	% total Variance	Cumulative Eigenval	Cumulative % variance	Number of variables
Jakarta Bay	stations	1	19.8	58.3	19.8	58.3	34
		2	5.8	17.1	25.7	75.5	
	temporal surveys	1	11.6	34.2	11.6	34.2	34
		2	10.4	30.6	22.0	64.8	
Lampung Bay	stations	1	21.1	66.0	21.1	66.0	32
		2	4.3	13.5	25.4	79.5	
	temporal surveys	1	10.5	33.9	10.5	33.9	32
		2	9.6	30.8	20.1	64.7	
Semangka Bay	stations	1	14.5	46.7	14.5	46.7	31
		2	8.2	26.5	22.7	73.2	
	temporal surveys	1	10.4	33.4	10.4	33.4	31
		2	9.1	29.2	19.4	62.6	

**App.27. T-test results of the bioassays of the effects of nutrient addition on phytoplankton growth. Bolds are significantly different to control (p<0.05)**

		Mean	Mean	t-value	p
		C (Control)	Treatments		
<b>Station 1</b>	C - NO3 10	0.28	0.55	-26.36	<b>0.000</b>
	C - NO3 30	0.28	0.81	-5.41	<b>0.006</b>
	C - NO3 50	0.28	0.70	-33.31	<b>0.000</b>
	C - NO3 70	0.28	0.79	-4.15	<b>0.014</b>
	C - PO4 10	0.28	0.37	-2.47	0.069
	C - PO4 30	0.28	0.33	-0.97	0.389
	C - PO4 50	0.28	0.36	-2.12	0.102
	C - PO4 70	0.28	0.45	-7.03	<b>0.002</b>
	C - NH4 5	0.28	0.45	-2.35	0.078
	C - NH4 10	0.28	0.60	-10.27	<b>0.001</b>
	C - NH4 20	0.28	0.63	-7.88	<b>0.001</b>
	C - NH4 30	0.28	0.76	-6.48	<b>0.003</b>
<b>Station 5</b>	C - NO3 10	0.12	0.21	-3.72	<b>0.020</b>
	C - NO3 30	0.12	0.25	-3.65	<b>0.021</b>
	C - NO3 70	0.12	0.12	0.12	0.910
	C - PO4 10	0.12	0.28	-4.98	<b>0.001</b>
	C - PO4 30	0.12	0.27	-12.59	<b>0.001</b>
	C - PO4 50	0.12	0.48	-2.09	<b>0.041</b>
	C - PO4 70	0.12	0.38	-5.22	<b>0.006</b>
	C - NH4 5	0.12	0.47	-20.86	<b>0.000</b>
	C - NH4 10	0.12	0.44	-65.09	<b>0.000</b>
	C - NH4 20	0.12	0.43	-4.47	<b>0.011</b>
	C - NH4 30	0.12	0.51	-6.93	<b>0.002</b>
	<b>Station 10</b>	C - NO3 10	0.48	0.80	-1.60
C - NO3 30		0.48	0.65	-1.65	<b>0.050</b>
C - NO3 50		0.48	0.73	-6.73	<b>0.003</b>
C - NO3 70		0.48	0.47	0.04	0.970
C - PO4 10		0.48	0.82	-8.33	<b>0.001</b>
C - PO4 30		0.48	0.73	-6.76	<b>0.002</b>
C - PO4 50		0.48	0.74	-6.92	<b>0.002</b>
C - PO4 70		0.48	0.69	-5.77	<b>0.004</b>
C - NH4 5		0.48	0.49	-0.24	0.820
C - NH4 10		0.48	0.44	1.13	0.320
C - NH4 20		0.48	0.60	-3.33	0.112
C - NH4 30		0.48	0.48	-0.01	0.992

Note : C - NO3 10 = Control vs Addition of nitrate to obtain final dosage of 10 µM nitrate.  
 C - PO4 10 = Control vs addition of phosphate to obtain final dosage of 10 µM phosphate.  
 etc.

App.28. Zooplankton abundance during December 2000 survey in Jakarta Bay.

Genera	Stations														
	1	2	3	4	5	6	7	8	9	10	11	12	M	A	P
<b>CRUSTACEAE/COPEPODS</b>															
<i>Acartia</i>	1200	400	1600	2400	0	400	400	0	0	400	800	1200	1600	1200	0
<i>Acrocalanus</i>	1200	1200	4400	0	0	400	800	0	800	0	0	0	0	0	400
<i>Canthocalanus</i>	0	0	0	400	0	0	0	0	0	0	0	0	0	0	400
<i>Centropageus</i>	0	0	400	400	0	0	0	0	0	0	0	0	0	0	0
<i>Corycaeus</i>	0	0	800	0	0	0	0	400	400	0	1200	800	2400	3200	800
<i>Euterpina</i>	800	0	400	800	0	800	0	0	400	2000	0	0	2400	4800	800
<i>Labidocera</i>	0	0	400	0	0	0	0	0	0	0	0	0	0	0	2400
<i>Microsetella</i>	0	0	0	0	400	0	0	0	0	0	0	0	0	0	1200
<i>Oithona</i>	400	400	4000	400	1200	400	0	0	1600	3200	2800	2400	4400	0	0
<i>Oncaea</i>	0	0	0	0	0	0	0	400	0	0	0	0	0	0	0
<i>Paracalanus</i>	400	400	2000	0	400	0	0	400	400	0	0	0	0	0	0
<i>Pseudocalanus</i>	0	0	1200	0	0	0	0	0	0	0	0	0	0	0	0
<i>Nauplius</i>	6800	2400	4400	2800	13200	21200	16800	14800	32800	41200	27600	35200	8800	4000	8400
	10800	4800	19600	7200	15200	23200	18000	16000	36400	46800	32400	39600	19600	13200	14400
<b>PROTOZOA</b>															
<i>Acanthometron</i>	0	0	0	0	400	0	0	0	0	0	0	0	0	0	0
<i>Codonellopsis</i>	2000	0	0	0	400	1200	800	0	1600	5200	3200	2400	4400	0	0
<i>Eutintinnus</i>	0	400	0	0	400	0	1600	0	0	0	400	800	0	0	0
<i>Favella</i>	0	0	0	0	4000	10000	0	7600	15200	20800	800	800	0	0	8400
<i>Leptotintinnus</i>	400	1600	800	400	4800	6800	0	11600	12000	15200	12800	8400	12800	14400	8800
<i>Tintinnopsis</i>	6400	4400	20800	6000	8400	15200	10000	15600	8800	22000	7200	12800	0	0	0
	8800	6400	21600	6400	18400	33200	12400	34800	37600	63200	24400	25200	17200	14400	17200
<b>UROCHORDATE</b>															
<i>Oikopleura</i>	0	400	0	0	400	400	400	400	400	400	0	0	0	0	0
<b>Polychete larvae</b>	400	400	1200	1200	0	800	0	1200	1200	2400	4400	4000	4800	4800	5200
<b>Gastropods larvae</b>	1200	1200	0	0	0	0	0	0	0	1200	0	0	0	0	0
<b>Total</b>	21200	13200	42400	14800	34000	57600	30800	52400	75600	114000	61200	68800	41600	32400	36800

App.29. Zooplankton abundance during February 2001 sampling in Jakarta Bay.

Genera	Station														
	1	2	3	4	5	6	7	8	9	10	11	12	M	A	P
<b>CRUSTACEAE/COPEPODS</b>															
<i>Acartia</i>	0	0	1200	800	0	400	0	800	0	1200	1200	800	1200	2400	2000
<i>Acrocalanus</i>	2000	1200	2800	400	800	0	0	400	1600	2000	0	0	0	0	0
<i>Canthocalanus</i>	0	0	0	0	0	0	400	0	0	0	0	0	0	0	0
<i>Corycaeus</i>	800	0	400	400	400	0	0	0	0	0	400	800	1200	0	0
<i>Euterpina</i>	1200	0	1200	400	0	0	1200	400	0	0	0	0	0	2400	2000
<i>Microsetella</i>	0	0	0	400	0	0	0	0	0	0	0	0	0	2400	2000
<i>Paracalanus</i>	1600	800	3600	400	0	0	800	0	400	400	0	0	0	2400	0
<i>Pseudocalanus</i>	800	1200	1200	0	400	0	0	400	0	400	800	1200	0	0	0
<i>Nauplius</i>	22000	15200	16000	10000	21200	19200	5600	4000	14000	12400	12000	12800	8400	7600	6400
	28400	18400	26400	12800	22800	20000	7600	6000	16000	16400	14400	15600	10800	17200	12400
<b>PROTOZOA</b>															
<i>Acanthometron</i>	0	0	0	0	400	0	0	0	0	0	0	0	0	0	0
<i>Codonellopsis</i>	3200	1200	5200	0	400	1200	800	0	1600	2800	800	1200	800	1200	800
<i>Eutintinnus</i>	0	0	400	0	800	0	1600	0	0	0	400	1200	800	1200	800
<i>Favella</i>	0	0	800	0	3600	3600	0	2400	5200	11600	800	800	800	1200	800
<i>Leptotintinnus</i>	4000	6400	7600	800	3200	9200	9600	15200	9600	5600	2400	3200	800	2400	0
<i>Tintinnopsis</i>	10400	3200	22000	7600	3600	6400	8400	5600	3200	8000	2400	3200	2400	2400	0
	17600	10800	36000	8400	12000	20400	20400	23200	19600	28000	6800	9600	5600	8400	2400
<b>CHAETOGNATE</b>															
<i>Oikopleura</i>	0	0	1600	0	0	0	400	0	0	400	0	0	0	0	0
<b>Gastropods larvae</b>	0	1200	0	0	0	0	0	0	0	1200	0	0	0	0	0
<b>Polychaete larvae</b>	0	1200	800	0	0	0	0	0	0	1200	800	1600	2000	2000	1200
<b>Total</b>	46000	30400	64800	21200	34800	40400	28400	29200	35600	46000	22000	26800	18400	27600	16000

M,A and P = Marunda, Angke and Priok river mouths, respectively.

App.30. Zooplankton abundance during April 2001 sampling in Jakarta Bay.

Genera	Stations													M	A	P
	1	2	3	4	5	6	7	8	9	10	11	12				
<b>CRUSTACEAE/COPEPODS</b>																
<i>Acartia</i>	0	400	400	0	800	7200	400	1200	2400	3600	800	1200	2400	3600	800	
<i>Acrocalanus</i>	800	800	2000	800	1200	12000	0	800	3200	6000	1200	800	400	1200	800	
<i>Evadne</i>	0	0	0	0	400	800	0	0	0	0	0	0	0	400	1200	800
<i>Corycaeus</i>	400	0	400	0	400	400	0	400	0	400	800	1200	0	1200	800	
<i>Euterpina</i>	400	400	0	0	400	0	0	0	0	0	800	800	2400	3600	800	
<i>Pennilia</i>	400	0	800	0	400	0	0	0	0	0	400	0	800	400		
<i>Paracalanus</i>	400	2000	2000	400	1200	1200	0	1600	2000	4000	4800	4400	5200	8400	4800	
<i>Parvocalanus</i>	0	400	800	0	0	0	0	400	400	0	1600	800	800	1200	0	
<i>Centropageus</i>	39600	27200	11600	8400	20000	64000	12000	35600	12400	70000	60400	73600	60400	72400	36800	
<i>Oithona</i>	2400	800	1600	400	3200	6000	0	3600	9200	13200	22000	21200	26400	22400	12800	
<i>Nauplius</i>	39600	27200	11600	8400	20000	64000	12000	35600	12400	70000	60400	73600	60400	72400	36800	
	42000	31200	18000	9600	24800	85600	12400	40000	20400	84000	70400	83200	72000	93600	46000	
<b>PROTOZOA</b>																
<i>Eutintinnus</i>	1200	0	0	0	400	1600	400	0	0	1600	0	0	400	800	1200	
<i>Favella</i>	0	400	0	0	400	0	0	0	400	0	0	0	400	800	400	
<i>Parafavella</i>	0	800	400	0	400	5600	0	800	800	1600	0	0	400	800	1200	
<i>Tintinnopsis</i>	0	0	400	2400	400	2000	0	0	0	3200	8000	8800	13200	8800	6000	
<i>Sticholonche</i>	0	0	0	0	0	0	0	0	0	1200	400	800	800	2400	0	
	1200	1200	800	2400	1600	9200	400	800	1200	7600	8400	9600	15200	13600	8800	
<b>UROCHORDATE</b>																
<i>Oikopleura</i>	4800	2800	2000	1200	0	9200	2000	4800	2000	8000	3200	2400	800	1200	800	
<b>CHAETOGNATE</b>																
<i>Sagitta</i>	800	1200	800	0	0	0	400	0	800	400	0	0	0	0	400	
<i>Polychaete larvae</i>	0	400	0	0	0	0	0	400	800	0	800	1200	3200	4400	4000	
<b>Total</b>	<b>48000</b>	<b>35600</b>	<b>20800</b>	<b>13200</b>	<b>26400</b>	<b>104000</b>	<b>14800</b>	<b>46000</b>	<b>24400</b>	<b>99600</b>	<b>82800</b>	<b>96400</b>	<b>91200</b>	<b>112800</b>	<b>59600</b>	

App.31. Zooplankton abundance during July 2001 sampling in Jakarta Bay.

Genera	Stations													M	A	P
	1	2	3	4	5	6	7	8	9	10	11	12				
<b>CRUSTACEAE/COPEPODS</b>																
<i>Acartia</i>	1200	400	1600	2400	0	400	400	0	0	400	800	1200	1600	1200	0	
<i>Acrocalanus</i>	1200	1200	4400	0	0	400	800	0	800	0	0	0	0	0	400	
<i>Canthocalanus</i>	0	0	0	400	0	0	0	0	0	0	0	0	0	0	400	
<i>Centropageus</i>	0	0	800	800	800	0	0	800	800	800	0	0	0	0	0	
<i>Corycaeus</i>	0	0	800	0	0	0	0	400	400	0	1200	800	2400	3200	800	
<i>Euterpina</i>	800	0	400	800	0	800	0	0	400	2000	0	0	2400	4800	800	
<i>Labidocera</i>	0	0	400	0	0	0	0	0	0	0	0	0	0	0	2400	
<i>Microsetella</i>	0	0	0	0	400	0	0	0	0	0	0	0	0	0	1200	
<i>Oithona</i>	1600	400	6000	0	1200	800	400	0	400	1200	800	1200	800	1200	400	
<i>Oncaea</i>	0	0	0	0	0	0	0	400	0	0	0	0	0	800	0	
<i>Paracalanus</i>	400	2000	2000	0	400	0	0	400	400	0	0	0	0	0	0	
<i>Parvocalanus</i>	0	0	1200	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Nauplius</i>	17600	24400	44400	8800	10000	24000	6800	8400	20400	10400	8800	17600	4400	2000	8400	
	22800	28400	62000	13200	12800	26400	8400	10400	23600	14800	11600	20800	11600	13200	14800	
<b>PROTOZOA</b>																
<i>Acanthometron</i>	0	0	0	0	800	0	0	0	0	0	0	0	0	0	0	
<i>Codonellopsis</i>	2000	0	0	0	400	800	2000	0	1600	4400	2800	2000	3200	2000	400	
<i>Eutintinnus</i>	0	400	0	0	1200	0	1600	0	0	0	400	800	0	0	0	
<i>Favella</i>	10000	4000	1200	2000	2000	2000	5600	5600	1200	10000	4400	4000	2400	2400	2000	
<i>Leptotintinnus</i>	400	1600	800	400	4800	6800	0	11600	12000	15200	12800	8400	12800	14400	8800	
<i>Tintinnopsis</i>	8800	3200	5600	400	4000	4000	8400	10000	6000	800	2400	6400	1200	2400	6000	
	21200	9200	7600	2800	13200	13600	17600	27200	20800	30400	22800	21600	19600	21200	17200	
<b>UROCHORDATE</b>																
<i>Oikopleura</i>	800	400	800	800	400	400	400	800	400	400	0	0	800	800	800	
	800	400	800	800	400	400	400	800	400	400	0	0	800	800	800	
<i>Polychaete larvae</i>	0	2400	800	800	0	0	400	0	1200	0	1200	4400	4000	3600	3200	
<i>Gastropods larvae</i>	2000	400	800	0	400	2000	400	0	3600	400	800	1200	1200	400	800	
<b>Total</b>	<b>46800</b>	<b>40800</b>	<b>72000</b>	<b>17600</b>	<b>26800</b>	<b>42400</b>	<b>27200</b>	<b>38400</b>	<b>49600</b>	<b>46000</b>	<b>36400</b>	<b>48000</b>	<b>37200</b>	<b>39200</b>	<b>36800</b>	

M,A and P = Marunda, Angke and Priok river mouths, respectively.

App.32. Zooplankton abundance during September 2001 sampling in Jakarta Bay.

Genera	Stations													M	A	P
	1	2	3	4	5	6	7	8	9	10	11	12				
<b>CRUSTACEAE/COPEPODS</b>																
<i>Acartia</i>	2400	800	800	1200	0	400	400	0	0	400	800	1200	1600	1200	0	0
<i>Acrocalanus</i>	800	400	2000	800	0	0	400	0	400	800	0	0	400	0	400	
<i>Canthocalanus</i>	0	0	0	400	0	0	0	0	0	0	0	0	0	0	0	400
<i>Centropageus</i>	0	0	400	400	0	0	0	0	0	0	0	0	0	0	0	0
<i>Corycaeus</i>	0	0	800	0	0	0	0	400	400	0	1200	800	2400	3200	800	0
<i>Euterpina</i>	400	0	400	400	0	400	0	400	400	1600	0	0	2000	4000	1200	0
<i>Labidocera</i>	0	0	400	0	0	0	0	0	0	0	0	0	0	0	0	2400
<i>Microsetella</i>	0	0	0	0	400	0	0	0	0	0	0	0	0	0	0	1200
<i>Oithona</i>	2400	800	400	400	0	400	0	2400	400	400	800	2400	4000	800	0	0
<i>Oncaea</i>	0	0	0	0	0	0	0	400	0	0	0	0	0	0	0	0
<i>Paracalanus</i>	400	0	0	400	800	800	0	1600	0	0	1200	4400	8800	800	2000	0
<i>Parvocalanus</i>	0	0	1200	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Nauplius</i>	22400	18400	15600	22000	10400	25600	26400	14800	35200	42400	31600	36800	24800	8400	8800	0
	28800	20400	22000	26000	11600	27600	27200	20000	36800	45600	35600	45600	44000	18400	17200	0
<b>PROTOZOA</b>																
<i>Acanthometron</i>	0	0	0	0	400	0	0	0	0	0	0	0	0	0	0	0
<i>Codonellopsis</i>	2000	0	0	0	400	1200	800	0	1600	5200	3200	2400	4400	0	0	0
<i>Eutintinnus</i>	0	400	0	0	400	0	1600	0	0	0	400	800	0	0	0	0
<i>Favella</i>	12800	0	4400	4800	8400	4400	8400	8800	8000	10000	4800	1200	0	4400	10000	0
<i>Leptotintinnus</i>	400	1600	800	400	4800	6800	0	11600	12000	15200	12800	8400	12800	14400	8800	0
<i>Tintinnopsis</i>	12800	10800	4400	11600	10000	5200	7600	6000	4000	6400	8400	13200	2000	2400	2000	0
	28000	12800	9600	16800	24400	17600	18400	26400	25600	36800	29600	26000	19200	21200	20800	0
<b>UROCHORDATE</b>																
<i>Oikopleura</i>	3600	2000	1600	1200	800	2400	400	0	800	1200	400	0	400	0	0	0
	3600	2000	1600	1200	800	2400	400	0	800	1200	400	0	400	0	0	0
<b>Polychaete larvae</b>	400	400	1200	1200	0	800	0	1200	1200	2400	4400	4000	4800	4800	5200	0
<b>Gastropods larvae</b>	1600	400	800	400	2800	3200	0	0	400	400	400	800	400	0	400	0
<b>Total</b>	62400	36000	35200	45600	39600	51600	46000	47600	64800	86400	70400	76400	68800	44400	43600	0

App.33. Zooplankton abundance during November 2001 sampling in Jakarta Bay.

Genera	Stations													M	A	P
	1	2	3	4	5	6	7	8	9	10	11	12				
<b>CRUSTACEAE/COPEPODS</b>																
<i>Acartia</i>	8400	9200	20400	8400	9200	10000	6000	6400	5600	6000	6400	1200	1600	4800	4800	0
<i>Acrocalanus</i>	1200	1200	4400	0	0	400	800	0	800	0	0	0	0	0	0	400
<i>Canthocalanus</i>	0	0	0	400	0	0	0	0	0	0	0	0	0	0	0	400
<i>Centropageus</i>	0	0	400	400	0	0	0	0	0	0	0	0	0	0	0	0
<i>Corycaeus</i>	0	0	800	0	0	0	0	400	400	0	1200	800	2400	3200	800	0
<i>Euterpina</i>	800	0	400	800	0	800	0	0	400	2000	0	0	2400	4800	800	0
<i>Labidocera</i>	0	0	400	0	0	0	0	0	0	0	0	0	0	0	0	2400
<i>Microsetella</i>	0	0	0	0	400	0	0	0	0	0	0	0	0	0	0	1200
<i>Oithona</i>	800	400	1600	800	3200	400	0	1600	0	3200	800	2400	4400	0	0	0
<i>Oncaea</i>	7200	5200	4000	3600	5600	0	2000	2800	800	400	0	0	0	0	0	0
<i>Paracalanus</i>	800	1600	3600	4400	2000	8400	8400	4800	0	0	0	0	1200	800	1200	0
<i>Parvocalanus</i>	0	0	1200	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Nauplius</i>	20400	8800	8400	12800	12800	8800	26000	12800	32800	44800	38000	44800	20400	14400	20400	0
	39600	26400	45600	31600	33200	28800	43200	28800	40800	56400	46400	49200	32400	28000	32400	0
<b>PROTOZOA</b>																
<i>Acanthometron</i>	0	0	0	0	400	0	0	0	0	0	0	0	0	0	0	0
<i>Codonellopsis</i>	2000	0	0	0	400	1200	800	0	1600	5200	3200	2400	4400	0	0	0
<i>Eutintinnus</i>	0	400	0	0	400	0	1600	0	0	0	400	800	0	0	0	0
<i>Favella</i>	1200	4800	2000	800	8400	10000	800	2400	800	5200	4800	800	0	0	8400	0
<i>Leptotintinnus</i>	400	1600	800	400	4800	6800	0	11600	12000	15200	12800	8400	12800	14400	8800	0
<i>Tintinnopsis</i>	8400	4400	9200	8000	4800	15200	8000	4800	4000	7600	6800	12800	8400	5200	6000	0
	12000	11200	12000	9200	19200	33200	11200	18800	18400	33200	28000	25200	25600	19600	23200	0
<b>UROCHORDATE</b>																
<i>Oikopleura</i>	800	400	400	800	800	400	400	400	400	400	0	0	0	0	0	0
	800	400	400	800	800	400	400	400	400	400	0	0	0	0	0	0
<b>Polychaete larvae</b>	1600	1200	1600	800	400	2400	0	2400	2400	2000	4800	4800	5200	4400	4000	0
<b>Gastropods larvae</b>	2400	1600	1200	800	0	400	800	800	0	1200	0	0	0	0	0	0
<b>Total</b>	56400	40800	60800	43200	53600	65200	55600	51200	62000	93200	79200	79200	63200	52000	59600	0

M,A and P = Marunda, Angke and Priok river mouths, respectively.



App.34. Zooplankton abundance during January 2001 sampling in Lampung Bay.

Genera	Stations															KK	WL
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
<b>CRUSTACEA/COPEPODS</b>																	
<i>Acartia</i>	0	0	0	0	1333	0	0	133	0	267	267	0	0	0	1600	0	0
<i>Acrocalanus</i>	133	933	1333	1467	1867	2933	4267	1067	1467	400	1200	400	267	400	2000	267	267
<i>Canthocalanus</i>	0	0	0	267	400	0	0	267	133	0	0	0	0	0	0	3067	2800
<i>Centropageus</i>	0	0	0	0	0	0	267	133	0	0	0	0	0	0	0	2133	0
<i>Corycaeus</i>	533	667	0	0	267	267	1200	400	400	0	133	267	400	267	2133	0	0
<i>Euterpina</i>	0	0	0	0	0	267	133	0	0	0	0	0	0	0	0	0	0
<i>Evadne</i>	133	533	0	0	267	0	0	400	0	0	267	0	0	0	2933	2933	2933
<i>Microsetella</i>	400	133	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Paracalanus</i>	1200	1867	0	0	0	0	0	1600	0	267	533	400	533	267	400	1067	1200
<i>Parvocalanus</i>	2933	5067	2533	3200	2000	1600	4267	4933	1333	267	2667	800	667	667	267	933	1200
<i>Penilia</i>	0	800	267	0	533	667	0	400	0	133	533	0	0	0	0	0	0
<i>Nauplius</i>	40133	36933	17733	22267	17333	8800	21067	27733	4400	9733	4667	8800	7333	5867	17600	16267	20800
<b>PROTOZOA</b>																	
<i>Codonellopsis</i>	133	0	0	0	0	267	0	0	0	0	0	0	0	0	0	0	0
<i>Eutintinnus</i>	133	533	0	0	0	267	0	1200	0	0	0	133	133	133	667	267	0
<i>Favella</i>	0	0	1067	133	0	267	0	0	133	0	0	0	0	0	0	267	0
<i>Globigerina</i>	0	0	0	0	133	0	0	0	0	0	0	0	0	0	267	0	267
<i>Peurpsis</i>	667	0	0	0	0	0	0	0	0	0	0	0	0	0	267	0	0
<i>Salpingella</i>	2667	400	0	0	0	0	0	800	0	267	0	0	0	0	0	0	0
<i>Tintinnopsis</i>	0	4533	1067	1867	0	0	0	2267	133	0	0	0	0	0	0	0	0
<i>Xystonella</i>	0	0	0	0	0	0	0	0	933	0	0	0	133	133	267	0	0
	45467	46933	21867	27200	24000	14800	31067	36933	7733	11200	10267	10667	9200	7467	29067	24533	29200
<b>CHAETOGNATE</b>																	
<i>Sagitta</i>	400	533	0	0	133	267	667	400	133	267	0	400	267	133	0	133	0
<b>UROCHORDATE</b>																	
<i>Oikopleura</i>	1733	16533	9733	10800	6400	2933	2133	4667	0	667	533	267	267	267	267	267	267
<b>POLYPLACOPHORE</b>																	
<i>Liolophura</i>	0	267	267	800	533	800	400	0	267	133	0	133	133	133	267	267	267
<b>Polychaete larvae</b>	0	667	0	0	0	267	267	0	0	0	0	0	0	0	0	800	2800
<b>TOTAL</b>	59467	86533	34000	40800	48533	22800	42000	53200	9467	13867	11733	11600	10400	8533	31067	26533	32800

App.35. Zooplankton abundance during February 2001 sampling in Lampung Bay.

Genera	Stations															KK	WL
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
<b>CRUSTACEA/COPEPODS</b>																	
<i>Acartia</i>	667	667	0	3600	133	0	0	0	0	0	0	400	0	0	2133	2800	4000
<i>Acrocalanus</i>	1333	667	1600	4933	0	533	400	800	1333	133	400	533	0	267	800	0	2933
<i>Canthocalanus</i>	533	133	400	0	0	400	800	0	0	267	267	533	0	0	800	1200	2800
<i>Corycaeus</i>	0	0	0	400	0	0	0	533	267	0	267	0	0	133	267	667	800
<i>Euterpina</i>	267	0	267	800	800	533	133	667	0	0	133	0	0	0	267	800	667
<i>Evadne</i>	0	0	0	0	0	133	0	0	0	267	0	0	0	0	0	0	400
<i>Microsetella</i>	0	0	133	0	0	0	0	267	400	0	0	0	0	0	0	2933	0
<i>Oithona</i>	133	0	2400	4667	0	0	400	1600	0	0	133	0	0	0	0	0	0
<i>Paracalanus</i>	133	1067	533	5600	533	1200	400	1200	267	133	1333	133	0	0	0	2933	3333
<i>Parvocalanus</i>	800	0	1200	3467	1467	267	267	133	2667	133	0	133	0	0	0	0	2933
<i>Nauplius</i>	24400	17867	16667	12933	26000	36533	16133	34133	32400	12533	12000	19067	267	1600	14933	20133	22133
	28266	20400	23200	36400	28933	39600	18533	39333	37333	13467	14533	20800	267	2000	19200	31467	40000
<b>PROTOZOA</b>																	
<i>Acanthometron</i>	533	0	0	0	267	133	400	267	133	0	0	0	0	0	400	400	400
<i>Codonellopsis</i>	267	667	667	0	933	2267	1333	667	3733	400	0	400	0	0	0	0	0
<i>Eutintinnus</i>	667	533	667	0	1067	933	800	1333	0	0	533	533	0	0	0	0	267
<i>Favella</i>	267	267	133	0	1067	533	800	1200	133	267	0	133	0	0	667	267	267
<i>Leprotintinnus</i>	0	400	0	0	133	267	0	133	267	667	0	0	0	400	0	0	0
<i>Paravella</i>	0	0	0	0	133	0	0	0	0	0	0	0	0	0	667	667	800
<i>Salpingella</i>	0	0	0	0	0	0	0	267	533	400	400	0	133	0	0	0	0
<i>Sticholance</i>	0	0	0	0	0	0	0	0	0	0	0	0	133	0	0	0	0
<i>Tintinnopsis</i>	1867	2000	1333	400	6933	5067	2667	6400	10133	2800	1867	1733	533	2000	9867	7333	4267
	3600	3867	2800	400	10533	9200	6000	10267	14933	4533	2800	2800	800	2400	11600	8667	6000
<b>CHAETOGNATE</b>																	
<i>Sagitta</i>	133	133	800	267	267	267	0	133	267	0	0	267	133	0	400	267	267
<b>UROCHORDATE</b>																	
<i>Oikopleura</i>	4133	2933	800	800	3467	4933	1200	2933	4400	2133	933	800	0	267	2933	2800	3067
<b>POLYPLACOPHORE</b>																	
<i>Liolophura</i>	133	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>Polychaete larvae</b>	133	933	0	2667	133	533	0	800	933	0	0	133	133	133	2000	2800	6800
<b>total</b>	36400	28267	27600	40533	43333	54533	25733	53467	57867	20133	18267	24800	1333	4800	36133	46000	56133

KK and WL = Kota Karang and Way Lunik river mouths, respectively.

App.36. Zooplankton abundance during May 2001 sampling in Lampung Bay.

Genera	Stations															KK	WL	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15			
<b>CRUSTACEA/COPEPODS</b>																		
<i>Acartia</i>	133	800	133	1467	133	533	133	0	133	0	0	0	267	267	533	2000	1600	
<i>Acrocalanus</i>	267	667	0	800	933	800	533	533	400	0	533	267	133	267	667	0	1467	
<i>Calanopia</i>	0	267	0	0	0	0	0	0	0	0	0	0	0	0	0	1600	0	
<i>Canthocalanus</i>	0	533	133	400	0	933	267	133	933	0	0	0	0	0	0	667	0	
<i>Centropageus</i>	0	0	0	0	0	0	0	0	0	0	0	0	267	400	533	0	800	
<i>Corycaeus</i>	0	267	0	133	133	0	267	0	0	0	0	0	0	0	0	0	0	
<i>Euterpina</i>	0	0	0	0	0	133	133	133	267	0	0	0	0	0	0	0	0	
<i>Microsetella</i>	0	0	0	0	0	267	0	0	0	0	0	0	0	0	0	0	0	
<i>Oithona</i>	533	267	1067	1467	1200	933	400	667	0	133	0	0	400	267	267	2933	667	
<i>Paracalanus</i>	133	800	0	533	267	400	400	133	533	0	0	0	400	267	267	2800	667	
<i>Parvocalanus</i>	133	533	667	400	667	133	0	133	267	133	0	0	0	0	0	0	0	
<i>Nauplius</i>	6667	7200	9200	8800	7600	8133	2800	4400	2400	2000	1067	2133	2000	10267	10667	10800		
	7867	11333	11200	14000	10933	12267	4933	6133	4933	2267	1600	2400	3467	3467	13200	20000	17067	
<b>PROTOZOA</b>																		
<i>Acanthometron</i>	400	400	133	0	800	0	0	267	133	133	267	400	133	0	267	400	667	
<i>Codonellopsis</i>	0	0	0	133	0	0	0	0	133	0	133	0	133	267	267	0	0	
<i>Eutintinnus</i>	0	133	133	0	133	133	533	400	0	400	267	800	133	0	400	0	267	
<i>Favella</i>	0	0	0	0	0	0	0	0	0	133	267	267	133	267	0	667	267	
<i>Leprotintinnus</i>	0	0	0	0	0	0	533	0	133	267	1200	400	0	0	0	667	133	
<i>Salpingella</i>	0	133	0	0	0	0	0	267	0	133	0	0	0	0	0	0	0	
<i>Sticholonche</i>	267	133	267	0	1067	0	0	133	0	0	0	0	0	267	0	0	0	
<i>Tintinnopsis</i>	533	267	0	667	0	0	1333	0	0	1333	2933	933	267	267	267	667	267	
	1200	1067	533	800	2000	133	2400	1067	400	2400	5067	2800	800	1067	1200	2400	1600	
<b>CHAETOGNATE</b>																		
<i>Sagitta</i>	0	267	400	0	400	0	0	0	0	0	0	0	133	0	133	133	133	
<b>UROCHORDATE</b>																		
<i>Oikopleura</i>	267	267	1333	0	800	667	667	933	133	267	400	267	267	133	667	667	400	
<b>Polychaete larvae</b>	133	267	267	133	400	0	0	0	0	0	133	0	133	267	267	267	267	
<b>Gastropods larvae</b>	0	133	400	133	133	533	267	400	0	0	0	0	133	267	800	1600	2933	
<b>TOTAL</b>	9467	13333	14133	15067	14667	13600	8267	8533	5467	4933	7067	5600	4800	5067	16267	25067	22400	

App.37. Zooplankton abundance during July 2001 sampling in Lampung Bay.

Genera	Stations															KK	WL
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
<b>CRUSTACEA/COPEPODS</b>																	
<i>Acartia</i>	133	533	133	800	933	133	267	400	133	0	0	0	133	267	667	800	667
<i>Acrocalanus</i>	133	533	933	1400	267	133	133	800	0	133	0	0	0	0	0	0	667
<i>Centropageus</i>	0	133	533	1000	667	0	267	533	0	133	0	133	133	0	0	0	667
<i>Corycaeus</i>	267	533	267	200	133	0	267	533	0	0	267	0	0	0	0	1067	0
<i>Euterpina</i>	0	133	400	0	0	0	0	0	0	0	0	0	267	267	2133	0	0
<i>Evadne</i>	0	133	800	200	0	0	0	0	0	0	0	0	0	0	0	1067	667
<i>Microsetella</i>	133	133	133	0	267	133	0	0	0	0	0	267	0	133	667	0	0
<i>Oithona</i>	133	133	1067	2400	1067	533	667	667	1333	667	133	267	0	0	0	1067	0
<i>Oncaea</i>	133	533	1333	0	400	400	0	0	133	133	0	267	0	0	0	0	267
<i>Paracalanus</i>	267	800	1067	1000	667	267	133	400	133	0	0	267	267	267	800	267	0
<i>Parvocalanus</i>	0	1200	2267	600	133	0	0	267	0	0	0	0	0	0	0	0	0
<i>Penaeus</i>	0	133	667	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Penilia</i>	0	400	133	200	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Nauplius</i>	29200	42133	20667	28200	25867	24000	15733	39067	30533	7867	6400	7600	2000	2133	26800	30800	29467
	30400	47467	30400	36000	30400	25600	17467	42667	32267	8933	6800	8800	2800	3067	31067	35067	32400
<b>PROTOZOA</b>																	
<i>Codonellopsis</i>	0	400	0	200	400	0	1067	400	2933	667	1333	3200	2933	1333	1600	1467	2000
<i>Dyctyocysta</i>	533	133	0	0	0	133	267	400	400	0	1067	1867	0	0	667	800	1067
<i>Eutintinnus</i>	400	0	133	0	267	133	133	267	400	533	800	1733	267	267	267	667	267
<i>Favella</i>	267	267	267	400	267	267	267	267	0	0	267	400	0	0	667	800	267
<i>Globigerinella</i>	0	3067	267	0	0	0	0	0	0	1067	0	0	0	0	0	0	0
<i>Leprotintinnus</i>	0	0	0	0	0	0	0	0	0	0	533	0	267	133	533	667	667
<i>Salpingella</i>	0	267	133	0	0	0	133	133	0	0	0	0	267	267	400	400	267
<i>Tintinnopsis</i>	1200	933	0	1000	667	133	667	533	1067	2533	8000	23333	800	267	267	400	800
	2400	5067	800	1600	1600	667	2533	2000	4800	4800	12000	30533	4533	2267	4400	5200	5333
<b>CHAETOGNATE</b>																	
<i>Sagitta</i>	133	933	533	200	267	533	267	400	0	133	0	0	0	133	667	800	800
<b>UROCHORDATE</b>																	
<i>Oikopleura</i>	2533	5067	9733	8400	4800	3333	1067	3067	2000	1733	667	533	267	267	400	667	667
<b>Polychaete larvae</b>	0	1600	1467	2000	133	800	0	267	0	133	0	0	0	133	800	1200	7333
<b>Gastropods larvae</b>	133	533	1067	1200	133	133	0	267	267	0	0	0	133	133	1600	2933	1467
<b>TOTAL</b>	35600	60667	44000	49400	37333	31067	21333	48667	39333	15733	19467	39867	7733	6000	38933	45867	48000

KK and WL = Kota Karang and Way Lunik river mouths, respectively.

App.38. Zooplankton abundance during September 2001 sampling in Lampung Bay.

Genera	Stations															KK	WL
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
<b>CRUSTACEAE/COPEPODS</b>																	
<i>Acartia</i>	0	0	0	267	667	0	0	267	133	133	267	400	0	267	2133	0	0
<i>Acrocalanus</i>	133	800	667	1600	267	1600	3333	667	1600	400	667	400	267	267	2000	800	800
<i>Canthocalanus</i>	0	0	0	133	667	0	0	267	667	0	0	400	0	0	0	2933	4267
<i>Centropageus</i>	0	400	0	0	267	133	267	0	0	0	0	0	0	0	2800	0	0
<i>Corycaeus</i>	267	267	0	133	267	267	667	533	1467	0	267	400	267	267	1867	0	0
<i>Euterpina</i>	0	0	0	0	0	267	267	0	0	0	0	0	0	0	0	0	0
<i>Evadne</i>	267	400	0	0	400	0	0	400	267	0	267	0	0	0	3333	3333	3333
<i>Labidocera</i>	0	0	0	0	0	0	0	0	267	267	0	0	0	0	0	0	0
<i>Microsetella</i>	267	267	267	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Paracalanus</i>	1067	1467	0	0	0	0	0	667	0	667	400	267	267	400	533	1067	1067
<i>Parvocalanus</i>	2133	2800	1467	7333	2800	1467	2933	2933	1600	267	2000	667	400	667	267	1067	1067
<i>Penilia</i>	0	133	400	0	667	267	0	267	0	267	267	0	0	0	0	0	0
<i>Nauplius</i>	29467	18800	19200	28133	20533	7333	16133	28133	7333	7333	4400	7333	7467	6133	26533	30000	29467
	33600	25333	22000	37600	26533	11333	23600	34133	13333	9333	8533	9867	8667	8000	39467	39200	40000
<b>PROTOZOA</b>																	
<i>Codonellopsis</i>	0	0	0	0	0	133	0	0	0	0	0	0	0	0	0	0	0
<i>Eutintinnus</i>	400	267	0	267	0	267	0	1067	0	0	0	133	133	133	667	667	267
<i>Favella</i>	0	0	1067	267	267	400	0	0	133	0	0	0	0	0	0	0	267
<i>Peurpsis</i>	800	0	667	0	0	267	0	0	0	0	0	133	133	133	267	400	400
<i>Salpingella</i>	2400	3067	0	267	0	0	0	667	0	267	0	0	0	0	0	0	0
<i>Tintinnopsis</i>	0	4400	267	4400	0	0	0	1467	133	0	0	0	0	0	0	0	0
<i>Xystonella</i>	667	0	0	0	0	0	0	0	933	0	0	0	133	133	267	267	400
	4267	7733	2000	5200	533	1067	267	3200	1200	267	0	267	400	400	1467	1600	1333
<b>CHAETOGNATE</b>																	
<i>Sagitta</i>	400	533	0	1200	133	400	400	267	400	267	267	133	133	133	400	400	400
<b>UROCHORDATE</b>																	
<i>Oikopleura</i>	1733	2000	2933	10800	3067	2933	2133	2800	0	667	533	267	267	133	1600	2000	2133
<b>POLYPLACOPHORE</b>																	
<i>Liolophura</i>	0	267	267	800	533	800	400	0	267	133	0	133	133	133	267	133	267
<b>Polychaete larvae</b>	0	667	0	5867	0	267	267	0	0	0	0	0	267	0	7333	4400	3867
<b>TOTAL</b>	48267	52667	27200	68800	31067	17467	27467	47333	15733	12400	10667	10667	10400	9733	53467	51467	52400

App.39. Zooplankton abundance during November 2001 sampling in Lampung Bay.

Genera	Stations															KK	WL
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
<b>CRUSTACEAE/COPEPODS</b>																	
<i>Acartia</i>	0	0	0	267	667	0	0	267	133	133	133	267	0	267	2000	267	667
<i>Acrocalanus</i>	133	800	667	1600	267	1600	3333	667	1600	267	1200	267	267	267	4400	800	533
<i>Canthocalanus</i>	0	0	0	133	667	0	0	267	667	0	0	267	0	0	0	2933	5067
<i>Centropageus</i>	0	400	0	0	267	133	267	0	0	0	0	0	0	0	4400	0	0
<i>Corycaeus</i>	533	267	0	133	267	267	667	533	1333	0	133	267	267	267	1600	0	0
<i>Euterpina</i>	0	0	0	0	0	267	267	0	0	0	0	0	0	0	0	0	0
<i>Evadne</i>	400	400	0	0	400	0	0	400	133	0	133	0	0	0	3467	1600	3733
<i>Microsetella</i>	533	267	267	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Paracalanus</i>	267	1333	0	533	0	133	133	267	267	133	400	400	267	267	400	667	1200
<i>Parvocalanus</i>	1333	3333	2133	3333	3067	2000	3333	3200	2133	533	2133	667	533	667	800	1467	1333
<i>Penilia</i>	0	133	400	0	667	267	0	267	0	267	267	0	0	0	0	0	0
<i>Nauplius</i>	28133	20667	17867	32533	20800	8800	17467	30533	6133	8800	5200	7733	7867	7333	28667	30933	31867
	31333	27600	21333	38533	27067	13467	25467	36400	12533	10400	9600	9867	9200	9067	45733	38667	44400
<b>PROTOZOA</b>																	
<i>Codonellopsis</i>	133	267	0	0	0	133	0	0	0	0	0	0	0	0	0	0	0
<i>Eutintinnus</i>	400	400	0	400	0	267	0	1067	0	0	0	267	267	267	667	667	133
<i>Favella</i>	0	0	667	400	800	267	0	1200	267	267	0	0	0	0	0	0	267
<i>Peurpsis</i>	667	0	667	0	0	267	0	0	0	0	0	267	267	267	267	667	267
<i>Salpingella</i>	1467	2800	267	267	0	0	267	533	0	267	0	0	0	0	0	0	0
<i>Tintinnopsis</i>	0	3067	267	8800	0	0	0	2000	267	0	0	0	0	0	0	0	0
<i>Xystonella</i>	533	0	0	0	0	0	0	0	1067	0	0	400	267	133	267	400	533
	3200	6533	1867	9867	1067	933	400	4800	1600	533	0	933	800	667	1467	2000	1333
<b>CHAETOGNATE</b>																	
<i>Sagitta</i>	400	533	0	1067	133	400	400	267	400	400	400	133	267	133	267	400	267
<b>UROCHORDATE</b>																	
<i>Oikopleura</i>	1600	2000	2933	7333	4267	3333	2267	3467	2800	800	533	667	400	400	10267	5200	6800
<b>POLYPLACOPHORE</b>																	
<i>Liolophura</i>	0	267	267	800	533	800	400	0	267	133	0	133	133	133	267	133	267
<b>Polychaete larvae</b>	0	800	0	7333	0	400	400	0	0	0	0	0	0	800	0	8667	7067
<b>TOTAL</b>	38000	39200	26400	67867	33600	19867	29600	46533	19467	14000	11867	11733	11867	11067	69867	57333	64800

KK and WL = Kota Karang and Way Lunik river mouths, respectively.

App.40. Zooplankton abundance during January 2001 sampling in Semangka Bay.

Genera	Stations														R
	1	2	3	4	5	6	7	8	9	10	11	12	13		
<b>CRUSTACEAE/COPEPODS</b>															
<i>Acartia</i>	0	0	400	0	800	800	0	0	800	0	800	0	3600	0	
<i>Acrocalanus</i>	800	0	0	0	800	0	0	0	400	400	0	0	2400	0	
<i>Corycaeus</i>	0	0	0	0	800	800	1200	0	0	0	800	400	0	0	
<i>Euterpina</i>	0	0	0	0	0	0	0	0	0	0	0	800	0	6000	
<i>Microsetella</i>	0	0	2400	800	400	800	0	400	400	0	800	0	1200	0	
<i>Oithona</i>	1200	0	800	0	800	0	800	0	800	800	0	0	800	3600	
<i>Paracalanus</i>	0	0	400	0	0	0	0	0	0	0	0	0	0	0	
<i>Nauplius</i>	6000	3200	10400	1200	3200	2000	3200	2800	3200	2000	1200	3600	15600	1200	
	8000	3200	14400	2000	6800	4400	5200	3200	5600	3200	3600	4800	23600	10800	
<b>PROTOZOA</b>															
<i>Tintinnopsis</i>	0	400	1200	0	0	0	0	0	2000	0	0	400	4400	0	
<i>Acanthomentron</i>	0	0	0	0	800	0	800	0	0	0	0	0	1200	0	
<i>Codonellopsis</i>	800	0	0	800	400	800	0	800	1600	0	0	2000	3600	0	
<i>Eutintinnus</i>	0	0	0	0	0	800	0	800	0	800	0	0	800	0	
<i>Favella</i>	0	800	0	0	0	400	0	0	0	0	0	400	800	0	
<i>Parafavella</i>	0	0	0	0	0	400	0	0	0	400	800	0	0	0	
	800	1200	1200	800	1200	2400	800	1600	3600	1200	800	2800	10800	0	
<b>CHAETOGNATE</b>															
<i>Sagitta</i>	0	0	0	0	0	400	0	800	0	0	0	0	800	0	
<b>UROCHORDATE</b>															
<i>Oikopleura</i>	0	0	800	0	0	0	0	0	800	400	0	400	400	0	
<b>Polychaete larvae</b>	0	0	1200	0	1200	0	400	0	400	0	0	0	4400	0	
<b>Gastropods larvae</b>	0	0	2400	400	0	400	0	400	0	0	0	0	800	0	
<b>TOTAL</b>	9200	4400	20000	3200	9200	7600	6400	6000	10400	4800	4400	8000	40800	10800	

App.41. Zooplankton abundance during March 2001 sampling in Semangka Bay.

Genera	Stations														R
	1	2	3	4	5	6	7	8	9	10	11	12	13		
<b>CRUSTACEAE/COPEPODS</b>															
<i>Acartia</i>	0	0	400	0	400	400	0	0	400	0	400	0	2000	0	
<i>Acrocalanus</i>	400	0	0	0	400	0	0	0	400	0	0	0	800	0	
<i>Corycaeus</i>	0	0	0	0	400	400	800	0	0	0	400	0	0	0	
<i>Euterpina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1200	
<i>Microsetella</i>	0	0	400	0	400	400	0	0	400	0	400	0	800	0	
<i>Oithona</i>	400	0	800	0	400	0	400	0	800	400	0	0	800	3600	
<i>Paracalanus</i>	0	0	400	0	0	0	0	0	0	0	0	0	0	0	
<i>Nauplius</i>	4400	2000	9200	1200	2000	2000	3200	2800	5200	2800	1600	4000	8800	3600	
	5200	2000	11200	1200	4000	3200	4400	2800	7200	3200	2800	4000	13200	8400	
<b>PROTOZOA</b>															
<i>Tintinnopsis</i>	0	400	400	0	0	0	0	0	2000	0	0	400	1200	0	
<i>Acanthomentron</i>	0	0	0	0	400	0	0	0	0	0	0	0	1200	0	
<i>Codonellopsis</i>	0	0	0	0	400	400	0	400	2400	0	0	1200	1200	0	
<i>Eutintinnus</i>	0	0	0	0	0	400	0	400	0	400	0	0	800	0	
<i>Favella</i>	0	0	0	0	0	400	0	0	0	0	0	400	800	0	
<i>Parafavella</i>	0	0	0	0	0	400	0	0	0	400	400	0	0	0	
	0	400	400	0	800	1600	0	800	4400	800	400	2000	5200	0	
<b>CHAETOGNATE</b>															
<i>Sagitta</i>	0	0	0	0	0	400	0	400	0	0	0	0	800	0	
<b>UROCHORDATE</b>															
<i>Oikopleura</i>	0	0	800	0	0	0	0	0	400	400	0	400	400	0	
<b>Polychaete larvae</b>	0	0	0	0	400	0	400	0	400	0	0	0	2400	0	
<b>Gastropods larvae</b>	0	0	0	0	0	0	0	0	0	0	400	0	1200	0	
<b>TOTAL</b>	5600	2400	12400	1200	5200	5200	4800	4000	12400	4400	3600	6400	23200	8400	

R = Semangka river mouth

App.42. Zooplankton abundance during May 2001 sampling in Semangka Bay.

Genera	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	R
<b>CRUSTACEAE/COPEPODS</b>														
<i>Acrocalanus</i>	400	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Paracalanus</i>	400	0	400	0	0	400	0	0	0	0	0	0	0	0
<i>Nauplius</i>	1600	400	800	400	800	0	1600	400	400	800	400	400	1600	0
	2400	400	1200	400	800	400	1600	400	400	800	400	400	1600	0
<b>PROTOZOA</b>														
<i>Tintinnopsis</i>	0	800	400	400	1600	0	800	1200	1200	0	400	0	800	0
<i>Acanthomentron</i>	0	0	0	0	0	0	0	0	400	0	0	0	0	0
<i>Codonellopsis</i>	0	0	400	0	0	400	400	0	0	400	0	400	0	0
<i>Eutintinnus</i>	0	400	0	0	0	0	400	400	0	0	0	0	0	0
<i>Favella</i>	0	0	0	400	0	0	0	400	400	0	0	0	0	0
<i>Parafavella</i>	0	0	0	0	0	0	0	0	400	0	0	0	0	0
	0	1200	800	800	1600	400	1600	2000	2400	400	400	400	800	0
<b>UROCHORDATE</b>														
<i>Oikopleura</i>	0	400	0	0	400	0	400	400	400	0	400	0	0	0
<b>Polychaete larvae</b>	0	0	0	0	400	0	0	0	0	0	0	0	1200	0
<b>Gastropods larvae</b>	400	0	1600	0	400	400	400	0	0	0	0	0	1600	0
<b>TOTAL</b>	2800	2000	3600	1200	3600	1200	4000	2800	3200	1200	1200	800	5200	0

App.43. Zooplankton abundance during July 2001 sampling in Semangka Bay.

Genera	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	R
<b>CRUSTACEAE/COPEPODS</b>														
<i>Acartia</i>	200	200	0	400	1200	600	200	600	400	400	200	600	1000	0
<i>Acrocalanus</i>	600	600	400	400	400	200	2400	400	0	0	0	600	400	200
<i>Euterpina</i>	0	0	200	200	400	600	200	0	200	400	0	0	600	0
<i>Oithona</i>	2800	600	5400	0	0	800	400	200	600	0	0	0	0	200
<i>Paracalanus</i>	1600	600	1400	0	400	0	1400	0	2200	2600	200	400	400	0
<i>Nauplius</i>	4600	2400	6600	3000	6600	4400	6800	2200	2200	0	1400	2200	12200	0
	9800	4400	14000	4000	9000	6600	11400	3400	5600	3400	1800	3800	14600	400
<b>PROTOZOA</b>														
<i>Tintinnopsis</i>	800	400	800	400	600	400	0	0	0	400	0	400	600	0
<i>Acanthomentron</i>	0	400	0	400	400	400	0	200	0	0	200	0	400	0
<i>Codonellopsis</i>	200	200	200	0	600	400	1400	0	600	0	200	0	0	0
<i>Leprotintinnus</i>	600	0	400	0	0	200	0	200	0	200	0	400	600	0
<i>Eutintinnus</i>	0	0	0	400	0	0	600	0	0	0	0	0	600	0
<i>Favella</i>	0	0	1400	0	0	0	200	0	0	0	0	0	0	0
	1600	1000	2800	1200	1600	1400	2200	400	600	600	400	800	2200	0
<b>CHAETOGNATE</b>														
<i>Sagitta</i>	400	200	200	400	200	200	0	0	200	0	0	0	400	0
	400	200	200	400	200	200	0	0	200	0	0	0	400	0
<b>UROCHORDATE</b>														
<i>Oikopleura</i>	0	200	400	0	200	200	0	0	200	0	200	200	400	0
<b>Polychaete larvae</b>	200	200	0	200	200	0	600	200	200	0	200	200	1000	0
<b>Gastropods larvae</b>	200	200	200	200	200	200	200	0	0	0	0	0	1200	0
<b>TOTAL</b>	12200	6200	17400	5800	11200	8400	14200	4200	6800	4000	2600	5000	18600	400

R = Semangka river mouth

App.44. Zooplankton abundance during October 2001 sampling in Semangka Bay.

Genera	Stations														R
	1	2	3	4	5	6	7	8	9	10	11	12	13	R	
<b>CRUSTACEAE/COPEPOD</b>	2200	3400	8800	3600	3200	2200	2800	4200	4000	3400	1400	2000	13800	800	
<i>Acartia</i>	0	0	200	200	200	200	600	600	1200	600	0	600	3200	600	
<i>Acrocalanus</i>	0	0	0	0	600	0	400	600	400	0	600	0	0	0	
<i>Corycaeus</i>	0	400	200	200	0	200	0	600	0	400	0	600	600	0	
<i>Centropageus</i>	0	0	0	0	0	0	200	0	600	400	400	0	1200	200	
<i>Oithona</i>	0	400	600	0	1600	0	400	0	0	400	0	0	600	0	
<i>Paracalanus</i>	0	0	1000	200	800	0	200	0	0	400	0	0	0	0	
<i>Nauplius</i>	2200	2600	6800	3000	0	1800	1000	2400	1800	1200	400	800	8200	0	
<b>PROTOZOA</b>	200	200	5000	1800	0	400	800	1000	1200	1200	800	800	8200	0	
<i>Tintinnopsis</i>	200	0	4400	600	0	200	0	400	400	0	0	0	6600	0	
<i>Acanthomentron</i>	0	200	0	0	0	0	0	0	400	0	200	400	1200	0	
<i>Codonellopsis</i>	0	0	200	600	0	200	400	400	400	400	400	0	400	0	
<i>Leprotintinnus</i>	0	0	400	600	0	0	0	0	0	400	0	400	0	0	
<i>Eutintinnus</i>	0	0	0	0	0	0	0	0	0	400	200	0	0	0	
<i>Favella</i>	0	0	0	0	0	0	400	200	0	0	0	0	0	0	
<b>CHAETOGNATE</b>	200	200	1000	400	1000	1000	400	200	0	0	0	0	200	0	
<i>Sagitta</i>	200	200	1000	400	1000	1000	400	200	0	0	0	0	200	0	
<b>UROCHORDATE</b>	200	200	1000	400	1000	1000	400	200	0	0	0	0	200	0	
<i>Oikopleura</i>	200	0	1000	400	400	400	0	0	0	0	0	200	0	0	
<b>Polychaete larvae</b>	0	0	200	0	0	200	0	200	0	0	0	200	2200	200	
<b>Gastropods larvae</b>	200	200	0	200	0	200	0	200	0	0	0	200	600	200	
<b>TOTAL</b>	3000	4200	16000	6400	5200	5000	4400	6000	5200	4600	2200	3200	25200	1200	

App.45. Zooplankton abundance during December 2001 sampling in Semangka Bay.

Genera	Stations														R
	1	2	3	4	5	6	7	8	9	10	11	12	13	R	
<b>CRUSTACEA</b>	3400	4400	4000	3000	20400	4600	16600	6000	3600	5600	2000	3600	22800	2400	
<i>Acartia</i>	0	400	0	400	200	400	200	400	600	0	0	600	1200	0	
<i>Acrocalanus</i>	0	400	0	0	2000	400	0	400	0	400	0	0	0	1200	
<i>Corycaeus</i>	0	0	0	0	0	0	0	400	600	400	200	0	1200	0	
<i>Centropageus</i>	200	0	0	0	0	0	0	0	0	400	0	600	0	0	
<i>Oithona</i>	0	0	600	400	4200	1200	3200	400	0	0	400	600	0	1200	
<i>Paracalanus</i>	200	400	200	0	5000	2600	2200	0	0	0	0	600	600	0	
<i>Nauplius</i>	3000	3200	3200	2200	9000	0	11000	4400	2400	4400	1400	1200	19800	0	
<b>PROTOZOA</b>	200	600	1800	600	1600	800	8800	2600	1400	2000	600	800	5200	0	
<i>Acanthomentron</i>	0	0	0	0	600	400	0	0	0	0	0	0	0	0	
<i>Codonellopsis</i>	0	0	0	0	0	0	3000	400	400	0	200	0	1200	0	
<i>Eutintinnus</i>	0	0	0	0	0	0	1000	400	0	400	0	400	400	0	
<i>Favella</i>	0	0	0	0	0	0	0	600	0	600	200	400	3200	0	
<i>Globogerinella</i>	0	0	200	0	200	400	200	0	400	0	0	0	0	0	
<i>Leprotintinnus</i>	0	0	200	0	0	0	0	0	0	1000	200	0	400	0	
<i>Parafavella</i>	0	0	0	0	400	0	1600	0	0	0	0	0	0	0	
<i>Tintinnopsis</i>	200	600	1400	600	400	0	3000	1200	600	0	0	0	0	0	
<b>CHAETOGNATE</b>	0	0	0	0	400	0	0	0	0	0	200	0	0	0	
<i>Sagitta</i>	0	0	0	0	400	0	0	0	0	0	200	0	0	0	
<b>UROCHORDATE</b>	200	200	200	400	0	200	0	0	0	0	800	0	0	0	
<i>Oikopleura</i>	200	200	200	400	0	200	0	0	0	0	800	0	0	0	
<b>Polychaeta larvae</b>	0	400	0	200	0	200	0	200	0	200	0	400	3200	400	
<b>Gastropoda larvae</b>	0	400	0	200	200	200	400	200	200	200	0	0	2400	400	
<b>TOTAL</b>	3800	5200	6000	4000	22400	5600	25600	8800	5000	7600	3600	4400	28000	2400	

R = Semangka river mouths

## **Erklärung**

**Hiermit erkläre ich an Eides statt, dass ich die vorliegende Dissertation selbständig angefertigt habe und dabei als Hilfsmittel nur die genannten Quellen benutzt habe. Desweiteren versichere ich, dass die vorliegende Dissertation weder ganz, noch zum Teil bei einer anderen Stelle im Rahmen eines Prüfungsverfahrens vorgelegt wurde.**

**Kiel, den 20.12.02.**

Ario Damar

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### **OCCUPATIONS**

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