Monitoring on

Density and Distribution of Meiofauna

in the **PAKKLONG** Sub-district Coastal Area

Southeast Asian Fisheries Development Center
TD/RES/93
LBCFM-PD No.36

Department of Fisheries,
Thailand
March 2004

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FOREWORD

Under ASEAN-SEAFDEC Fisheries Consultative Group (FCG) Scheme, Thailand takes duty as the lead country among ASEAN member countries and the Training Department (TD) takes as lead department of SEAFDEC to implement coastal resources management program. This program is mainly supported by Japanese Trust Funds.

Under the coastal resource management program, TD and Department of Fisheries (DOF), Thailand collaborated in formulating and planning the collaborative coastal fisheries management project. An aim of the collaborative project is to promote and achieve sustainable use of resource utilization. TD and the DOF, Thailand agree to transfer essence of technologies, accumulated knowledge and lesson learned, which gain through the implementation of coastal fisheries management project to other SEAFDEC member countries through the SEAFDEC's information mechanism. This information may help ASEAN-SEAFDEC member countries to re-prior consider their own policies and formulate new direction for cost-effectiveness of coastal fisheries resource management plan and implementation.

Niwes Ruangpanit
Secretary-General

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ABSTRACT

A monitoring on density and distribution of meiofauna in the Pakklong Sub-district coastal area, Chumphon Province was conducted in April, August and October 2002. The sediments were collected at twelve stations both for meiofauna and sediment composition analysis. The result indicated that inside Pathew bay area are most abundance resources. And it has reverse relationship with silt percentage, which is main factor for meiofauna density.

Furthermore, density and distribution of meiofauna were also effected and related with other factors like temperature, dissolved oxygen, rainfall, salinity, transparency, bottom depth, pH as well as current speed and direction.

The Pathew bay is abundant area and appropriate for aquaculture activities. However, the consideration on other environment conditions is imperative for planning on aquaculture management.

Key words: Meiofauna density, Meiofauna distribution, Pakklong Sub-district, Coastal Aquaculture

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I. Introduction

Monitoring on density and distribution of meiofauna in the Pakklong Sub-district coastal area is one sub-activity of a baseline survey on the marine environmental condition of Pakklong Sub-district, Chumphon Province under collaborative pilot project; " Locally Based Coastal Fisheries Management in Pathew District, Chumphon Province" (LBCFM-PD). This project was conducted by cooperation between Training Department of Southeast Asian Fisheries Development Center (SEAFDEC/TD) and Department of Fisheries, Thailand. The purpose of the project is to establish a practical framework for locally based coastal fisheries management through the encouragement of fishers' participation. The supports on the creation of alternative job opportunities also provide in coastal fishing communities. One of activities is aquaculture, which needs fundamental environmental information of coastal area in order to apply for aquaculture management framework.

The purpose of this monitoring is to determine the density and horizontal distribution of meiofauna. Due to meiofauna is recognized playing an important role of the small food web, and integrating meiofauna in a substantial compartment of the benthic energy flux. So the coastal areas with high density will be considered to be the most abundant sources. It is one of various factors needs to be considered for aquaculture management planning.

1.1 What is Meiofauna?

The term "**Meiofauna**" was defines by Mare (1942) as benthic organism [1] associated with marine sediment that pass through a 500 mm sieve but are retained on a 42 mm sieve, which the term "**Meiobenthos**" are largely used as synonyms (Giere, 1993). While organism larger than 500 mm are called Macrofauna or Macrobenthos. It is rather big-size benthos such as molluse, coral, sea cucumber, shrimp and crab etc. The last group is Microfauna or Microbenthos, whose size is smaller than 42 mm. The most organisms in this group are protozoa. Thus, meiofauna are recognized conceptually as a valid intermediate between macro- and microfauna (Giere, 1993 and Kennedy, 1999).

These show benthic organisms can be grouped by their size. However many papers refer to benthos can be organized to group by taxonomy and living behavior of habitat like infauna, epifauna and epibenthos (Ayuttaka, 2001).

Meiofaunal communities can be further sub-divide into two groups. ***Temporary meiofauna*** are juveniles of the macrofauna that will eventually grow into adult larger than 500 mm. ***Permanent meiofauna*** is organisms where whole life-cycle are less than 500 mm. (Kennicutt, 1994 and Monthum, 2002).

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[1] *Benthic organisms are all organisms occurring on or in the bottom of aquatic habitats.*

These organisms normally live in small space between sedimentary particles, hence they also have another synonyms **"Interstitial Fauna"** (**Fig. 1**). They are common in sand and silt area, which high species biodiversity (Ayuttaka, 2001).

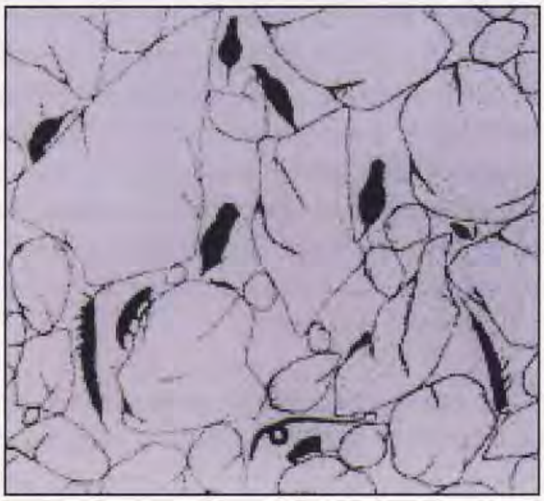


Fig. 1 Interstitial Fauna (Ayuttaka, 2001)

1.2 Why must be Meiofaua?

Due to benthos are not changing the species composition, density and migration fast as the plankton since they have a substrate to support them, so they can be good indicator in abundant or pollution monitoring for various areas. Gray *et. al.* (1992) and Barg (1992) also mention that benthic assemblages can be use as an indicator in aquaculture pollution studies because they are fairly stationary, tolerate the pollution or die and integrates effect of pollution over time.

In microfauna scope, the monitoring on too small benthic organism causes a lot of error. For macrofauna operation seems to be easier than the small one, clear visibility and specimen collection have to operate in a wide area, related to their size. The last reason becomes a trouble in data collection method. About 10-m^2 sediment from each station will be collected in order to make least errors. So the focus on medium-size benthos or meiofauna study is the last alternative and proper for monitoring. And because of their small size and high density, organisms of the meiobenthos are best collected in small samples of sediment (Gray *et. al.*, 1992).

Kennedy (1997) and Monthum (2002) reviewed on the suitability of meiofauna for use in monitoring marine environment health can be assess on biological indicators should be representative of the identification of their source, and ubiquitous distribution.

Performance of a valued ecosystem component, readily measurable, respond quickly and unambiguously to inputs, integrate the effects of multiple pollution inputs without confounding.

1.3 Meiofauna Assemblages and Factors

There are various kinds of organisms were called Meiofauna like nematode, copepod, polychaete, oligochaete, foraminiferan, etc. Their assemblage depends on sediment composition at that area and show a definite zonation based on grain size (Nybakken, 1997). Abiotic habitat factors as temperature, salinity, oxygen, pH value and etc. also have effects to meiofauna living (Giere, 1993). Thus, this paper was extended study on sediment analysis in order to calculate percentage of each particle size and consider on physico-chemical characteristics, which was the result from ***The Marine Environmental Condition of the Pakklong Sub-district Coastal Area and Their Effect on Coastal Aquaculture*** by Laongmanee *et. al.*, 2003.

1.4 The Information on Coastline and Climatic Conditions in Chumphon Province

1.4.1 Coastline of study site

The coastline of study site is located on the eastern side of Chumphon Province, southern part of Thailand. It is composed of various kind of ecosystem like coral reef, mangrove areas, a foreshore, rocky shore and sand dunes.

The fisherfolks along coastline operate on several activities, both aquaculture and fisheries. The aquaculture activities are fish cage culture, mussel culture and shrimp farm. Almost of fishing activity are small-scale. The fisheries activity cause small fish processing plant in the fishing village. There is a tourist resort located along coastline as well.

1.4.2 Climatic conditions in Chumphon Province

The climatic conditions in Chumphon Province are tropical. It likes other provinces in southern part of Thailand, high temperature and humidity. It is effected of monsoon around 10 months annually, with two monsoon phases. First monsoon period is from May to October, which called southwest monsoon. It causes the rain from Indian Ocean to Chumphon Province. The second is northeast monsoon, carry rain from South China Sea to the Province since October to February.

Because of the monsoon influence, it causes rainy seasons relatively long. It is the period from May to December. The rainfall is highest in the northeast monsoon due to low atmospheric pressure and depressions. The mountain torrent flows to plain area from western to eastern part of Chumporn Province. This evidence induces flooding to the area. While summer season is the period from February to April. This period is less influence of monsoon but temperature increases until the highest temperature in April. After short summer seasons, it cycles to monsoon season again. Thus, April is the transitionperiod between two seasons.

II. Materials and Methods

The monitoring on density and distribution of meiofauna classify to 2 issues, meiofauna study and sediment analysis. The two issues are reasonable relationship because when describing meiofauna habitat, grain size is a key factors, which directly determines spatial and structural condition, and indirectly determines the physical and chemical milieu of the sediment (Giere, 1993).

The samples were collected from 12 survey stations (**Fig. 2**). For meiofauna study, it using Smith McInthy grab. Sediment collections were also taken from the same grab to ensure that two type of sample came from the same place. The survey period was April, August and October 2002 (the last month was collected only for meiofauna study). Because of we expected April was the representative in transition period between northeast and southwest monsoon while August and October in monsoon season period. The surveys were done onboard Meen Niweth, the research vessel under the Chumphon Marine Fishery Research and Development Center, Department of Fisheries, Thailand.

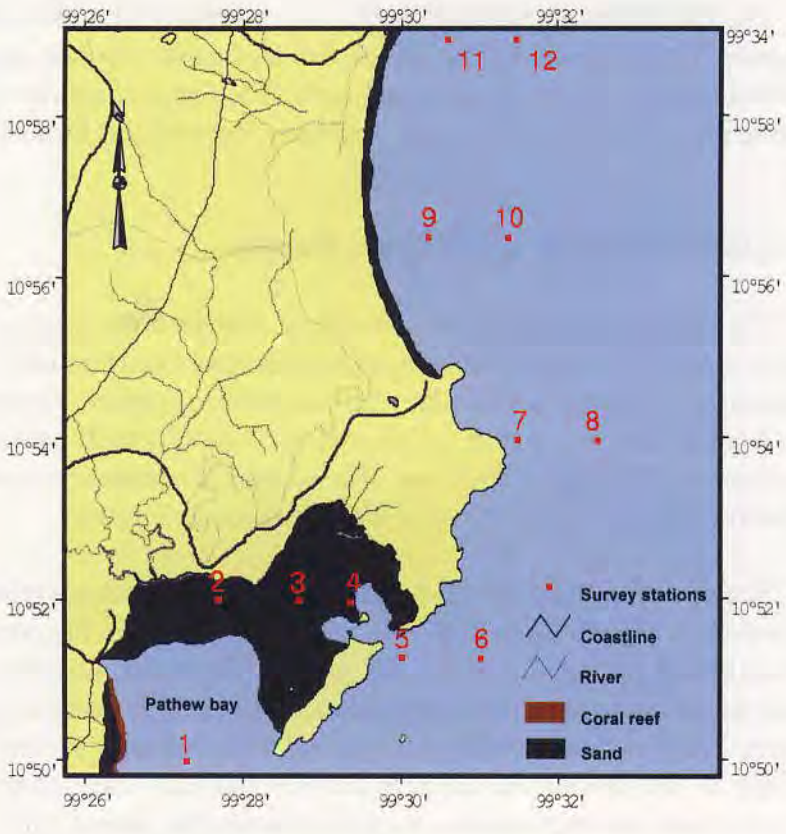


Fig. 2 Map of survey and sampling stations

2.1 Meiofauna Study

In meiofauna study process, it started by meiofauna collection from survey station, Pakklong Sub-district. And then laboratory analysis was made at the Southeast Asian Fisheries Development Center (SEAFDEC), Training Department. The last step was meiofauna identification and counting, which were done in the same laboratory.

2.1.1 Meiofauna collection

As mention above, sediment samples were collected using Smith McInthy grab, three centimeter from surface of the sediment was collected by 3-cm diameter syringe for monitoring on density and distribution of meiofauna (**Fig. 3**). It was collected for 2 replications of each station. The samples were preserved in 4% formaldehyde, labeled station and date.

2.1.2 Laboratory analysis

It is a meiofauna extraction by decanted and centrifuged methods as presented in Weerawat, 2001. The samples were rinsed over a 1 mm sieve to separate shells and detritus from the sediment. The sediment that passes through the 1 mm sieve then was rinsed over a 32 mm sieve (**Fig. 4**). And finally transferred to a cylindrical polyethylene tube for centrifuging.

Ludox HS40 solution with a density of 1.18 was added into the centrifuge tube containing the sediment at a ratio of 1 part sediment: 5 parts Ludox solution.

The tubes were placed inside the machine for centrifuging for at least 10 minutes at a speed of 1800 rpm (**Fig. 5**). After centrifuged the supernatant liquid was again rinsed through a 32 mm mesh size so that the silicates from the Ludox was washed out from the meiofauna and finally was transferred into a receiving bottle. The processes were repeated three times to ensure that all the meiofauna was completely extracted from the sediment. Meiofauna samples inside the receiving bottles were then fixed with 4% formalin and immediately stained using 1% Rose Bengal solution prior to storage.

2.1.3 Counting and meiofauna identification

The fixed meiofauna samples stained with 1% Rose Bengal solution were first rinsed with tap water prior for identification counting using a stereoscopic-microscope (**Fig. 6**). Identification of the meiofauna taxa was done with the use of the pictorial key of Higgins and Thiel (1988).

Fig. 3 Meiofauna collection

Fig. 4 Meiofauna extraction by decanted method

Fig. 5 Meiofauna extraction by centrifuged method

Fig. 6 Meiofauna counting

2.2 Sediment Analysis

In sediment analysis process, it started from sediment collection, which were collected from same grab of meiofauna using 4-cm diameter syringe. After that it is the method for sediment classification by laboratory analysis by method of Buchanan, 1984. This step was made at the laboratory of Department of Marine Science, Faculty of Fisheries, Kasetsart University, Thailand. The last step was calculation for sediment composition.

2.2.1 Sediment collection

The sediments were collected using corer with various level sediments. But it was focus on surface to 3-cm depth. The sample from 3-cm diameter corer was preserved in freezer after labeled.

2.2.2 Laboratory analysis

Each sediment sample was transferred to plate and made dry in oven for 3 hours at 105 °C. Whatman GFC filter paper (125 mm diameters) also made dry with same method (**Fig. 7**). After 3 hours, dry filter papers were weighted and marked because their weight do not equal. The sediments from each station were weighted for 30 grams. All samples were rinsed over a 500 mm and 63 mm sieve one by one. Both sediment groups on sieves were filtered on GFC filter paper (**Fig. 8**). Finally each sample was separate to 2 sizes. For finding the dry weight, all sediments were dried again in oven for same period and degree. Filter paper and sediment were weighted together.

2.2.3 Calculation for sediment composition

The sediment composition in this study could divide to 3 groups. They are coarse sand (over than 500 mm), fine sand (63-500 mm) and silt (62-4 mm). The calculation compared starting dry weight or 30 grams, as mention above, is 100 percentages. And then calculated sediment weights of over 500-mm size and between 63-500-mm size share the percentage. It is very important to minus filter paper weightbefore comparison. Each filter paper had its dry weight. The rest percentage is silt or the sediment that could pass 63-mm sieve. Finally the percentage value of sediment composition could find out and showed percentage of coarse sand, find sand and silt.the sediment that could pass 63-mm sieve. Finally the percentage value of sediment composition could find out and showed percentage of coarse sand, find sand and silt.

Fig. 7 Sediment and filter paper dry

Fig. 8 Sediment analysis (filtering)

III. Results

3.1 Meiofauna Study

The monitoring on density and distribution of meiofauna in 12 survey stations were conducted for 3 months namely April, August and October. There are 6 groups of meiofauna were found from identification process namely Nematode, Copepod, Sarcomastigophoran, Turbellarian, Polychaete and Oligochaete.

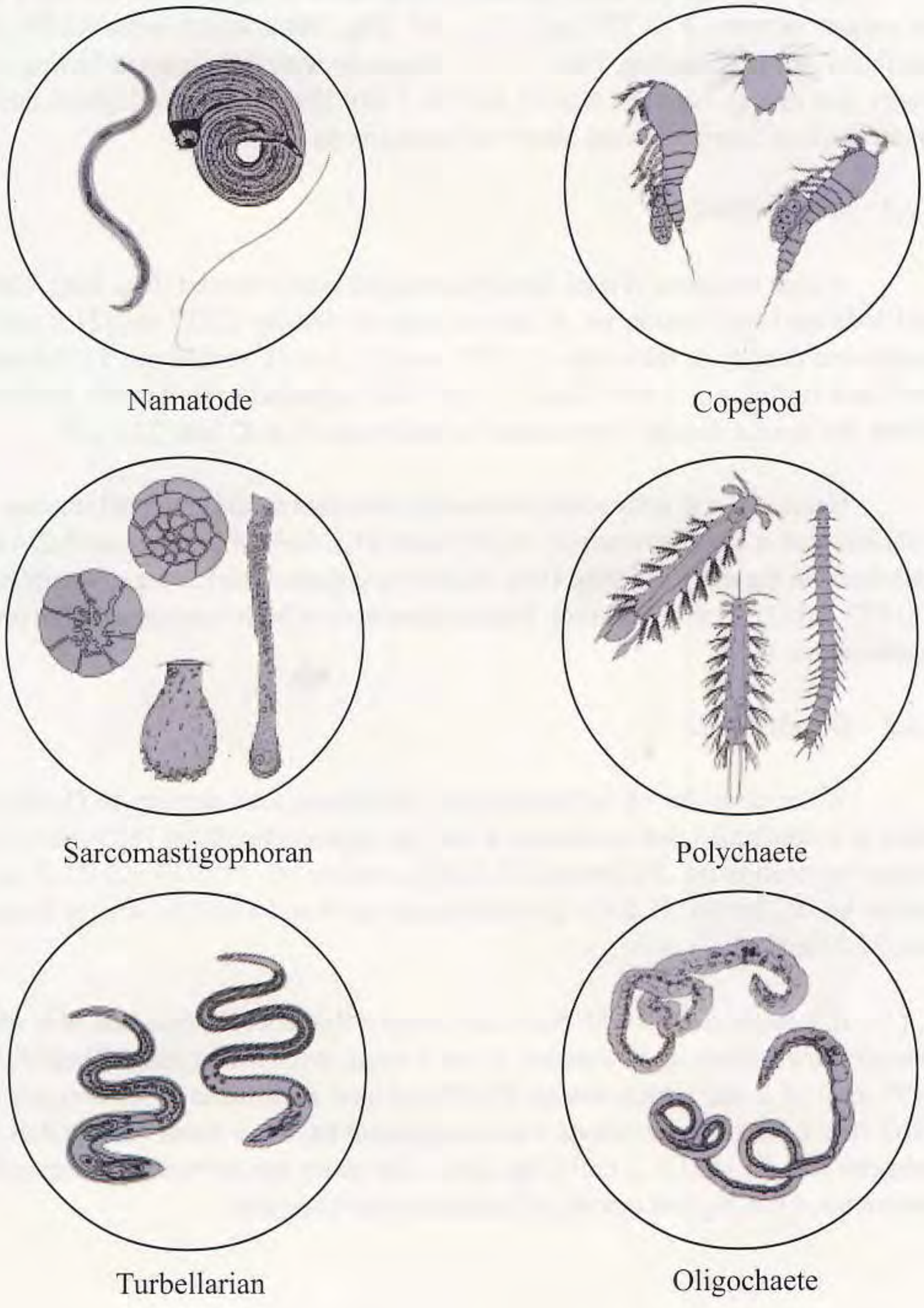


Fig. 9 Groups of meiofauna

3.1.1 April 2002

In term of the total density of meiofauna, a high variation of total density was observed (**Fig. 10a**). The result indicated that station no. 4 had the highest density (225 ind./21.2 cm^2). Follow by station no. 5 (94 ind./21.2 cm^2), station no. 11 (47 ind./ 21.2 cm^2) and station 12 (33 ind./21.2 cm^2), while station 10 had the lowest density (5 ind./21.2 cm^2).

Nematode was the most abundant meiofauna at all stations having a density that ranged between 6 to 227 ind./ 21.2 cm^2 (**Fig. 10b**), which were 84.9% of total meiofauna in the sampling. Next to the nematode was the copepod having a mean density that ranged between 0 to 21 ind./21.2 cm^2 (**Fig. 10c**). The highest density of nematodes and copepods were observed in station no. 4.

3.1.2 August 2002

A high variation of total density in August was observed (**Fig. 11a**). The result still indicated that station no. 4 had the highest density (2237 ind./21.2 cm^2). The meiofauna density at station no. 2 (1071 ind./21.2 cm^2), station no. 3 (566 ind./21.2 cm^2) and station no. 1 (397 ind./21.2 cm^2) are regarded high density, respectively. While the lowest density is presented on station no. 6 at 42 ind./21.2 cm^2.

Nematode still is the most outstanding abundant meiofauna at all stations having a density that ranged between 32 to 2023 ind./21.2 cm^2, which shared 91.2% of total meiofauna in the sampling (**Fig. 11b**). Follow by copepod that having a density between 0 to 173 ind./21.2 cm^2 (**Fig. 11c**). Highest densities of both meiofauna were observed in station no. 4.

3.1.3 October 2002

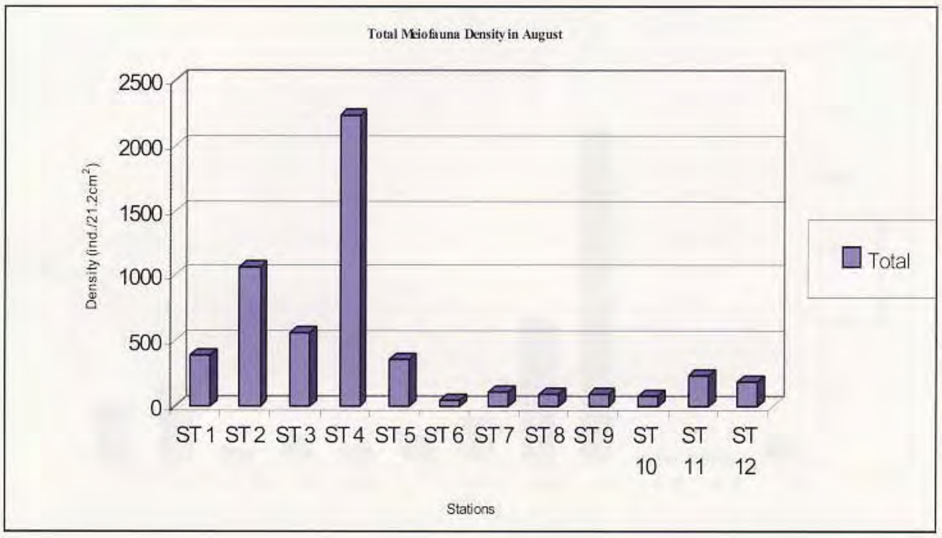
When consider on information of meiofauna total density in October (**Fig. 12a**), it is confirmed that station no. 4 had the highest density at 1603 ind./21.2 cm^2. Follow by station no. 2 (426 ind./21.2 cm^2), station no. 11 (229 ind./21.2 cm^2) and station no. 3(228 ind./21.2 cm^2), while station no. 8 and 9 had the lowest density (24 ind./21.2 cm^2).

It is same results with April and August that shows nematode was the most abundant meiofauna at all stations. It has a mean density that ranged between 21 to 1495 ind./ 21.2 cm^2 which shared 92.38% of total meiofauna in the sampling (**Fig. 12b**). And next to the nematode was the copepod having a mean density that ranged between 0 to 76 ind./21.2 cm^2 (**Fig. 12c**). The result agreed with other months that station no. 4 has highest density of nematode and copepod.

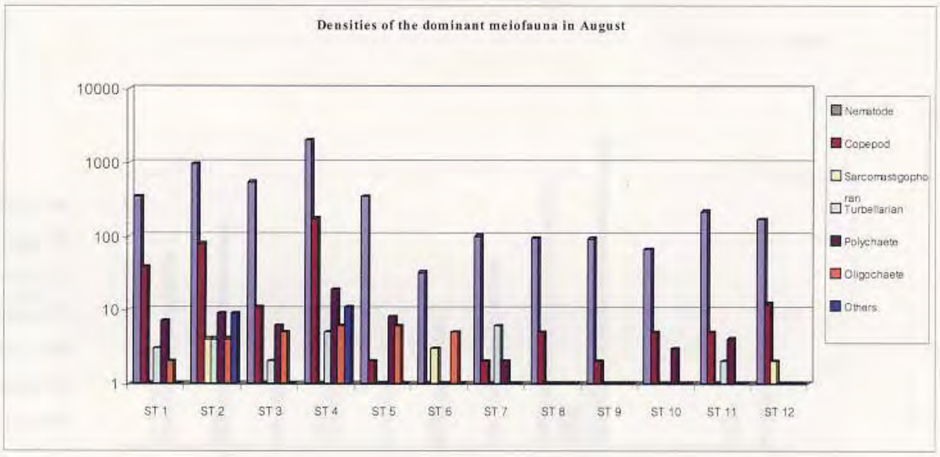
a
b
c

Fig. 10a to 10c Chart of total meiofauna density, Densities of the dominant meiofauna including nematode and excluding nematode in April.

a



b



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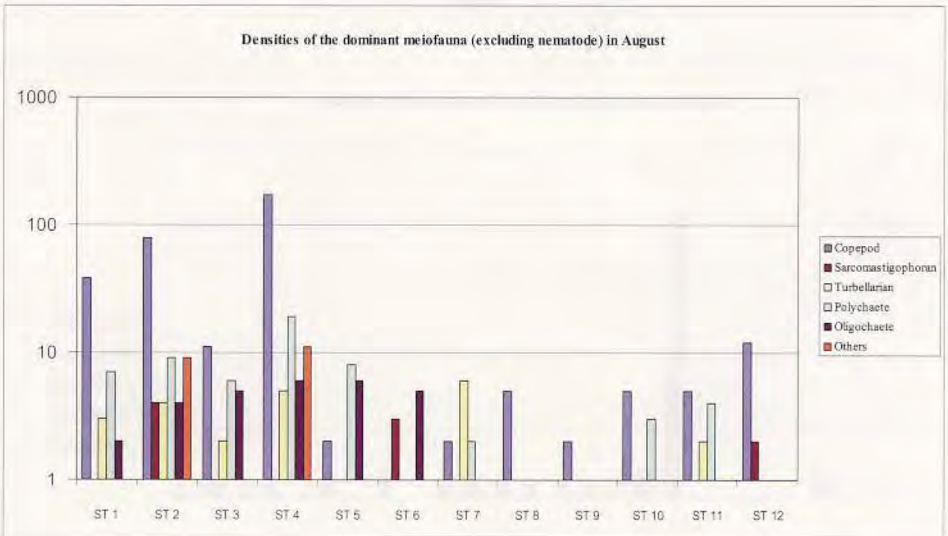
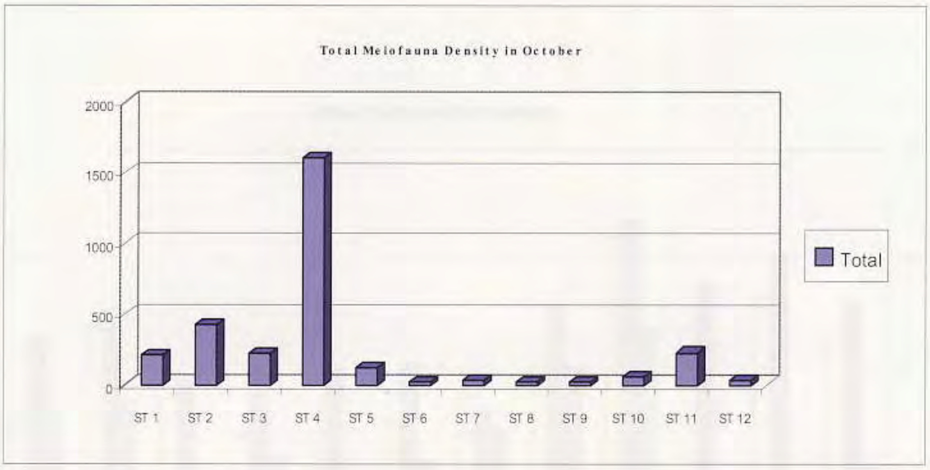


Fig. 11a to 11c Chart of total meiofauna density, Densities of the dominant meiofauna including nematode and excluding nematode in August.

a



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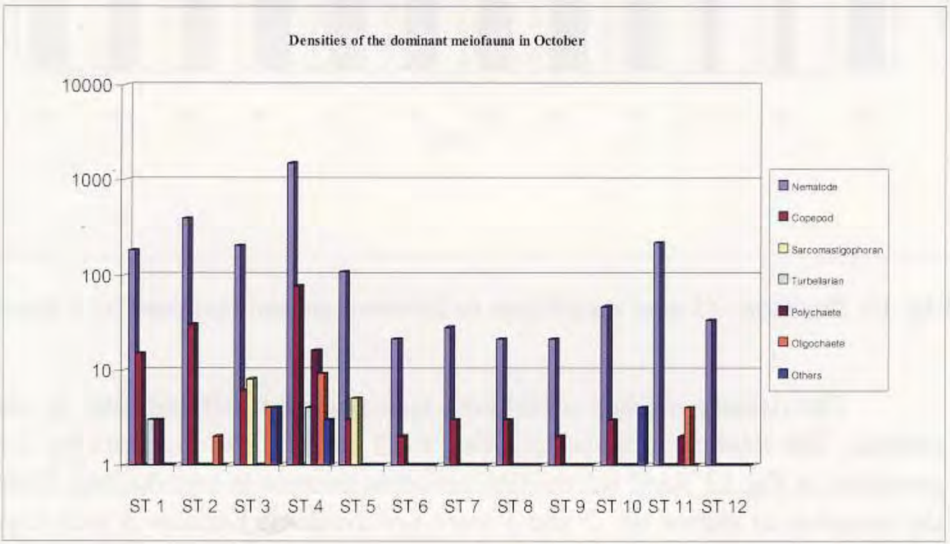

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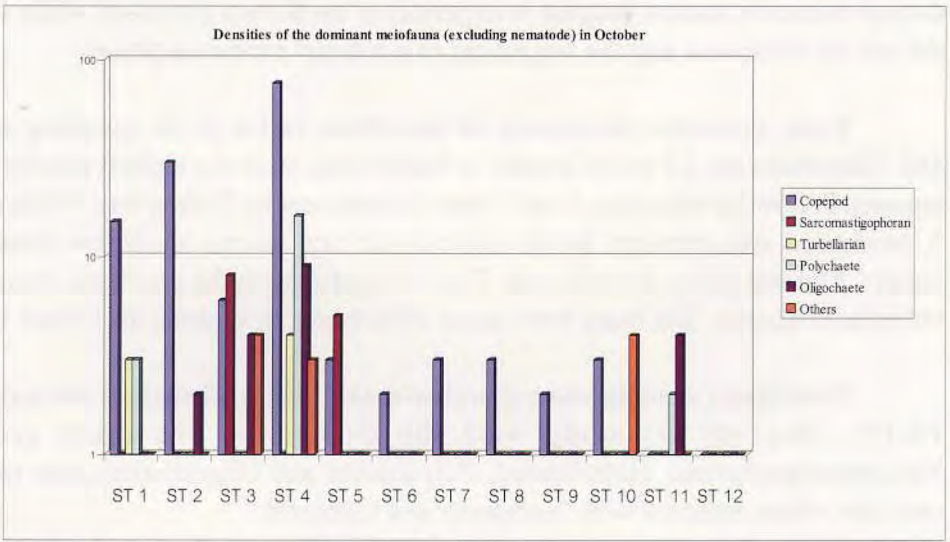


Fig. 12a to 12c Chart of total meiofauna density, Densities of the dominant meiofauna including nematode and excluding nematode in October.

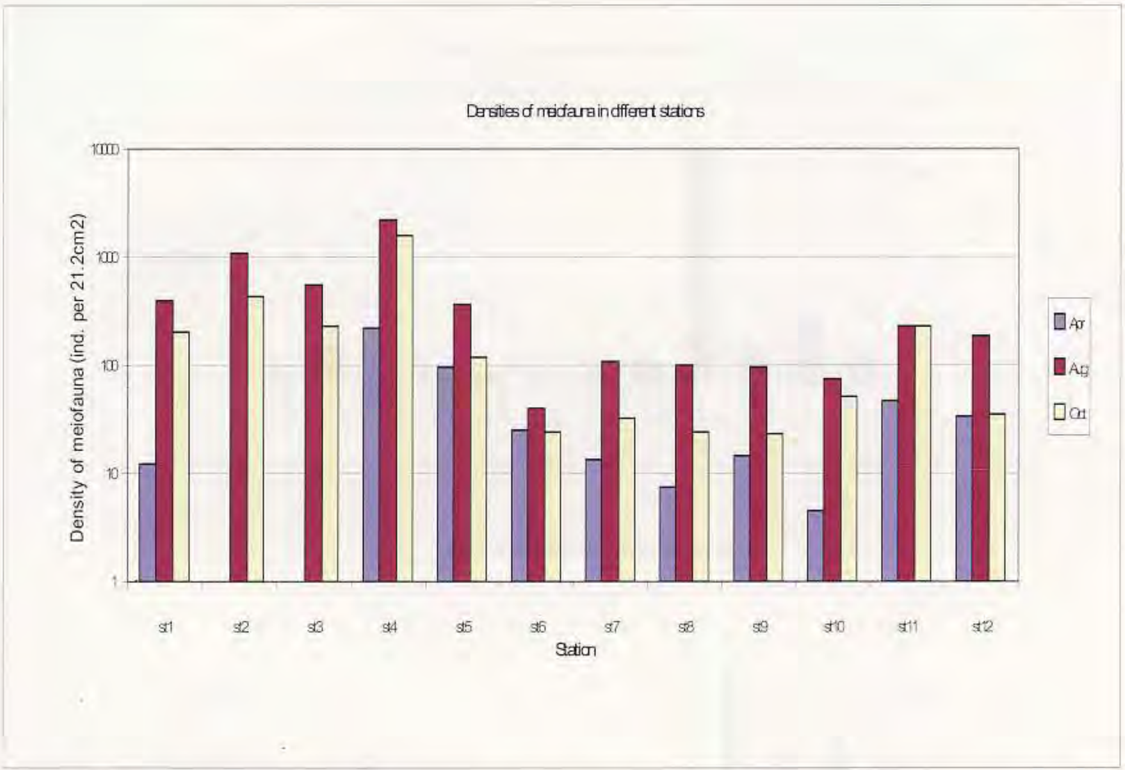


Fig. 13 Densities of total meiofauna in different station compare by 3 months

The density of each meiofauna taxa manifest differentiates in stations and months. The total meiofauna densities in 12 stations can compare by 3 months as presented in **Fig. 13**. April is transition period as mention in introduction. Unfortunately, the samples on station no. 2 and 3 were not available because it was impossible to reach there due to too low tide during the samples collection. August and October are during monsoon season. August is in period of southwest monsoon while October is the late of southwest and the beginning of northeast monsoon phase.

From all results, the density of meiofauna varied in the sampling areas (**Fig. 14**). The station no. 2,3 and 4, located in Pathew bay, were the highest density area in all seasons. Follow by station no. 1 and 5 were located near by Pathew bay. While station no. 6, connected area between inside and outside bay, always show low density in the results. The last group is station no. 7 to 12 parallel with the coastline, similar in low meiofauna density. But there were some differences in stations no 11 and 12.

Nematodes were the most abundant meiofauna at all stations and months (**Fig. 15-17**). Next to nematode were the Copepods. The other groups are Sarcomastigophorans, Turbellarians, Polychaetes and Oligochaetes, but were found very few when compare with Nematode and Copepod.

From all results, 12 stations show significant differences by ANOVA ($P<0.05$) as appendix 3. But when consider on seasons, they do not difference significantly ($P>0.05$) by same method as presented in **Appendix 4**.

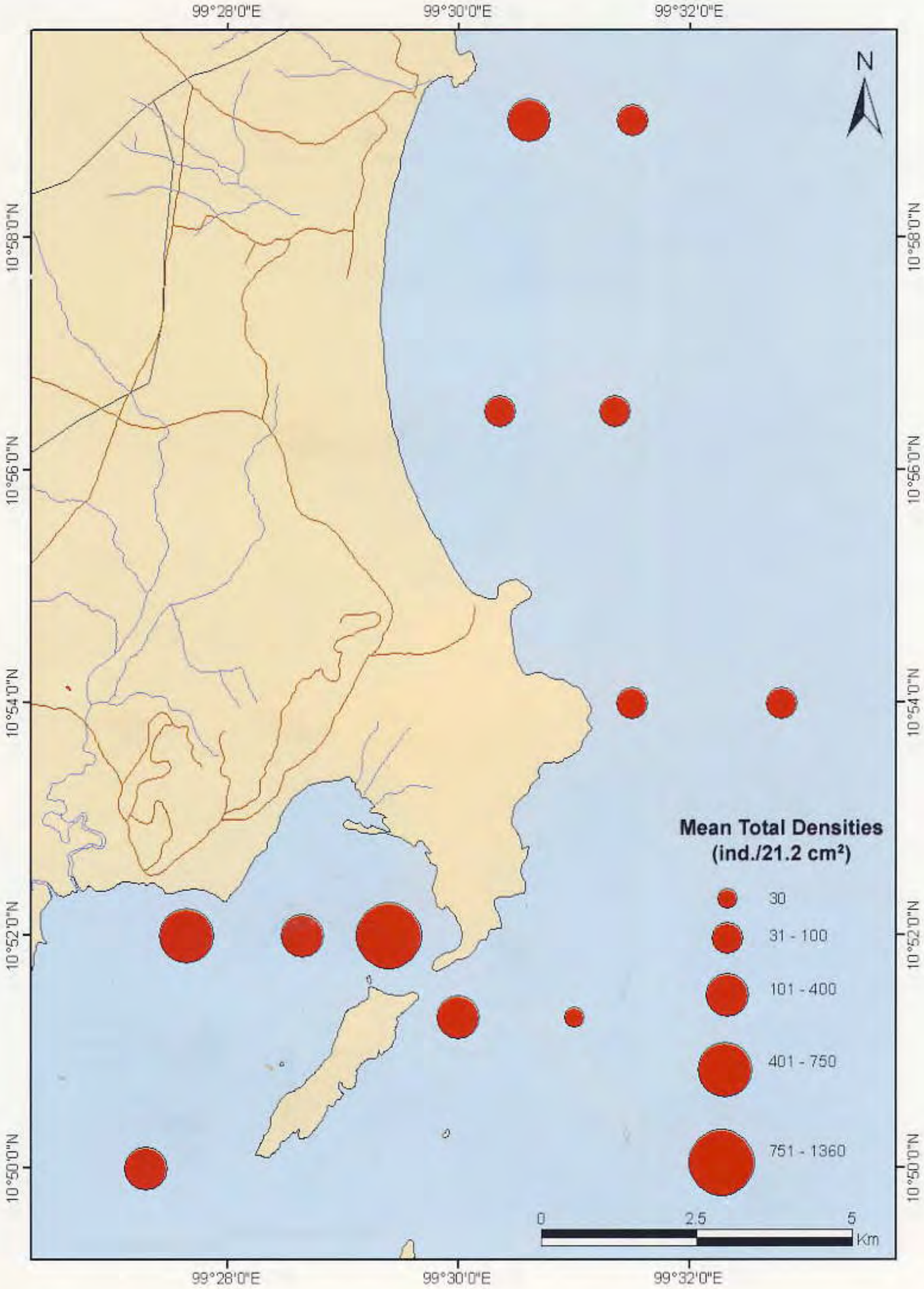


Fig. 14 Plot Mean Total Densities from 3 months (ind./21.2 cm^2)

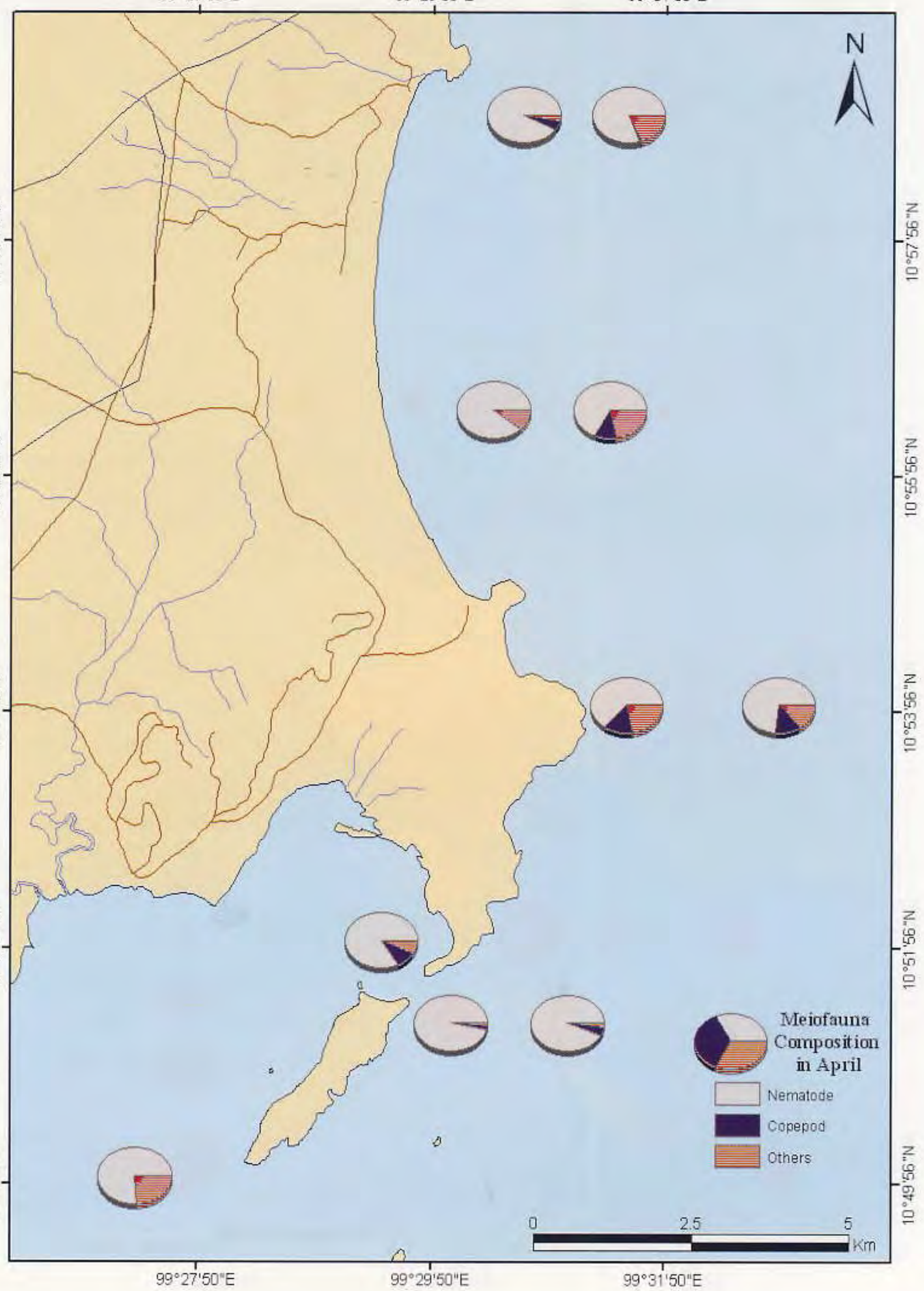


Fig. 15 Pie graph of meiofauna composition in April (No Data on station no. 2 and 3)

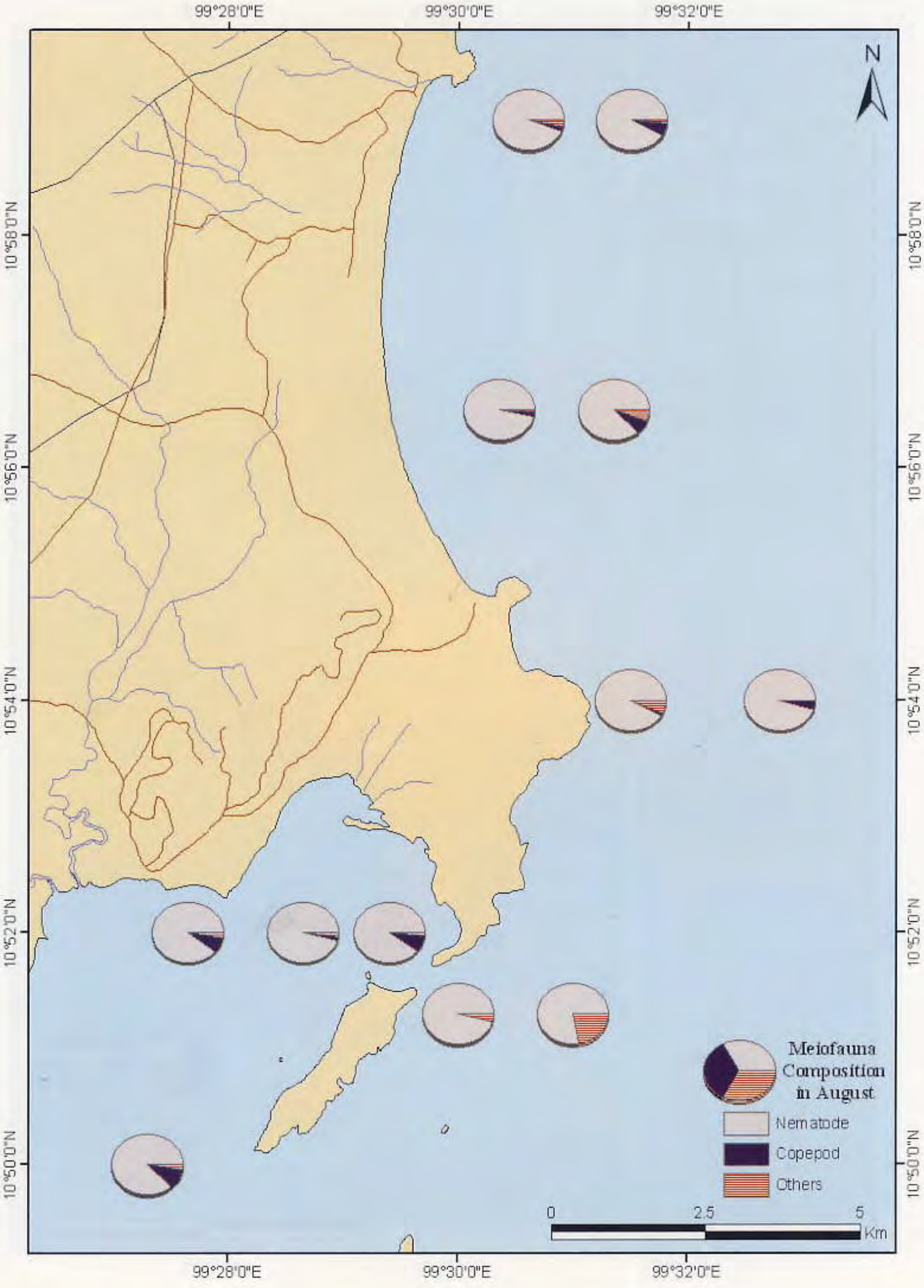


Fig. 16 Pie graph of meiofauna composition in August

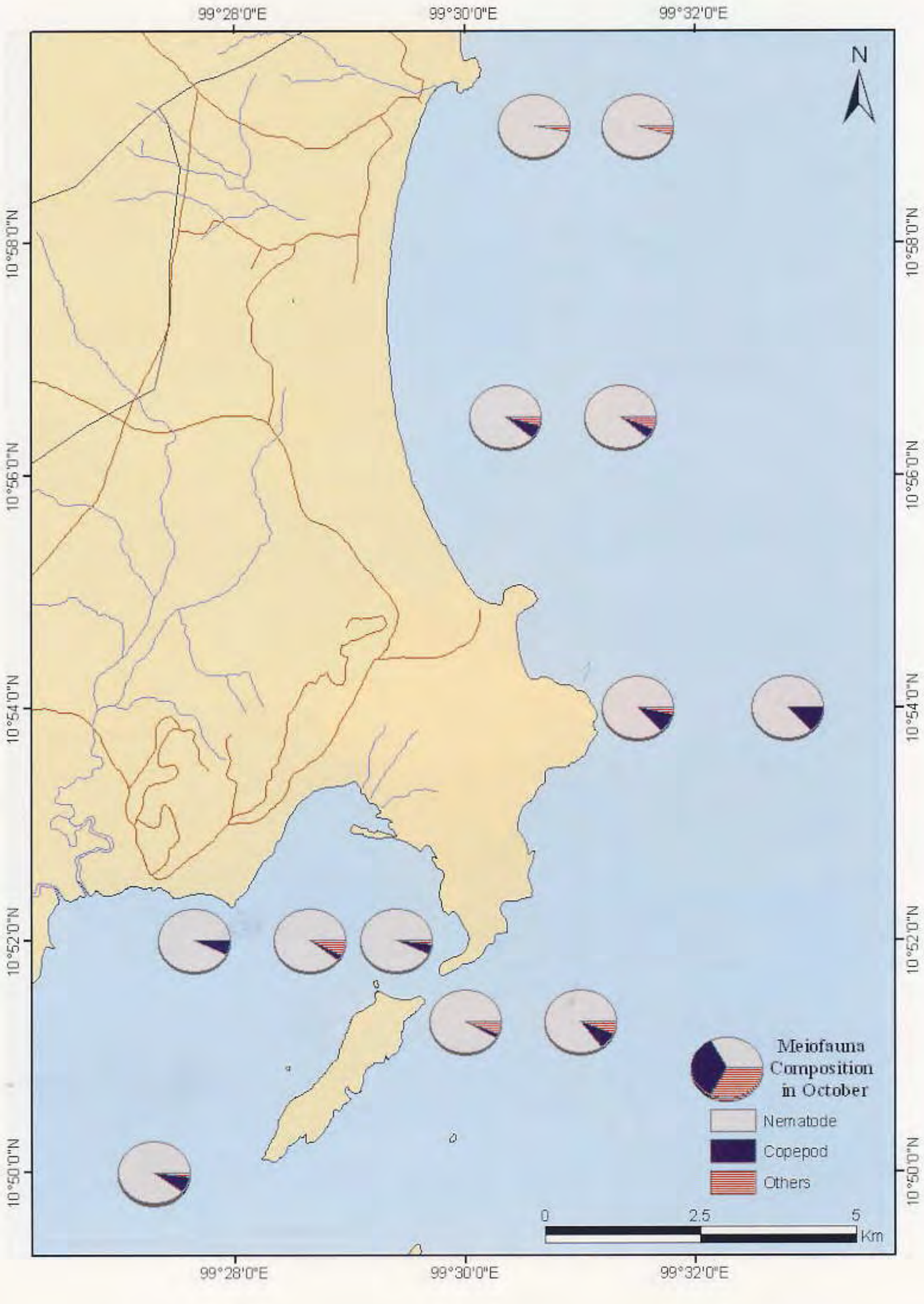
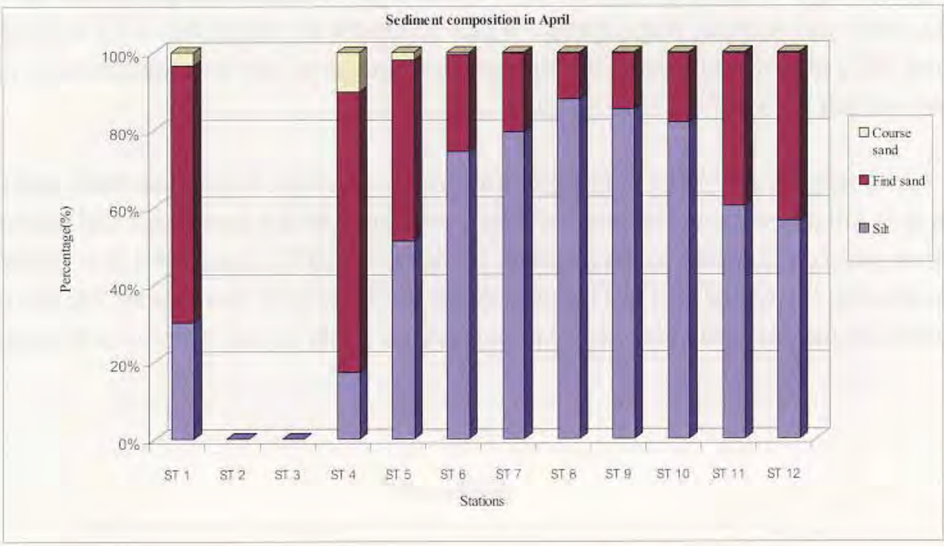


Fig. 17 Pie graph of meiofauna composition in October

3.2 SEDIMENT ANALYSIS

Sediment analysis conducted for 2 months as April and August in order to know the composition both during transition period and monsoon phase. This study could show the change of sediment composition and linkage between grain size and meiofauna.

a



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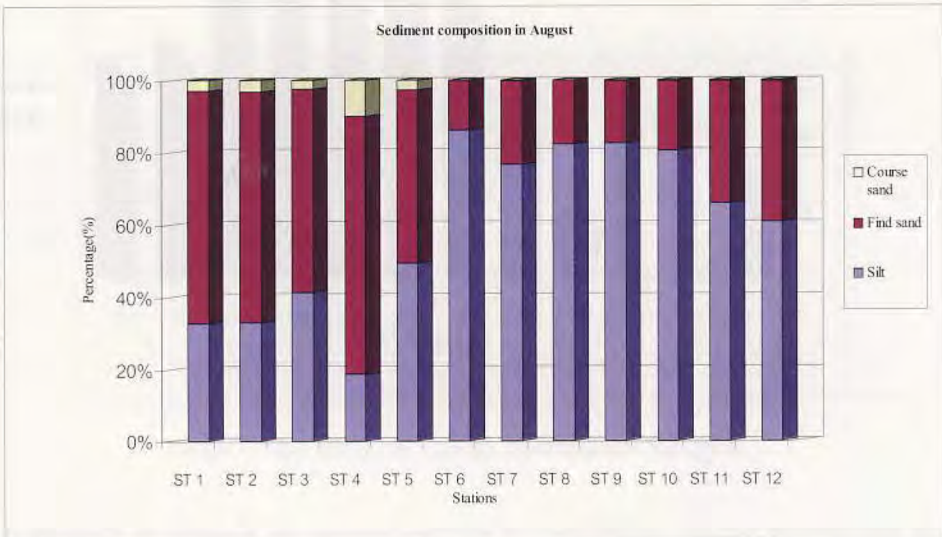


Fig. 18a and 18b Sediment composition in April and August

In term of the sediment composition, percentage of each particle size was observed (**Fig.18a and 18b**). Coarse sand visible shared percentage in sediment composition at station no. 1-5, ranged from 2.1-10.3 % in April and 2.3-9.8 % in August. The highest percentage of coarse sand was at station no.4 in both months. While the rest areas (station no. 6-12) were shared very few coarse sand percentage.

As according to the resemble result, high percentage fine sand were station no.1-5, ranged from 46.7-72.5% in April and 48.1-71.6% in August. Follow by station no.11 and 12 shared average 38.75%. Low percentage of fine sand were station no. 6-10, the lowest area in April was station no. 8 at 11.8% and station no.6 in August at 13%.

Silt percentage seems to be reverse from coarse and find sand. The area used to share highest percentage of sand as station no 4 became lowest percentage of silt, at 17.2 % and 18.6% in April and August, respectively. While sediment in station no. 6-12 composed of silt more than 50% in both months. The highest percentage of silt was station no.8 at 87.9% in April and station no.6 at 86.2% in August.

Although the sampling sediment composes of coarse sand, fine sand and silt, but we focus on only silt percentage. Because of main constituent in this area is silt and it has reasonable description and relationship to meiofauna. Nybakken (1997) described that if the grain size becomes coarse, the water will not be held in the sand and will drain away. On the other hand, fine-grained sediments are able to hold considerable water in the interstices through capillary action.

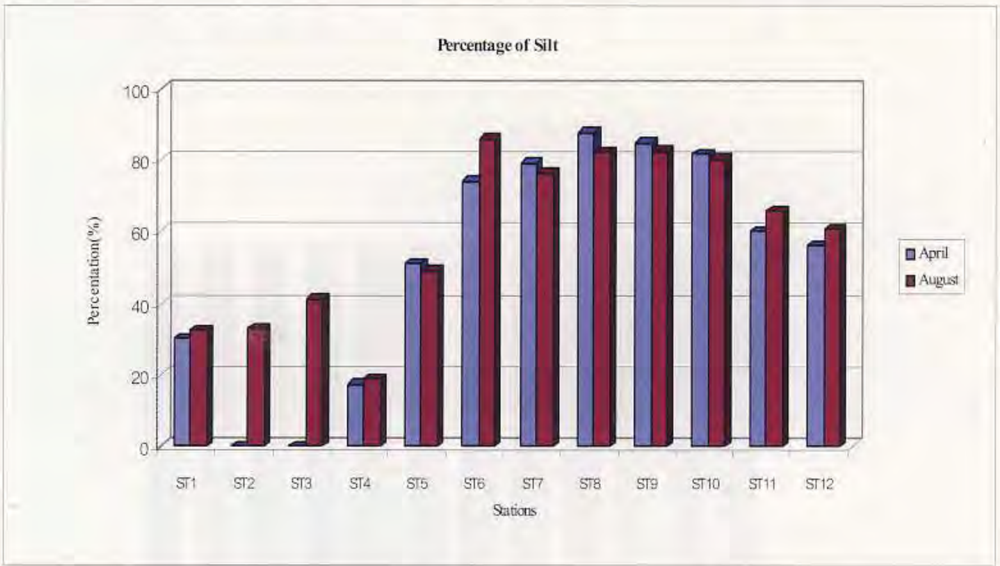


Fig. 19 Percentage of silt in April and August

In the season aspect, overview of silt percentage in August is slightly higher than April, except station no.7-10 as presented in charts. That might effect from strong current speed and its direction, which was observed during June (**Appendix 6**). When focuses on the areas, station no.6-10 were highest percentage of silt follow by station no 11-12, station no. 1 and 5 that located outside Pathew bay. And the lowest percentage of silt presented in station no.2-4.

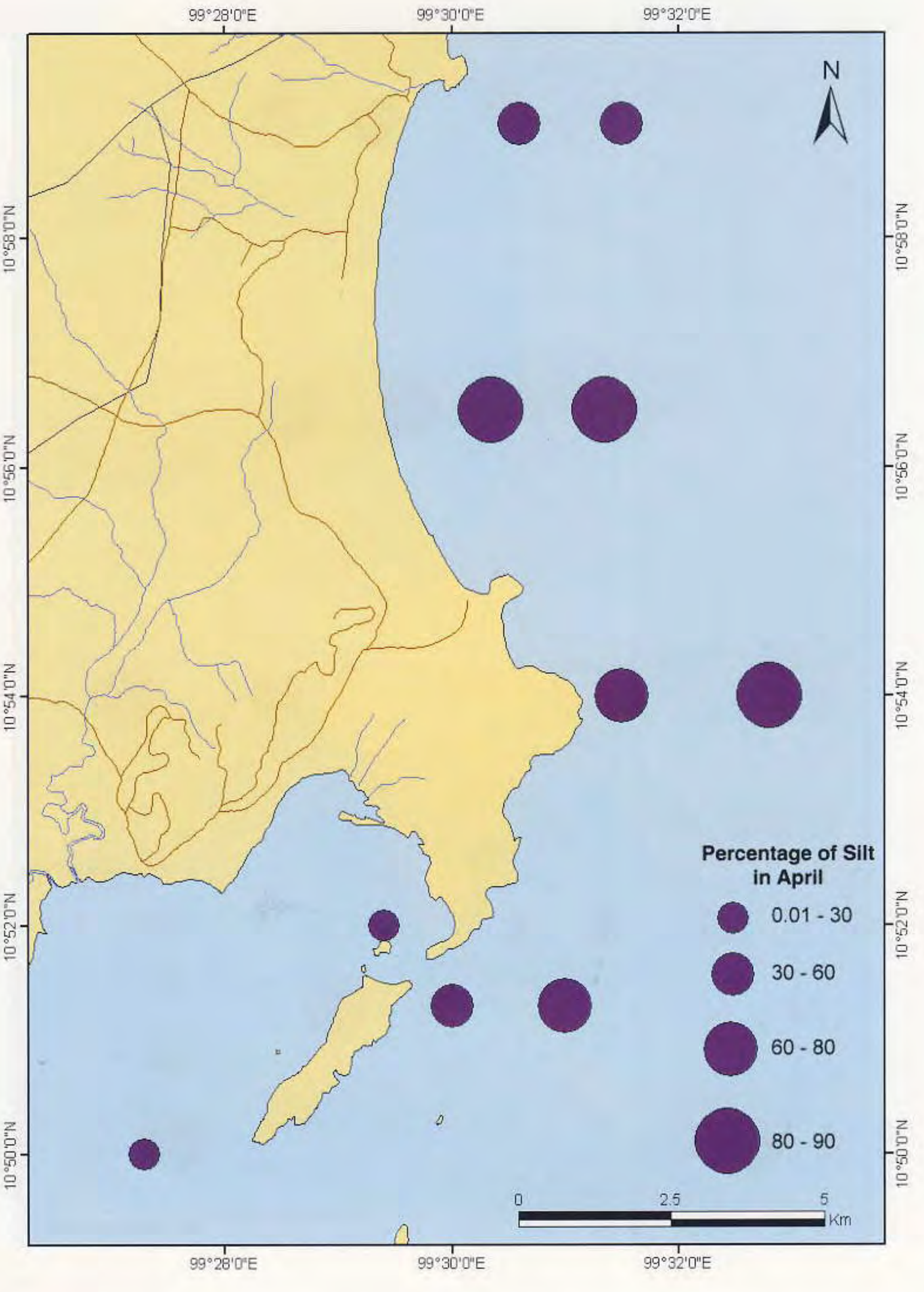


Fig. 20 Plot of Percentage of silt in April (No Data on station no. 2 and 3)

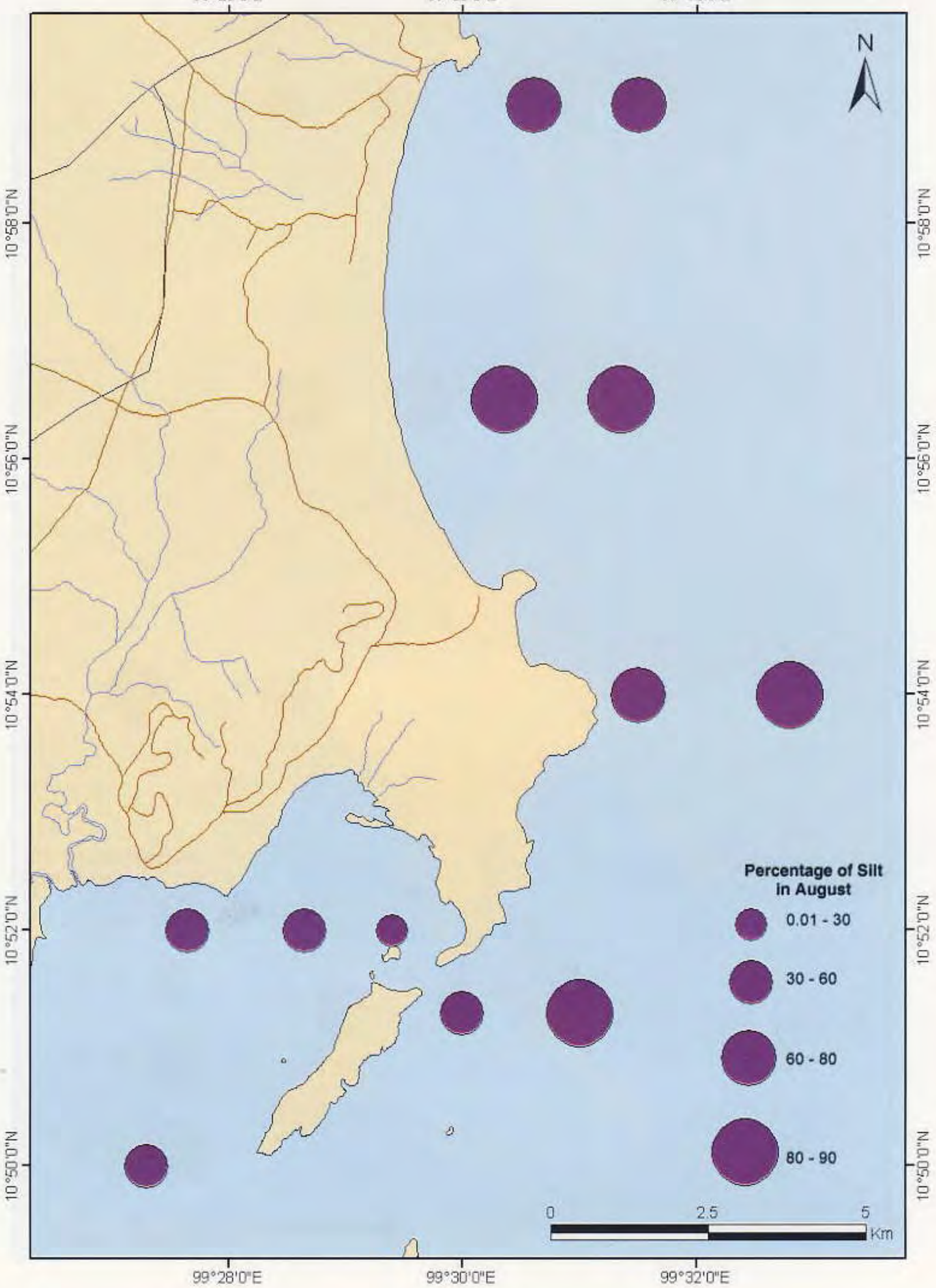


Fig. 21 Plot of Percentage of silt in August

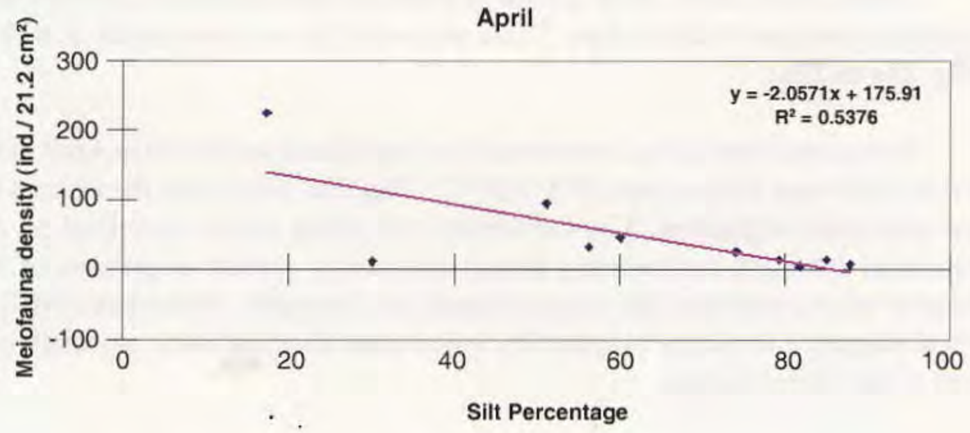
IV. Discussion

In terms of the total density of meiofauna, August is the highest density in all stations follows by October, and April is the lowest (**Fig. 13**). The results show variation in seasonal period, which is in line with Fenchel, 1978 from Nybakken (1997). He has note that in temperate shallow water areas, there is an annual change in the densities of the dominant groups and also seasonal changes on the abundance of meiofauna organisms.

While highest density was found at station no. 4 followed by station no. 2,3 and 1 respectively (**Fig.13 and 14**). This result could find reverse relationship to silt percentage (**Fig. 22a and 22b**). Higher density of meiofauna related to lower of silt percentage.

Nybakken (1997) also mention that grain size is great importance because it controls the ability of the sediment to retain and circulate water. The circulation of water through the pore spaces in the sediment is important as well because this water movement is responsible for renewing the oxygen supply.

a



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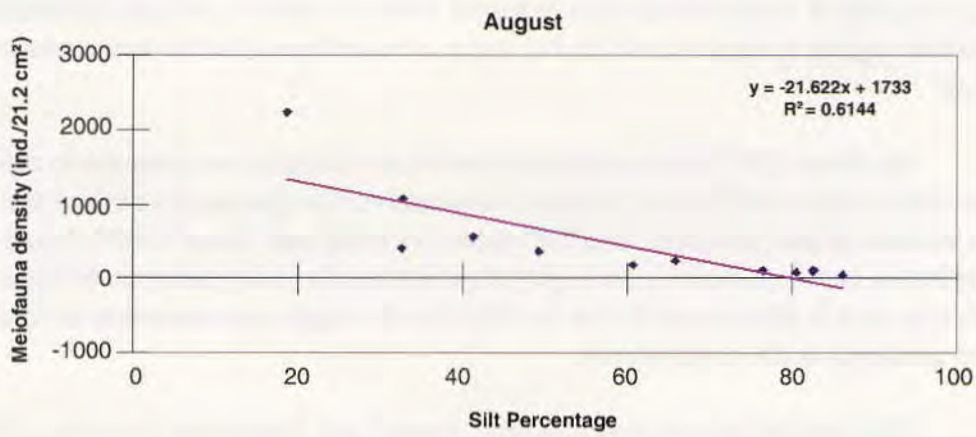

Fig. 22a and 22b Relationships between meiofauna density and silt percentage

Fine particle as silt has very small particle spaces that cause less oxygen supply in sediment. Therefore, the numbers of survival meiofauna or interstitial organisms are slightly. This supports the concept on grain size is important to their living. Furthermore, it might attribute to their species because finer sediments being preferred by nematodes, coarser often by copepods (Giere, 1993).

From the result, Pakklong Sub-district coastal areas are mainly composed of silt particle and nematodes are exactly dominant species. It causes their body structure could perfectly adapt to live in sands and silt especially a thick heavy cuticle (Castro, 1997 and Nybakken, 1997). The relationships between meiofauna density and silt percentage are presented.

The view of area consideration with physio-chemical factors, it could be divided into 4 groups. They are station no.1, station no.2-4, station no. 5-6 and the last group is station no. 7-12. The result from ANOVA indicated that 4 groups of stations different significantly (**Appendix 5**).

Unless main factor, there is a lot of evidence that meiofauna are vital links in many natural processes and relationships. These supported the mention results as well (**Appendix 6, Fig. 23a to 23h**).

In seasonal aspect, the lowest density of meiofauna was found in April. It might due to absolute high water temperature (29.5-34.8 °C, **Fig. 23a**) that causes the vertical migration of some meiofauna organisms. This confirmed with Giere (1993) described on environment temperature can have a structuring impact and causes vertical migrations of the sensitive species if other conditions like oxygen supply are favorable. Nybakken (1997) refer to the vertical migration is usually triggered by temperature changes and is especially prominent in beach in the temperate zone.

When considered on dissolved oxygen (DO) in April (**Fig. 23b**), it is range 5.7-7.3 mg/l, supported vertical migration behavior because dissolve oxygen available. However dissolve oxygen in August and October seem to be sufficient but the temperature suitable for living.

Monthum (2002) indicated that the meiofauna distribution depended on redox potential, especially vertical distribution. Copepod was sensitive if oxygen supply reduces while nematode can tolerate in this situation. And the studies of Long and Ross (1999) found differential distribution has been shown to be highly depended on the redox potential of the microhabitat, which in turn is determined by the availability of oxygen and oxidation state of sulfur and other nutrients in the environment.

High rainfall was observed in May, August and September (over than 200 mm each month, **Fig. 23c**). The sediment and some organisms load from nearby freshwater outflow toPathew bay and closed stations. These evident caused oligochaetes, common freshwater species, were identified and recorded as few result in August and October.

Low salinity in October (**Fig. 23d**), especially station no.1-4 at 29.2-29.7 ppt and station no. 9-12 at 28.6-28.9 ppt, patronized oligochaetes living. This is another factor for describe freshwater worms, washed by water runoff from land since the beginning of rainy season, could survive in October. Another meiofauna characteristic is they are able to adapt to a wide range of salinities (Giere, 1993 and Monthum, 2001). So the salinity ranged between 28-34 ppt, result from monitoring, seem to be less effected to meiofauna survival.

In area aspect, high densities are stations in Pathew Bay. When consider on transparencies (**Fig. 23e**), stations no. 2,3 and 4 of all sampling months were extremely low (not over than 1.5 m). The transparency related to organic matter in reverse way and more associated with the particulate suspended matter than dissolved organic (Rust and McArthur, 2001) Transparency fallen because organic matter in the water increasing.

Monthum (2001) reviewed on dissolved organic matter (DOM) was absorbed by meiofauna through their soft and large epidermis surface. Thus, the sediments with high DOM concentrations are favored by meiobenthos. Sugar and free amino acids are principle organic elements, which become highly enrichment (Giere, 1993).

While particulate organic matters (POM) are detritus and living organic substances like bacteria, microalgae and other animals. Amino acid and Nitrogen compounds, from natural process of POM, are important nutrients. These cause the number of meiofauna increase (Monthum, 2001). This is in line with the studies of Rosenberg (2001) found that the increased input of nutrients has lead to increase primary production and consequently more organic material has accumulated on the bottom. And Mare (1942) stated that the content of organic matter has a significant influence on the distribution of meiofauna.

So, POM indicated in same direction with the result on meiofauna density. Moreover, the information on August also confirmed with density at all stations except no.6-8 were highest when compare with April and October (**Fig. 19**).

Apart from organic enrichment, the bottom depth is might be another factor, which effect to meiofauna density in area aspect. Because of bottom depth plays an important role on nutrient circulation from water mass into sediment. Photosynthesis and primary production influenced to meiofauna consumption. Rosenberg (2001) stated that food for the benthos is generally higher in shallow than deeper areas. And distribution of benthic faunal group in communities related to a gradient of decreasing food availability and water movement with increasing depth.and encourage the monitoring result as station no. 1-5 and 11 (**Fig. 23f**). Many factors can explain high density from inside Pathew bay and adjacent stations, but only this factor can refer for station no. 11. It is shallowest station among parallel coastline stations (no.6-12) while others are over than 12-meter depth.

The pH value is another factor but plays only minor role for marine meiobenthos. Normally, the value is slightly alkaline seawater (pH 7.5-8.5) (Giere, 1993 and Monthum, 2001). There are unusual situation in the case of pH value drops below 7 or increases over than 9. The result from baseline survey is in normal range and dose not outstanding effect to meiofauna (Fig. 23g).It is a resemble concept of Nybakken (1997), he describe the number of organism is highest in intertidal areas and decrease with increasing depth. Therefore, shallow stations should have high density Although organic matters and nutrients are important factors for the indication of ***abundance*** resource areas, but their supply have to appropriate with the aquatic organism in the food webs. The exceeded organic materials and nutrients result in ***polluted condition*** of the water. The oxygen supply is another factor for meticulous consideration. Low oxygen supply from living cycle of aquatic organisms brings about polluted condition of coastal area as well. These present that the manipulation of the factors to satisfactory level is essential for management.

Implication of Meiofauna Density and Distribution Information to Aquaculture in the area

Cage culture, mussel culture and shrimp farm are aquaculture activities in Pakklong Sub-district coastal area, which need good marine environment for valuable products. Nevertheless other human activities like small processing plant, tourist resort and fishing operation cause changing of water quality and environment condition. This study should be information base for further activities. Because of sediment grains of upper layers are constantly being resuspended and deposited. Thus, the location and amount of interstitial space is constantly changing. When a large amount of aquaculture waste including organic material were release to the coastal area, it might cause eutrophication that presented on meiofauna density and distribution variation. This phenomenon induces toxicity to aquatic animal especially mussel culture because they are filter feeder. Hence the encouragement of aquaculture activities should consider on monitoring of this issue while the activities implement as well. The results can analyze by compare with information base in order to investigate operations. This would find the appropriate number of farm for carrying capacity and nutrient circulation.

V. Conclusions

This monitoring could determine the density and horizontal distribution of meiofauna in Pakklong Sub-district coastal area. They distribute along coastline with different densities. The high-density areas are inside Pathew bay (station no.2-4), follow by adjacent area (station no. 1, 5 and 6). The low-density areas are station no. 7-12, which parallel coastline. These depended on silt percentage in reverse relationship as main factor. Beside silt percentage, other factors like temperature, dissolved oxygen, rainfall, salinity, transparency, bottom depth, pH as well as current speed and direction were effected to the monitoring result as natural processes and relationships.

Based on meiofauna is recognized playing an important role of the small food web, it is integrated in a substantial compartment of the benthic energy flux. So they indicated that Pathew bay and closed areas (station no. 1-5) are abundant resources and suitable for aquaculture activities. However, the consideration on other environment conditions is necessary for aquaculture management planing.

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Appendix 1 : Biology of dominant meiofauna that found in the stations

1. Nematode

Nematodes or widely known as roundworms dominate all meiofauna samples in abundance. They are very common species and can be founded in various kind of sediment. The body is cylindrical, long, narrow and tapering to head and tail. They resemble tiny threads. The outside skin is a thick cuticle, which is both tough and flexible used as a protective covering. Inside is the digestive and reproductive system. Most nematodes feed on bacteria, fungi, and other soil organism.

2. Copepod

Copepods are small crustacean, tiny relative of crab and shrimp. Free-living species are perhaps most familiar, but there are also many highly specialized parasitic copepod. In meiobenthos samples, copepods after nematodes rank usually second in overall abundance. Their body is often tear-drop-shaped which tapering at the posterior. The copepod trunk is composed of thorax and abdomen. The head is fused with the first one or two thoracic segments. They feed on small food items like bacteria, protozoan, diatoms or other unicellular forms.

3. Sarcomastigophoran

There are many groups of creatures that were called Sarcomastigophoran, including protozoa like amoebae and foraminiferan. The amoebae from supralittoral marine environments feed on algae, rotifer and protozoa. Another group is tiny single-celled organism that construct shells or known as foraminiferan. The shells are commonly divided into chambers. They feed on dissolved organic molecules, bacteria, diatom, phytoplankton and small copepod.

4. Turbellarian

Turbellarians were called free-living flatworm. They are one group of unsegmented worms with obviously head and tapered at the tail end. They are soft, flatted organism, sometime vividly coloured that live in the sea. Many species are believed to occur in tropical reefs and live in habitats like mud and anaerobic sand. They feed on bryozoan, small crustacean and nematode.

5. Polychaete

Polychaetes are known by many names: bristleworms, lugworms, clam worm, sea mice etc. Most of them are marine species, living in intertidal zone and always found under rocks or in abandoned shell. They can also burrow into mud or sand. Polychaetes are segmented worms with well-differentiated head. The outstanding appearance is leg-like appendage used in various ways for locomotion. Their feeding styles vary as grazers, predators or scavengers.

6. Oligochaete

Oligochaetes are another group of segmented worms, lacking a definite head and having relatively few appendages. The body is cylindrical and thin. They are mostly found in moist soil and freshwater. So these benthic organisms are known as earthworm or aquatic worms. They are scavengers.

Appendix 2 : Occurrence of meiofauna (ind./21.2 cm²) by stations and months.

April

Species/Stations	1	2	3	4	5	6	7	8	9	10	11	12
Nematode	10	n.d.	n.d.	189	91	24	9	6	13	3	44	27
Copepod	0	n.d.	n.d.	21	2	1	2	1	0	1	2	1
Sarcomastigophoran	0	n.d.	n.d.	9	0	0	1	1	2	1	1	5
Turbellarian	1	n.d.	n.d.	2	1	0	0	0	0	0	0	0
Polychaete	1	n.d.	n.d.	2	0	0	1	0	0	1	1	1
Oligochaete	2	n.d.	n.d.	2	1	1	1	0	0	0	1	0
Others	0	n.d.	n.d.	2	0	0	1	0	0	0	0	1
Total	**14**	n.d.	n.d.	**227**	**95**	**26**	**15**	**8**	**15**	**6**	**49**	**35**

August

Species/Stations	1	2	3	4	5	6	7	8	9	10	11	12
Nematode	347	962	542	2023	345	32	100	95	93	66	220	172
Copepod	38	79	11	173	2	0	2	5	2	5	5	12
Sarcomastigophoran	0	4	0	0	0	3	0	0	0	1	1	2
Turbellarian	3	4	2	5	0	1	6	0	1	1	2	1
Polychaete	7	9	6	19	8	1	2	0	1	3	4	1
Oligochaete	2	4	5	6	6	5	0	0	0	0	1	0
Others	0	9	0	11	0	0	0	0	0	0	0	0
Total	**397**	**1071**	**566**	**2237**	**361**	**42**	**110**	**100**	**97**	**76**	**233**	**188**

October

Species/Stations	1	2	3	4	5	6	7	8	9	10	11	12
Nematode	184	393	204	1495	109	21	28	21	21	46	220	33
Copepod	15	30	6	76	3	2	3	3	2	3	1	0
Sarcomastigophoran	0	0	8	0	5	0	1	0	0	0	0	0
Turbellarian	3	1	1	4	1	0	0	0	0	0	1	0
Polychaete	3	0	1	16	0	1	0	0	0	0	2	0
Oligochaete	0	2	4	9	1	1	0	0	1	0	4	1
Others	0	0	4	3	1	0	0	0	0	4	1	1
Total	**205**	**426**	**228**	**1603**	**120**	**25**	**32**	**24**	**24**	**53**	**229**	**35**

Appendix 3 : ANOVA statistical test by station aspect.

Groups	Count	Sum	Average	Variance
Station 1	3	611.5	203.8333	36768.5833
Station 2	2	1495.5	747.7500	207690.1250
Station 3	2	791.0	395.5000	57122.0000
Station 4	3	4062.5	1354.1667	1057599.0833
Station 5	3	572.5	190.8333	21613.0833
Station 6	3	90.5	30.1667	80.3333
Station 7	3	153.5	51.1667	2508.0833
Station 8	3	131.0	43.6667	2406.0833
Station 9	3	134.0	44.6667	1996.5833
Station 10	3	130.5	43.5000	1273.0000
Station 11	3	507.0	169.0000	11169.2500
Station 12	3	253.5	84.5000	7727.2500

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4954354.83	11	450395.8933	**3.88410093**	0.003277	2.258517
Within Groups	2551094.79	22	115958.8542			
Total	7505449.62	33				

Appendix 4 : ANOVA statistical test by season aspect.

Groups	Count	Sum	Average	Variance
April	10	476.5	47.6500	4567.1694
August	12	5463.5	455.2917	398982.6572
October	12	2993.0	249.4167	196895.9015

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	909680.9	2	454840.5	**2.137742**	0.134982	3.30482
Within Groups	6595769.0	31	212766.7			
Total	7505450.0	33				

Appendix 5 : ANOVA statistical test by group of station aspect

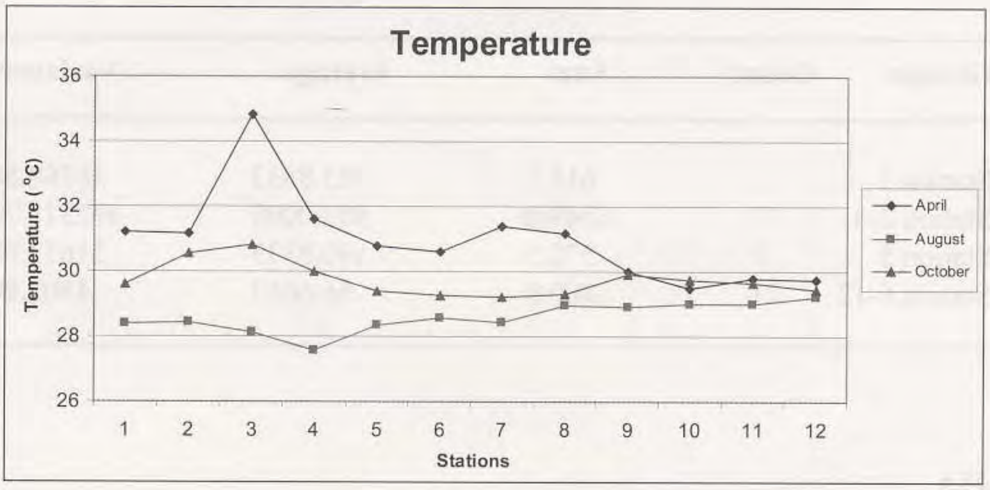
Groups	Count	Sum	Average	Variance
Station 1	3	611.5	203.8333	36768.580
Station 2-4	7	6349.0	907.0000	592311.700
Station 5	3	572.5	190.8333	21613.080
Station 6-12	21	1400.0	66.6667	4802.908

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3738758	3	1246253.0	**9.925841**	0.000105	2.922278
Within Groups	3766692	30	125556.4			
Total	7505450	33				

Appendix 6 : The information on other factors in April, August and October

a



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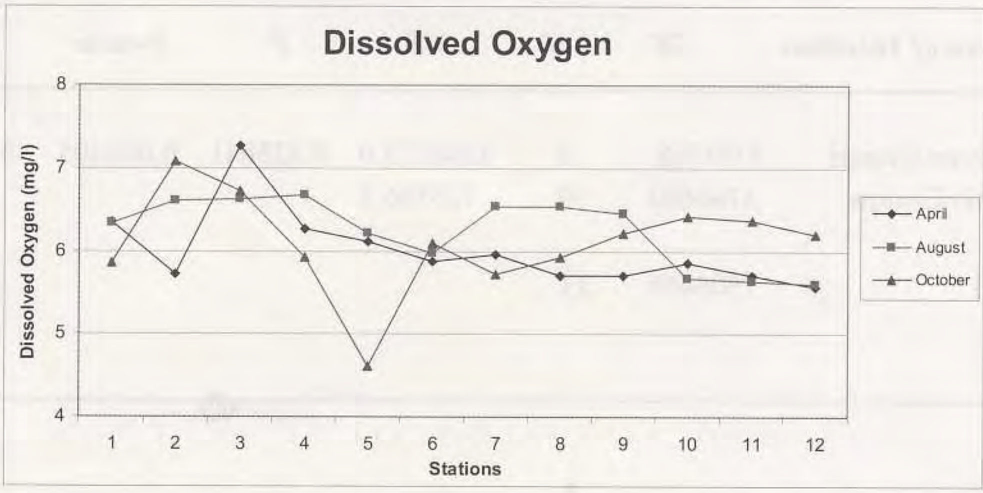

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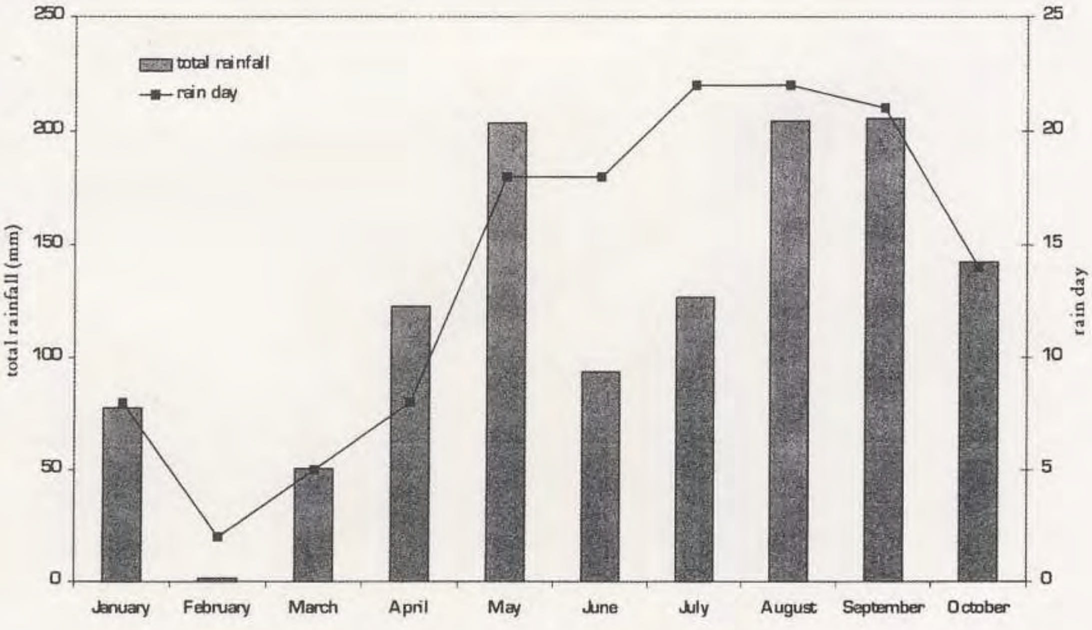

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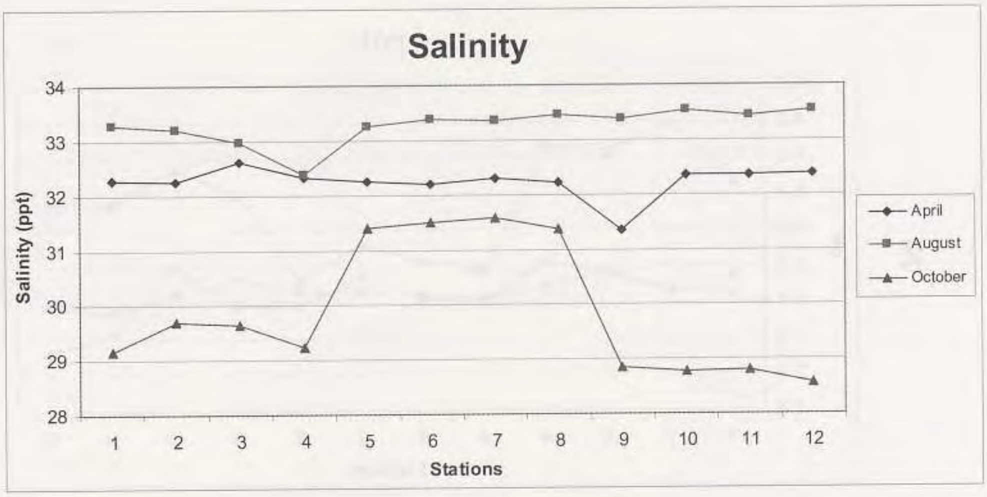
Salinity
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33
32
31
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29
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Salinity (ppt)
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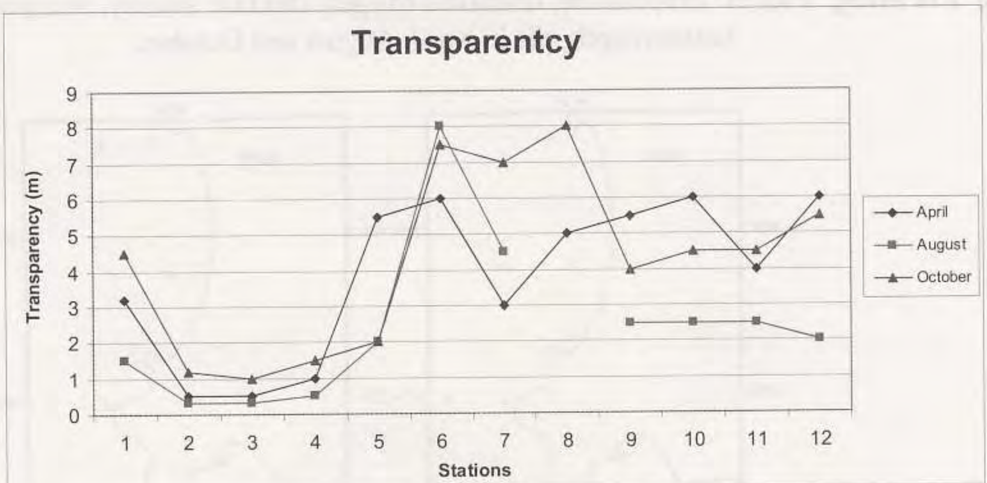
Stations
April
August
October

e


Transparentcy
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8
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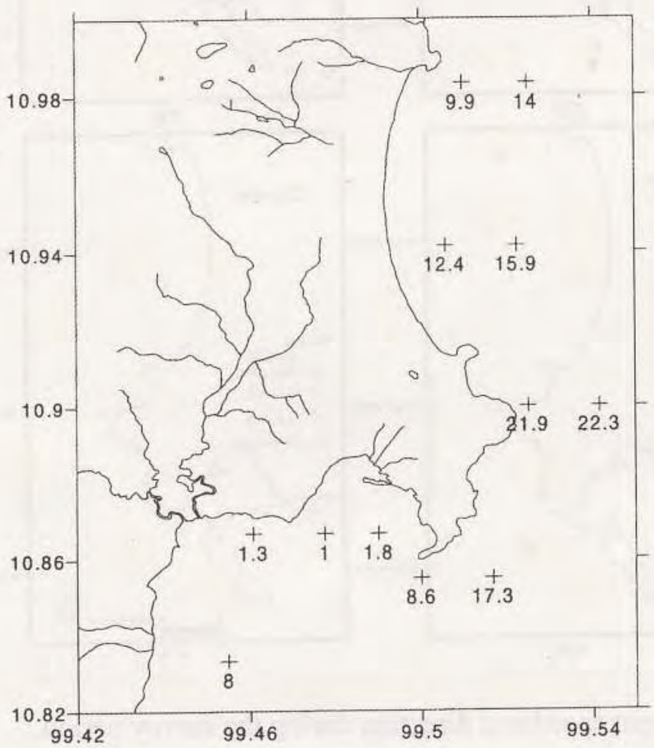
Stations
April
August
October

f


10.98
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10.9
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10.82
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99.46
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1
1.8
8.6
17.3
8

g

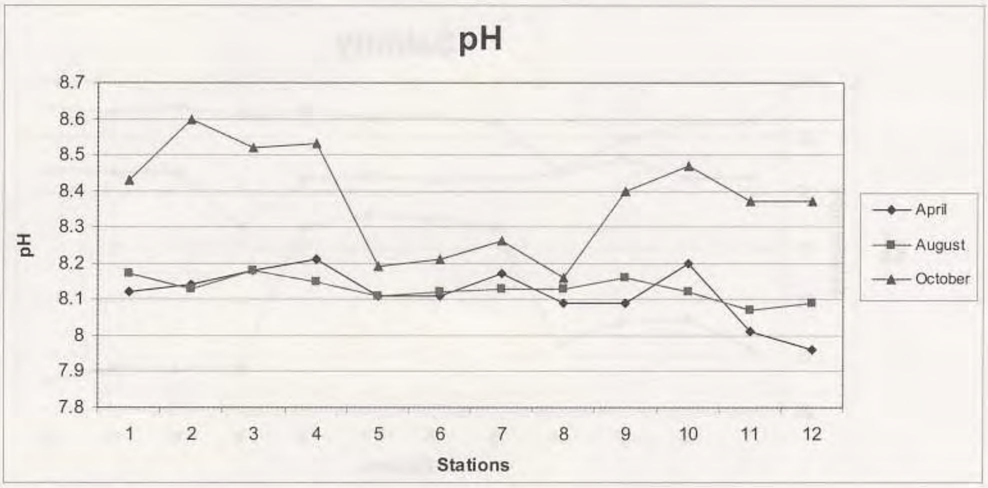

Fig 23a to23g Plot of temperature, dissolved oxygen, rainfall, salinity, transparency, bottom depth, pH in April, August and October.

h

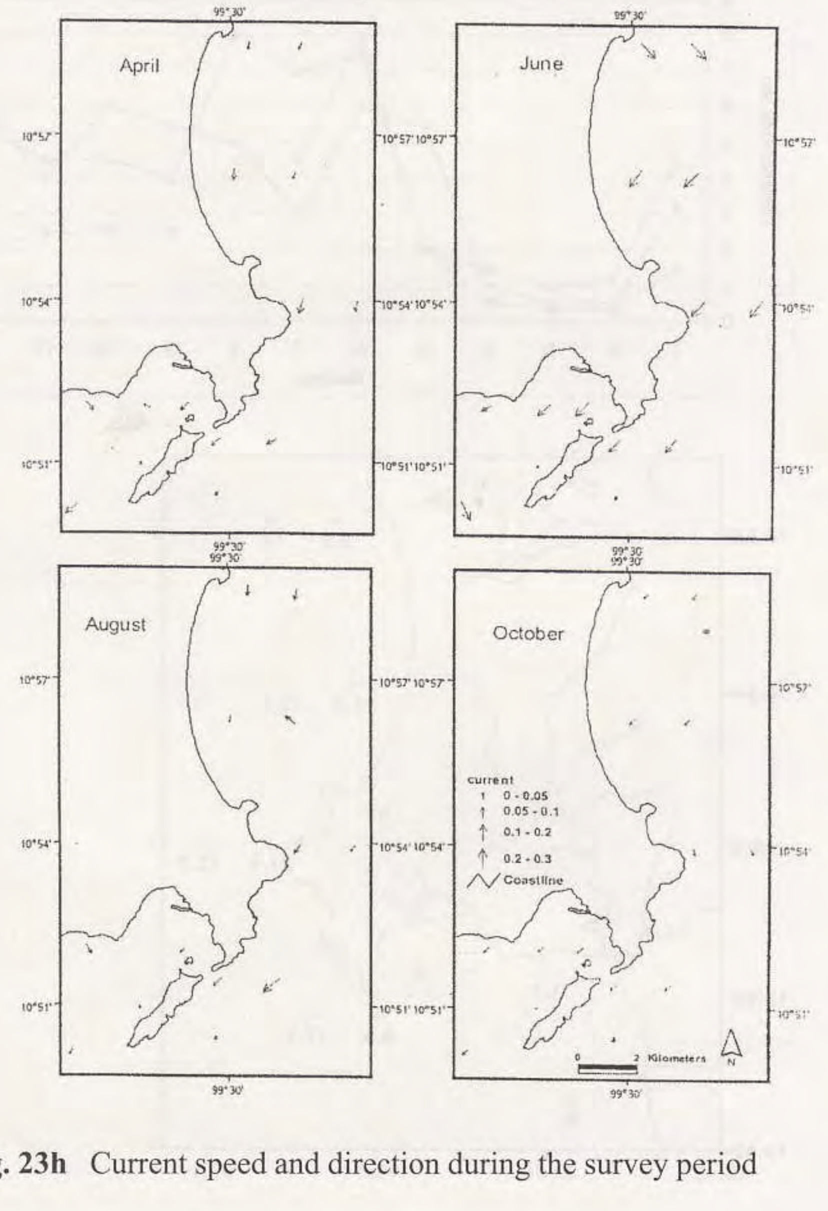

Fig. 23h Current speed and direction during the survey period

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