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VARIATION OF SEAWATER PROPERTIES IN DARVEL BAY, LAHAD DATU, SABAH

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ABSTRACT. *Darvel bay is the biggest semi-enclosed bay in the eastern part of Sabah. This study was carried out at Darvel Bay in March, September and December 1999. It was aimed at investigating the fluctuations of physical seawater characteristics (salinity, temperature and density distribution) in the bay during two monsoon seasons and its transition period. These parameters were measured using Hydrolab Surveyor 3 at 1 m and 25 m depths at the sixteen oceanographic stations in the bay. The salinity was less than 32.7 psu in March. It increased during the monsoons where salinity ranged between 31.2 psu to 34.43 psu. Strong currents from open sea supplied high saline water and formed strong stratification during the peak of the northeast monsoon. Freshwater discharged from Tingkayu and Silabukan rivers was about 42 m^3s^{-1} and 47 m^3s^{-1} respectively and decreased salinity at the eastern and northeastern part of the bay was 1 m. Sea surface temperature increased from March to December due to the seasonal effect. The temperature ranged between 27.1°C to 29.7°C in March and between 28.8°C to 29.9°C during the monsoons. Seawater density in March ranged between 18.9 to 20.8 and similar to the density observed in September. However, the range increased between 18.9 - 22 in December. Based on salinity and density parameters, Darvel bay is characterized as well - mixed during the transition and southwest monsoon and strongly stratified during the northeast monsoon.*

KEYWORDS. Seawater properties, stratification, seasonal monsoons, Darvel Bay

INTRODUCTION

The South East Asia waters are mainly controlled by the northeast and southwest monsoons (Wyrtki, 1961; Oakley, *et al.,* 2000). Sabah is situated at the tip of the Borneo Island, experiencing the southwest monsoon between May to September and is characterized by being a calm and dry season. The northeast monsoon prevails between November and February and is characterized by strong winds and heavy rainfall. The effects of the monsoons depend on the location of the area. As example, at the northwest coast of Sabah stronger winds occur during northeast monsoon than on the east coast of Sabah. Strong wind and currents during monsoon not only affect the sea bottom sediment but also the distribution of marine organisms (Chatananthaweji and Bussarawit, 1987). A case study at Phangnga Bay, Thailand, demonstrated the inter-seasonal variability in climate regimes which lead to subsequent changes in oceanographic conditions in the bay (Khokiattiwong *et al.,* 1991).

Seawater properties play an important role for management options, which promote the optimal use of resources and mitigation of some important problems in estuarine system and associated coastal areas. These parameters influence the growth and distribution of corals, mangroves and invertebrates that inhabit the marine environment. Some species of fish are known to migrate with or within the surface layer are due to changes of the water characteristics (Bond, 1979). Significant changes in survival rates of planktonic organisms, which drift in the surface water, could occur if the sea temperature and other parameters vary. The variations in sea surface temperatures are also known to cause the collapse of fisheries industries (Philander, 1989). The main objective of this study was to investigate the fluctuations of seawater temperature, salinity and density during two monsoons season and transition period.

STUDY AREA

Darvel Bay is located at the western part of the Celebes Sea, which is directly connected to the Sulu Sea in the north and opens to the Pacific Ocean in the east. Timbun Mata Island on the southern point forms the bay into a semi-enclosed area. There are more than 50 small islands and reefs that form its complex bathymetry. During the rainy season, suspended sediment mostly carried by the Tingkayu and the Silabukan rivers into the bay (Figure 1). About 80 percent of the coastline is covered by the mangrove forest in which 17,126 hectares is declared as mangrove reserves by the Forestry Department. Sandy coastline is only observed at the Northeastern and Southwestern parts of the bay. Sea grass beds and coral reefs are mainly scattered around the islands and shallow water areas. Arrangement of the marine ecosystems plays an important role as breeding and nursery ground of many marine fishes in the Darvel Bay.

The economy of local people living along the coastline is based on fishery, aquaculture and mariculture (De Silva, *et al.,* 1999). As in many places in Sabah, since 1970s logging activities were followed by the agricultural practices, mainly for oil palm and cocoa plantations in catchments areas, it drastically changed the freshwater discharge to the bay (Oakley, *et al.,* 2000). Aside from these, an increase of illegal squatters along the coast threatens both marine life and marine ecosystems. So far, only a few scientific studies have been conducted in this area. Only in 1988, an intensive research for marine biodiversity in this area was been carried out by the Borneo Marine Research Institute, Universiti Malaysia Sabah (De Silva, *et al.,* 1999). However, the variation of seawater properties were not considered in that report. The study area covers the middle of the bay between Latitudes 4^0 42' N to 4^0 56' N and Longitudes 118^0 15' E to 118^0 30'E as shown in Figure 1. This comprises about 45% of the sea surface area of 1,360 km^2. The average depth is about 35 m depth.

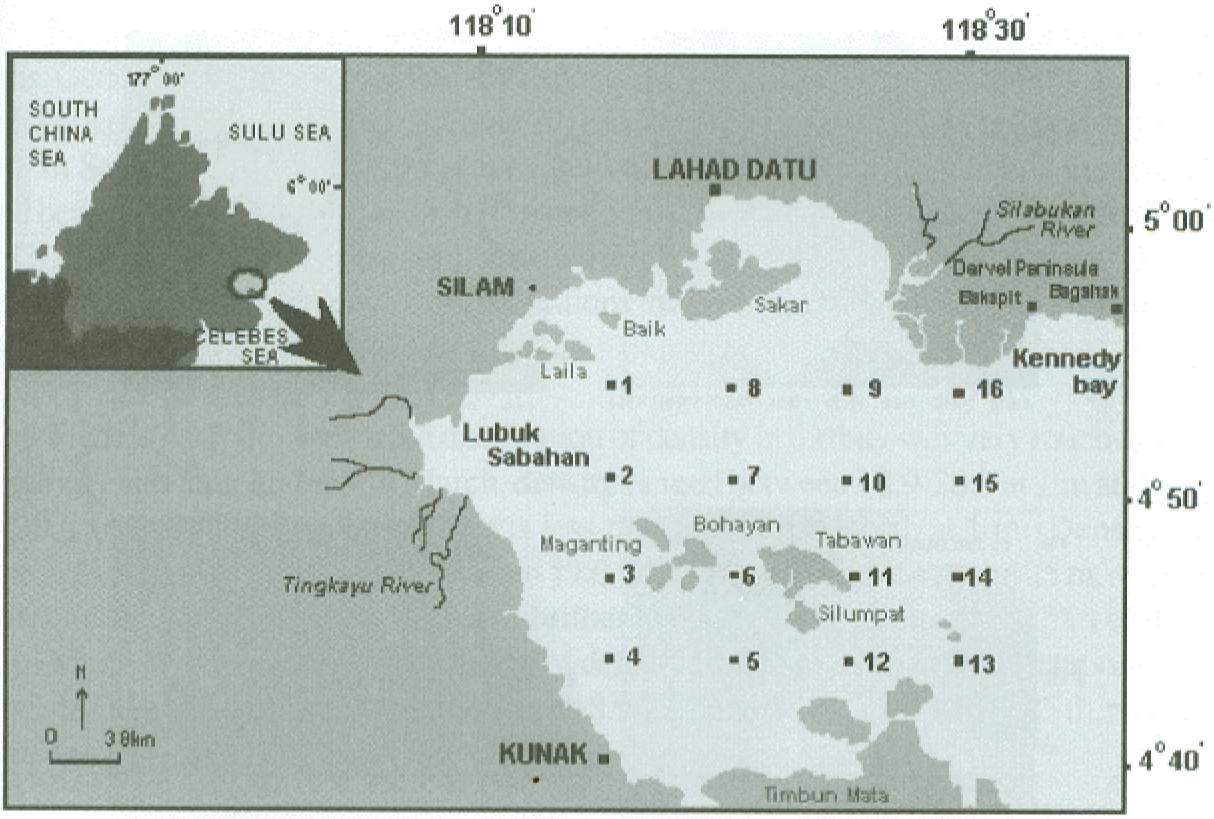

Figure 1. Study area and location of the 16 sampling stations

MATERIALS AND METHODS

The study was carried out in Darvel Bay in September and December 1999, representing the two monsoons season, while data taken in March represent the transition period where the northeast monsoon has weakened (Wyrtki, 1961). The tide gauge (Water Logger 14X-030) was deployed for 14 days starting from 20th July 2001 to the 2nd August 2001 to support this study. There were 16 sampling stations for seawater parameters with a distance between the stations of approximately 6 km (Figure 1). Data was collected between 9.30 am to 1.00 pm with time differences within stations of 10 to 20 minutes. Temperature and salinity were measured using Hydrolab surveyor 3 multipurpose at 1 m and 25 m depths during spring tides. The seawater density (Ãt) values were given as a function of these two parameters. Freshwater discharge from Tingkayu and Silabukan rivers were measured only during the southwest monsoon. River discharge could not be measured due to bad weather and very strong current flow in December. The variation of seawater properties and tidal data were analyzed using Surfer 7 and Microsoft Excel, respectively.

RESULTS

Horizontal distributions of salinity in Darvel Bay are shown in Figures 2a-f. Salinity ranged in March at 1 m between 31-32.1 psu and lower than 31.4 psu at northern part of the bay (Figure 2a).

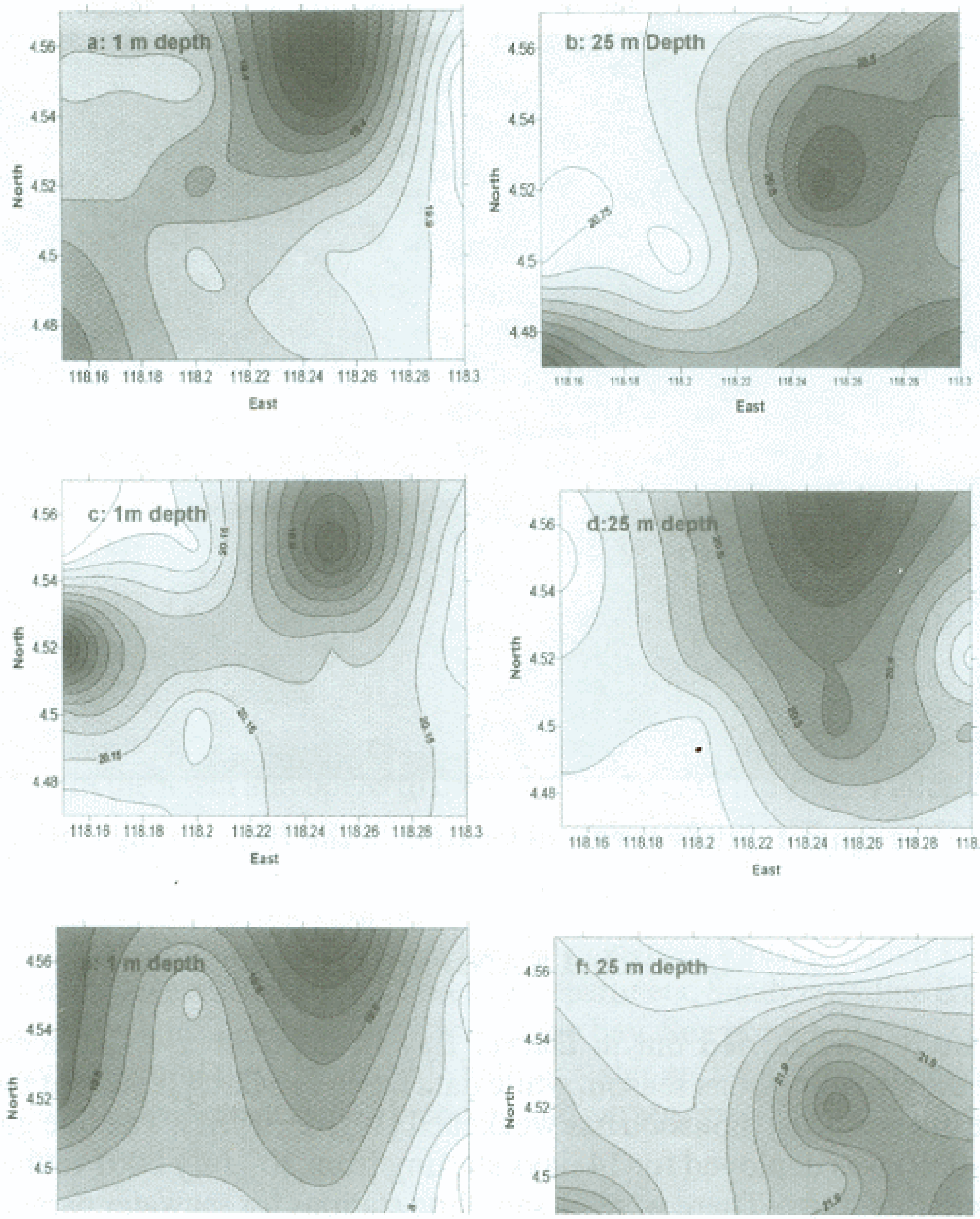

Figure 2a-f. Salinity distribution I March (a-b), September (c-d) and December (e-f) 1999.

At 25 m, salinity was relatively high ranging between 32.2-32.7 psu (Figure 2b). In September, salinity at 1 m was generally higher than in March, and considerably low salinity was observed at the northeast and the eastern part of the bay (Figure 2c). Salinity was ranged between 32.1–33.1 psu where low salinity occurs in the middle of the bay. At 25 m, salinity ranged between 32.7-33.2 psu, where less than 32.7 psu was detected at northern part of the bay (Figure 2d). In December, salinity at 1 m was less than 32 psu at north and northwest of the bay and higher than the salinity in March and September (Figure 2e). Salinity ranged from 31.2-33.9 psu and increased towards the open sea. However, at 25 m, most of the stations experience the highest salinity, which ranged between 32.1-34.4 psu (Figure 2f).

Figures 3a-f, show the seawater temperature distribution in Darvel Bay for three difference months. Generally, temperature gradually decreases with depth. The temperature at sea surface in March varied between 28.4°C-29.8°C and 27.1°C-28.1°C at 1 m and 25 m, respectively (Figures 3a-b). In September, temperature ranged between 29.4°C-29.9°C at 1 m and decreased into ranged between 28.7°C-29.1°C at 25 m (Figures 3c-d). In December, temperature varied between 28.9°C-29.7°C at 1 m and decreased between 27.7°C-28.4°C at the 25 m (Figures 3e-f). The temperature difference between sampling stations in March was about 1°C and less than 0.8°C in September and December.

Figures 4a-f, shows that the distribution of density in the bay was very much affected by both salinity and temperature. In March, density ranged between 18.9-20.1 at 1 m and between 20.3-20.8 at 25 m (Figures 4a-b). This is less than 19.4 in the north at 1 m. Density did not change in September, which ranged between 19.6-20.4 and 20.3-20.8 at 1 m and 25 m, respectively (Figures 4c-d). Mainly, density decreased either towards northern or eastern part of the study area. In March and September, the change of density from 1 m to 25 m for all stations was less than 0.8. In December density ranged between 18.9-21.2 and 21.6-22 at 1 m and 25 m, respectively (Figure 4e-f).

The freshwater discharge from Tingkayu and Silabukan rivers during the southwest monsoon was approximately 42 m^3s^{-1} and 47 m^3s^{-1}, respectively. Although, those rivers combine with many small rivers before reaching their estuaries, the freshwater discharge mainly flowed and mixed with the seawater along the coastline. Observations from field studies, noted that brownish color of seawater due to suspended sediment is seen about 2-5 km wide along the coast line, though still clear water in the central of bay.

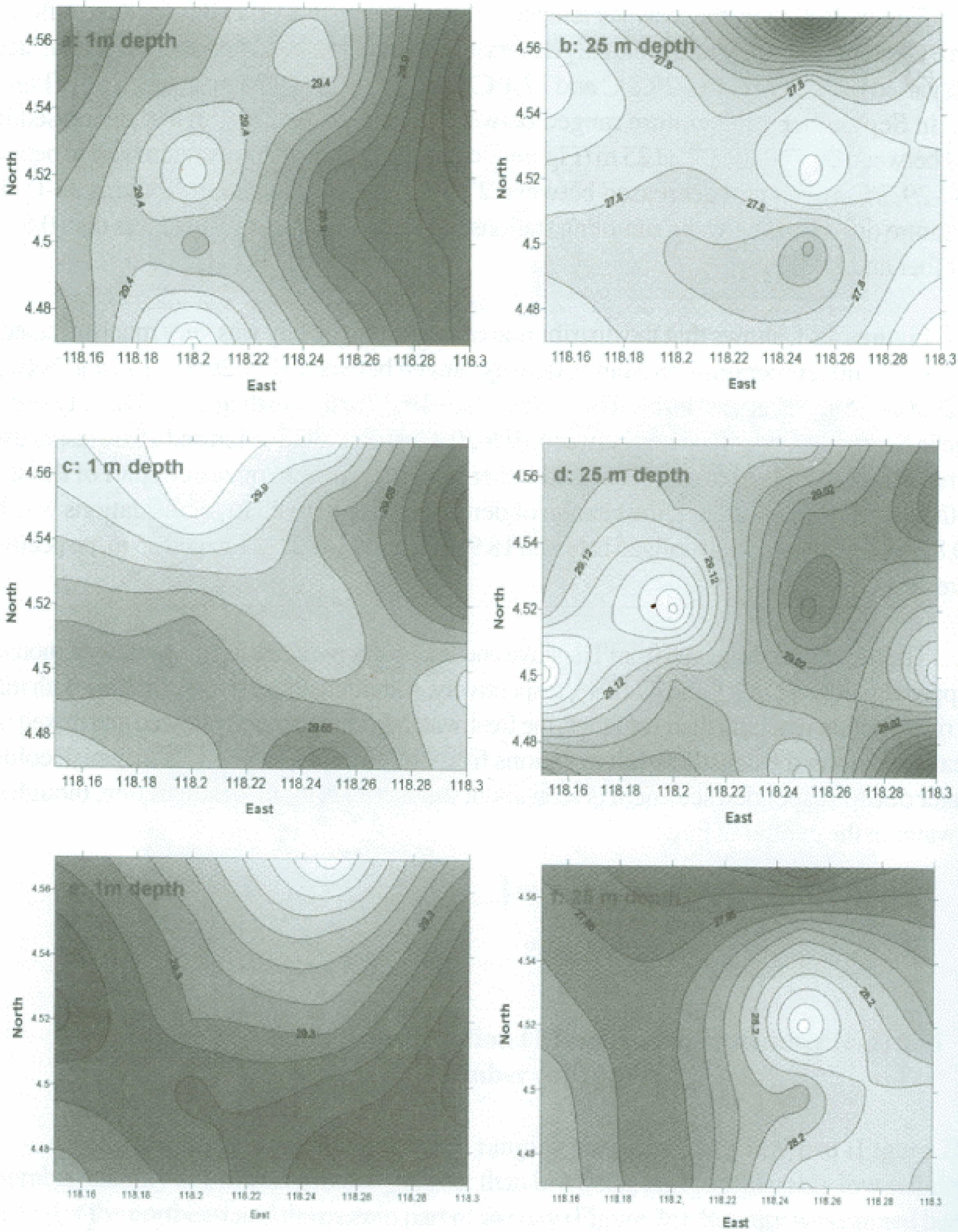

Figure 3a-f . Seawater temperature distribution in March (a-b), September (c-d) and December (e-f) 1999.

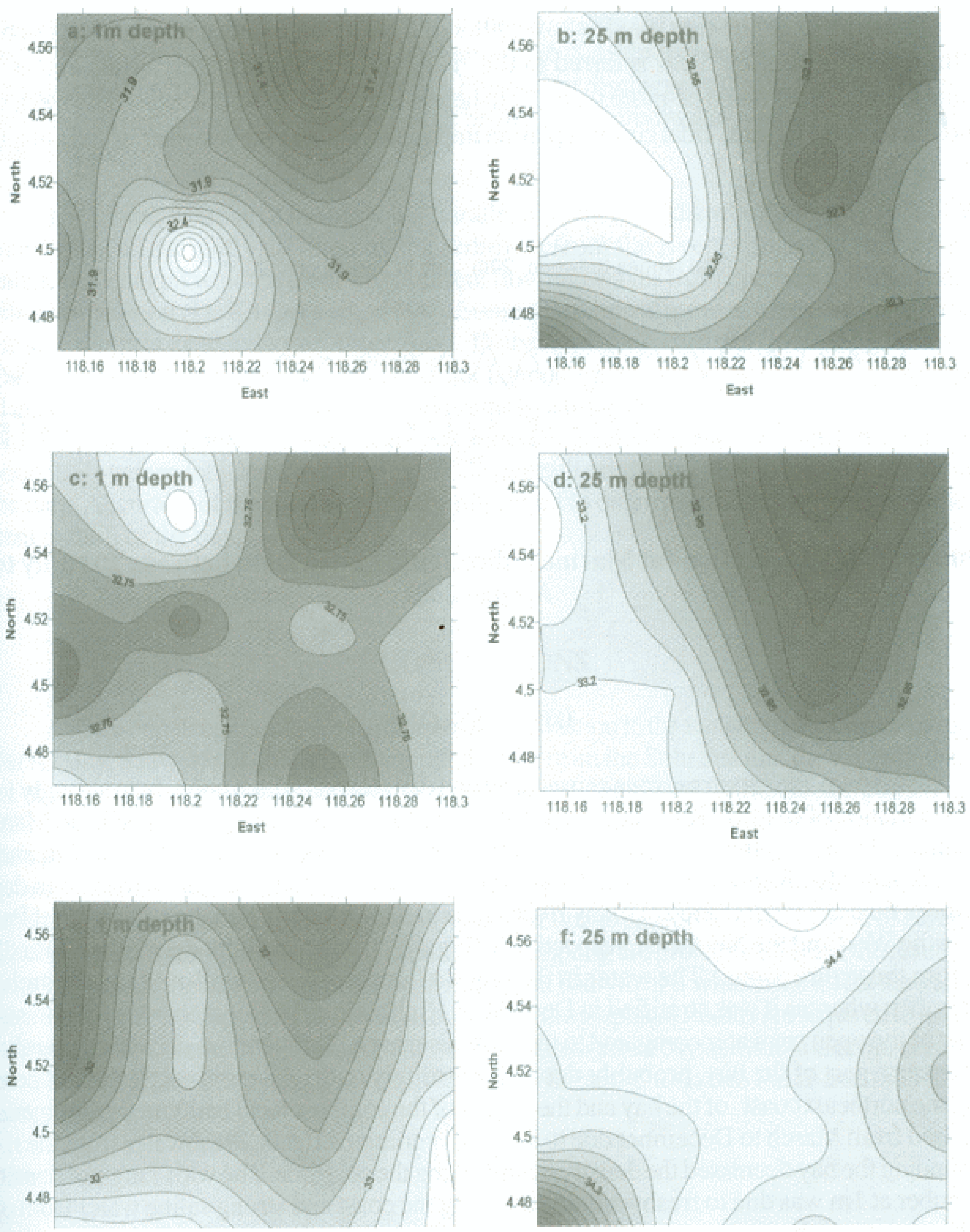

Figure 4a-f. Density distribution in March (a-b), September (c-d) and December (e-f) 1999.

Results from the tide gauge showed that the tidal range of Lahad Datu was between 0.49m to 2.59m (Figure 5). If referred to the Tide Table Malaysia 2001, this area is tidal dominated with tidal range of more than 2.0 m height and considered that very little fresh water run-off in terms of its size. Tidal currents play an important role to drive seawater in and out into the bay.

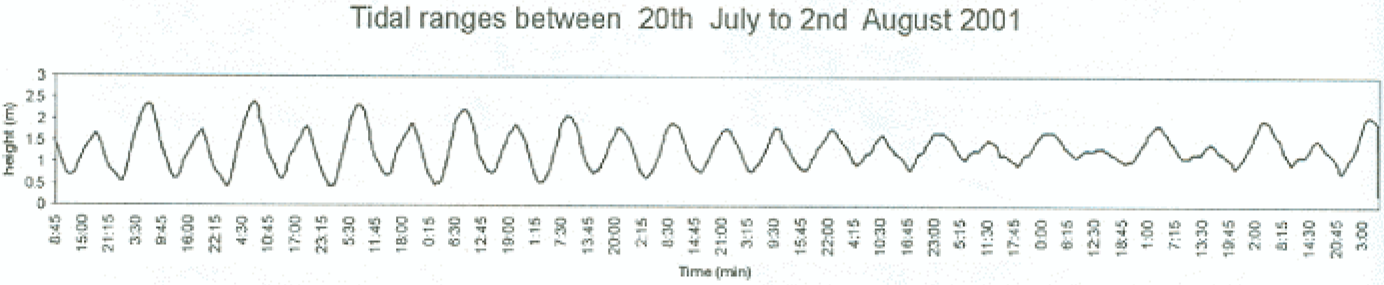

Figure 5. Tidal fluctuations at Marine Police Jetty, Lahad Datu between 20th July to 2nd August 2001

DISCUSSIONS

Seasonal monsoon seasons cause rainy and dry seasons which contribute strongly to the annual variation of salinity (Khokiattiwong, 1991). In Darvel Bay, salinity increased from March to December. However, the difference in salinity between stations was about 1 psu at 1 m and 0.5 psu at 25 m in March and September. In December, the salinity increase from 1 m to 25 m depths was more than 2.3 psu. There are many rivers and streams at Lubok Sabahan and Darvel Peninsula in the West and the Northeast, respectively (Figure 1), where salinity decreases markedly at 1m from these directions. The water in the bay was considered as well-mixed in March and September, whereas it was stratified in December. High salinity in December was due to strong inflow of the open seawater compared to the river discharge. Temperature decreased mainly at 1 m at eastern part of the bay, probably due to the strongly in driven currents from the open sea along the northeast coast of the bay and the effects of the complex local bathymetry. Temperature increased from March to December due to seasonal variation effects. Freshwater from the rivers surrounding the bay decreased the density mainly along the coastline. The wide range of density in December at 1m was due to freshwater influx along the coast and strong saline water from open sea driven into the bay.

Distribution of seawater parameters in the Southeast Asian water are particular complex owing to the mixing of coastal and oceanic water, the present of large shelves and land–enclosed deep-sea basins (Wyrtki, 1961). In Darvel Bay, oceanic water masses are transported by the inter-seasonal variability of monsoons either from the Sulu Sea or the West Pacific Ocean through the Celebes Sea. Strong wind during the northeast monsoon and a low sea level gradient in the Indonesian Seas during the southwest monsoon drives water into the Celebes Sea and flow persistently south to the Makassar Strait throughout the year (Miyama *et al.*, 1995; Toole *et al.*, 1990; Wyrtki, 1961). The Coriolis force is about $1.6 \times 10^{-5} m^{-3} s^{-1}$ causing a deflection of the water to the right, which finally enters this bay. Freshwater discharge in the bay mainly affects only a few kilometers from the estuaries, in which brownish colored water was observed during the time of sampling.

The characteristics of the seawater parallel to coral reefs distribution in the area of West Kennedy bay was slightly affected by the sediment from the rivers compared to the coral at Bagahak and Bakapit which is exposed to current flow and waves from open sea especially during Northeast monsoon (De Silva, *et al.,* 1999). Some of the coastline area at the northeastern part of the study area is exposed to strong erosion. Probably, strong currents flow along the coast of Bagahak and Bakapit can reach Laila and Baik Islands, and flows backward to open sea by the tidal current. Comparison of measured and predictive tidal data from the Tide Table Malaysia 2001, showed that Lahad Datu district is experiencing semidiurnal tides and categorized as mesotidal. However, long term monitoring of tides are still needed in order to increase the accuracy of the data. Accuracy of the tidal data is very important to determine both the water volume and current pattern of the bay.

CONCLUSIONS

A monsoonal regime plays an important role in relation to the variation of seawater properties in Darvel Bay. Seawater of this area is supplied either from the Sulu Sea that flows along the west coast of Sabah or directly supplied by the seawater from the West Pacific Ocean carried by the Mindanao current into the Celebes sea. Salinity in September and December was higher in most of the sampling stations compared to salinity in March, especially at 25 m depth. However, the water was strongly stratified in December as strong currents drive high saline water into the bay. Temperature was increased from March to December due to seasonal effects. Time of sampling, weather condition (sunlight intensity) and period of sampling are probably affected the results. The current flow inside the bay is obstructed by the complex bathymetry, which also affect the variation of seawater properties and water circulation. Further hydrographical studies are required to ascertain actual water movements in the area for any studies of marine ecosystems and marine organisms that are being carried out by the Universiti Malaysia Sabah, The Sabah Parks and the Fisheries Department.

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