Horizontal Distribution of Salinity and Temperature on Merbok Estuary, Malaysia

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Abstrak

Telah dilakukan studi mengenai karakteristik dan distribusi salinitas dan temperatur dan water system di estuaria Merbok dan di sekitar perairan pantai. Penelitan ini difokuskan pada proses-proses fisika. Hasil analisis menunjukkan suatu pola variabilitas khusus mengenai fenomena yang terjadi secara horizontal. Pada kondisi debit air (discharge) yang tinggi, air dengan salinitas (isohalines) rendah akan terdapat di dekat mulut sungai. Pada kondisi debit air rendah, keberadaan air sungai mengisi lebih jelas di estuaria bagian bawah. Pola yang sama juga teramati untuk parameter temperatur di daerah yang sama yang disebabkan rendahnya debit sungai. Dengan debit yang lebih tinggi dapat menyebabkan perubahan temperatur air payau dibandingkan debit yang lebih rendah. Hal ini menyebabkan terjadi proses transisi stratifikasi antara debit air yang tinggi dan rendah tersebut.

***Kata kunci** : debit sungai (discharge), salinitas, temperatur, perairan pantai, estuaria.*

Abstract

The characteristics and distribution of the salinity and temperature and water systems in the Merbok Estuary and nearby coastal waters are examined. This research focuses mainly on physical processes. The results analysis provides an insight the typical scales of variability of the horizontal phenomena. During high discharges, the lower salinity water (isohalines) was more evident near the estuary mouth due to high discharge. During low discharge, the invasion of freshwater in the lower estuary was much less pronounced. Similar temperature trend was observed for the estuary possibly due to low discharge phenomenon. Bigger amount of freshwater can dictate the brackish water temperature compare to smaller amount of freshwater. There was a transition in stratification between high and low river discharge.

***Key words** : river discharge; salinity; temperature; coastal water; estuary*

Introduction

Merbok Estuary is situated on the northwest side of the Peninsular Malaysia, has a length of 35 km and a mean depth of 15 to 3 m and the estimated of mean annual discharge of 20 m^3s^{-1}, and can exceed 50 m^3s^{-1} during high discharge months (Dyer *et al.*, 1992). The catchments area of the estuary measures 550 km^2 with the mean annual discharge is estimated as 20 m^3s^{-1} and the average annual rainfall is 2,1 m. The strong stratification event occurred during the period of observation was partly driven by a modest freshwater spate which coincided with neap tides condition. Investigation of transverse distribution of longitudinal currents of the Merbok Estuary showed significant and systematic variations in the speeds and phases of the depth-averaged semidiurnal currents (Ong *et al.*, 1994; Dyer *et al.*, 1992). Semidiurnal current phases, that changes flow direction occurred earlier in the shallow waters near the shore. Recently, Bakar *et al.* (2004) examined the influence of meteorological forces upon the estuarine systems over the whole length of this estuary.

Salinity and temperature were noted to be important components of the estuarine system (Liblik & Lips, 2009), and also at the Merbok Estuary. Mixing processes of estuarine water and seawater would result the fronts in estuary and adjacent coastal waters. It is important to identify environmental impacts and conditions in an examination of physical oceanography studies focusing on the effects of river discharge (Vinogradov *et al.*, 2004). This research mainly focused on the temporal and spatial distributions and evolution of salinity and temperature. The methods of analysis from the distributions were to resolve the horizontal scales of the estuarine water in the lower estuary and in the coastal zone around the estuary mouth. It will be illustrated and investigated this phenomenon of a pulsed estuarine water at the Merbok Estuary.

Materials and Method

Figure 1 shows map of the study area with details of the boundaries of the lower Merbok Estuary and coastal zone showing the interest of observational area. The study area located at Latitude 5° 38' N and

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5° 42' N and Longitude 100° 19' E and 100° 24' E. The width range of the estuary from about 2 km at the mouth to about 20 m towards the upper reaches of the estuary, with depths varying from 18 to 1m. The estuary mouth is relatively shallow and wider than that of the lower estuary, opens to the Malacca Straits. The interest area of the measurements was in the last 5 km from the estuary mouth and 2 km outside in coastal zone, which means that the exact location of seawater and freshwater mixing could be determined.

Eight field measurements were done at the study area during eight months between October 2002 to June 2003, by using a 10 meter local fishing boat. The salinity (S) and temperature (T) measurements were carried out using an instrument

YSI 30 SCT meter for the surface measurements and a GPS was used to determine the location of stations. The current magnitude and direction at near surface and close the bottom in the study area during the spring tide survey was measured with 3D-ACM acoustic current meter. The surveys consist of 40-50 stations formed repeated transect patterns and with two transect along and across the estuary in throughout the lower estuary till the outside. Generally, axial transects were carried out starting at station 1 inside the lower estuary and moving down outer of the estuary mouth to the last station.

Low discharge conditions were associated with droughts and periods of low rainfall, and vice versa. Because of the Merbok River is not gauged, from the catchment and evapotranspiration, Uncles *et al*. (1990) and Ong *et al*. (1991) estimate that the mean annual discharge of about 0,63 km^3yr^{-1}. In this study, the spatial and temporal distribution of the Merbok estuarine water was observed under varying conditions of river discharge. The river discharge condition was divided into two groups based on salinity value in the lower estuary. Low discharge was defined as a higher salinity and high discharge was defined as a lower salinity values in the lower estuary.

Results and Discussions

Salinity

Surface salinity distribution for high discharge is surveyed on 26 October 2002 (Figure 2) after a total of 16,6 mm of rain fell in the catchment area. Salinity is observed to increase gradually from inside of the estuary toward offshore with values ranges between 23,5 and 30,0 ‰. The patterns represent increasing horizontal mixing between freshwater discharge and seawater. The inner part shows the upriver discharge influence and it was defined by the salinity of 22,8-25,0 ‰. The outer zone shows a northward flow along the coast, with salinity between 28,0 and 30,0 ‰. The salinity pattern was increasing progressively with distance to the estuary mouth indicating that mixing processes. The similar discharge cases was surveys in 10 April, 19 and 20 May 2003. Contrary to this period, same structure but different conditions was found during the surveys in 22 and 23 March, 7 and 17 June 2003. Low salinity water was limited to the immediate vicinity of freshwater inputs.

Low discharge distribution, the salinity structure was slightly different from the high discharge case (Figure 2b). Observed salinity range for the lower salinity existed in the inner side and higher salinity occurred in the outer side, showing a weak gradient with downstream, and the salty water intrusion at the

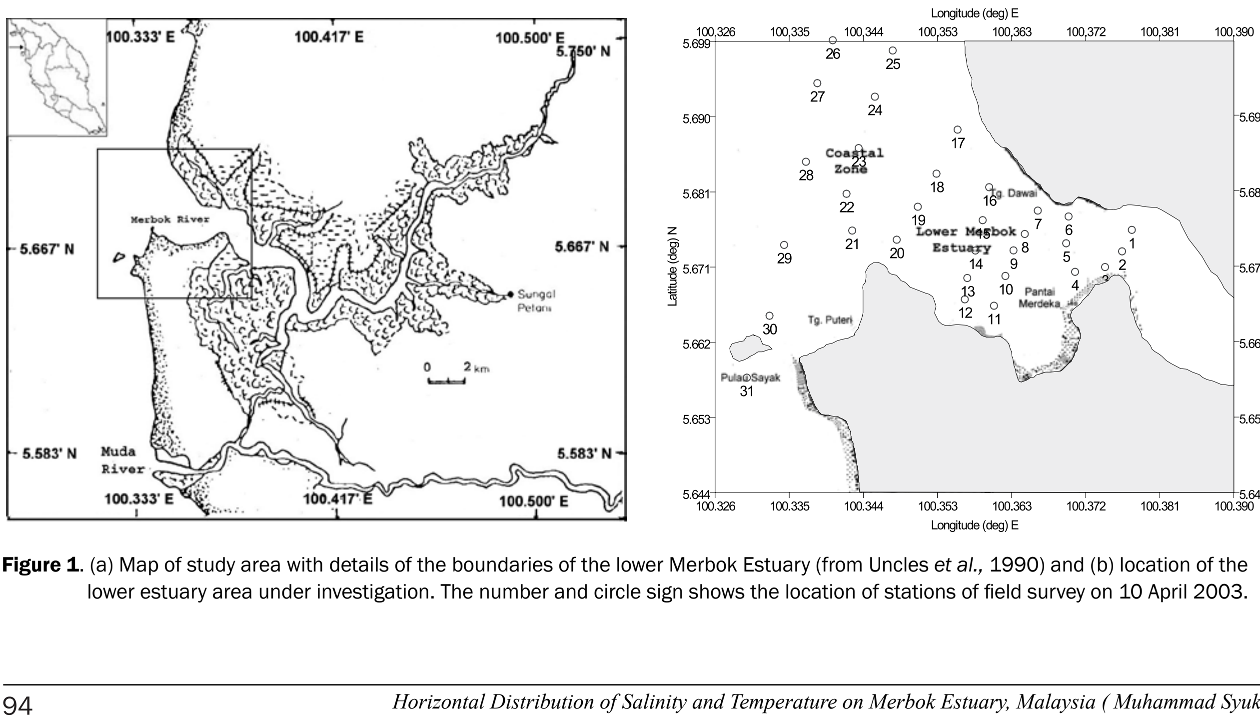
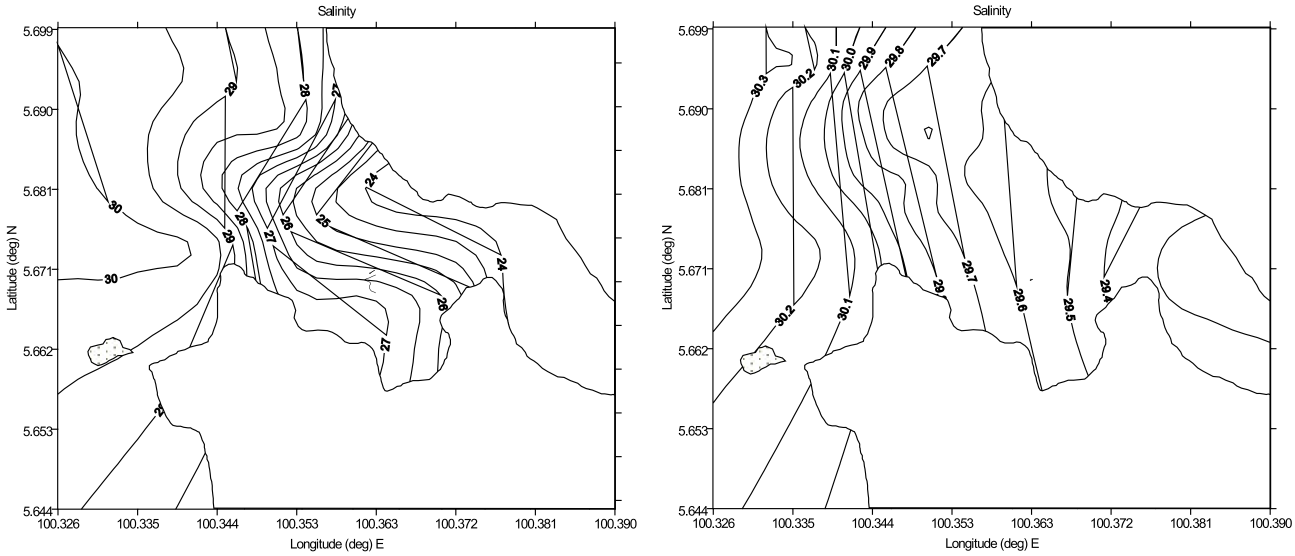


Figure 1. (a) Map of study area with details of the boundaries of the lower Merbok Estuary (from Uncles *et al.,* 1990) and (b) location of the lower estuary area under investigation. The number and circle sign shows the location of stations of field survey on 10 April 2003.



(a) (b)

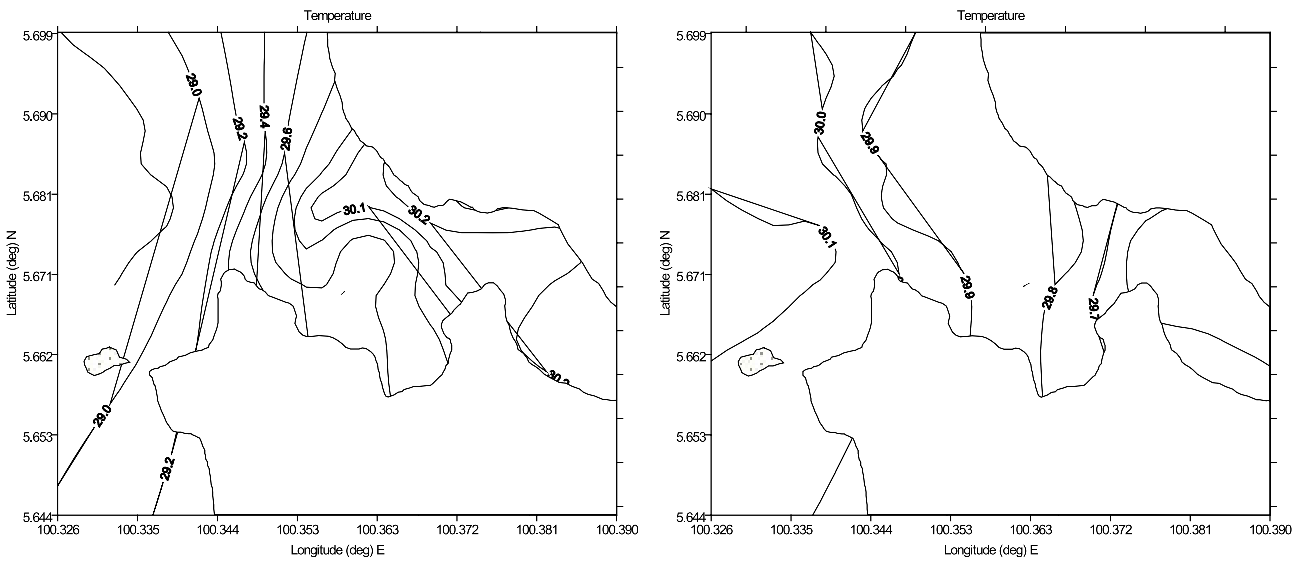
Figure 2. Horizontal distributions of salinity (‰) during (a) high discharge, on 26 October 2002, and (b) low discharge, on 23 March 2003.

mouth shows more upriver penetration in than during high discharge.

Temperature

The study area has a tropical climate characterized by condition of warm and dry during low rainfall period and cooler in higher rainfall period. It can be considered that high rainfall in catchment area would cause high discharge in the estuary. During high discharge period, i.e. survey on 26 October 2002 (Figure 3a), the distribution of temperature has a relatively small gradient (30,3-28,8 °C). Inner side of estuary was relatively warmer than the coastal zone, and temperature decreases gradually from the estuary towards the ocean. This behavior is similar with the salinity pattern described in above.

During low discharge survey on 23 March 2003, the surface distribution of temperature show also small variation horizontally (Figure 3b). The pattern of temperature shows warmer coastal water (30,1 °C) separated by sharp gradients from the colder freshwater (29,3 °C). The distribution of temperature shows similar pattern to that of high discharge period. How-



(a) (b)

Figure 3. Horizontal distributions of temperature (°C) during (a) high discharge, on 26 October 2002 and (b) low discharge, on 23 March 2003.

ever, opposite to high river discharge case, here estuarine water was cooler than seawater. This pattern was believed to be a consequence of the local rainfall condition in rivers catchment area, shows cooler waters from river was resulted by high intensity rainfall in catchment area (about 24 mm) a day before survey.

Salinity pattern

The major effect of freshwater discharge on salinity was to determine the position of the brackish water down estuary and thus flush salt from the estuary. The horizontal salinity gradients are seem to decrease with depth. The rate of decrease of horizontal salinity gradients are rapidly from surface to bottom layer. During low discharge, the invasion of freshwater in the estuary was much less pronounced, reflected in the high values of near surface and close bottom water salinities. In this period, the surveys were conducted on 22 and 23 March, and 7 and 17 June 2003. The horizontal salinity value was higher than that in high discharges. It is believed that high salinities and nearly homogenous during these periods were caused primarily by the transient response of the system to a change in river discharge. This was due to fact that small amount of freshwater flow from the river do not afford to pushes down the salinity in that direction through its spill channel. Therefore, the salinity distribution in the lower estuary was determined by the balance between the freshwater discharge from the river and the coastal-ocean salinity. The results of surface salinity herein are nearly consistent with those obtained in the other studies of the Yangtze River, East China Sea (Delcroix, 2002). The seasonal sea surface salinity shows a minimum in salinity value during the months when the river outflow is maximum.

Temperature pattern

Generally, the horizontal distributions of temperature within the study area were relatively straightforward and largely reflected a natural mixing of heat contents between brackish river waters and coastal waters. The annual cycle of atmospheric temperature was evident in alteration of river and sea waters. Maximum estuary and coastal temperatures were observed during the April 2003 survey. Horizontal temperature increases gradually from the estuary towards the ocean. During high discharge the temperature has a relatively constant gradient. Low temperature of the freshwater discharge in the estuary, caused the surface temperature over the lower estuary to be lower than that over the coastal water. The freshwater seem to travel along the northern coastline of the estuary. In low discharges, the surface distribution of temperature show also constant gradient. The temperature of the seawater changes during its transit to the estuary, in relation to the mixing processes and / or to heat exchange with the atmosphere. In several cases temperature of seawater is higher than temperature in the estuary. High river discharge reduces temperature on warm days (with higher atmospheric temperature), presumably because water arrives in the lower estuary and adjacent coastal zone before its temperature can equilibrate with air temperature. Low discharge condition increases water temperature on colder days (with lower atmospheric temperature), probably because of the moderating effect of the less variable water from down estuary.

This temperature patterns can also be explained by the condition of small freshwater input from the river, and also by surface heating of solar radiation that influence over the shallow estuary water. It is the nearly same results with observation by Ilahude *et al*. (2004), there was small vertical and horizontal variation of temperature that observed in shallow coastal water around Timika, West Central Irian Jaya. Beside, the atmospheric temperature cycle is responsible for the temperature variability in study area. Despite the strong vertical and horizontal gradient salinity, the temperature distribution in the estuary remains almost homogeneity. Probably the coastal waters reach a thermal equilibrium with the atmosphere before flowing upstream underneath the estuarine waters. The conditions explain the characteristics of quasi-thermal homogeneity in the lower estuary that was observed during high and low river discharge.

Conclusions

The salinity distribution in the lower estuary was determined by the balance between the freshwater discharge from the river and the coastal-ocean salinity. During high discharge, horizontal distribution of salinity is increase gradually from inside of the estuary toward the coastal waters, that is represent increasing horizontal mixing between freshwater discharge and seawater. Contrary to this periods, it was found the same structure but low salinity water was limited to the immediate vicinity of freshwater inputs, and the vertical distribution indicating a relatively weak salinity gradient. The temperature distribution in the Merbok Estuary characterized by small gradient. During high discharge period, the distribution of temperature about 30,3-28,8 °C, and in low discharge 30,1-29,3 °C. In general, this behavior is similar with the salinity pattern.

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