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PRELIMINARY STUDY ON LIMNOLOGICAL FEATURES OF LAKES AND RIVERS IN THE PEAT SWAMP AREA OF CENTRAL KALIMANTAN

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Abstract

Water quality, zoobenthos and epiphytic invertebrates were surveyed for waters in the peat swamp area of Central Kalimantan, Indonesia, during 22-25 February 1998. Water temperature was stratified markedly at depths of 0-1.5 m in Lekes Sabuah and Sembuluh. In Lake Sabuah, euphotic depth was as low as 0.76 m due to light attenuation by high concentration of dissolved organic matter as well as phytoplankton in the surface layer of water. Oxygen depletion was observed at bottom layers of Lake Sabuah and of northern inlet bay of Lake Sembuluh, where only a small number of zoobenthos (Oligochaeta) were collected. Water temperature was not stratified in the Kumai and Sekonyer Rivers. Dissolved oxygen concentration was low throughout the water column in the Sekonyer River. In the present lakes and rivers, biological production seemed to take place at depths of 0-1.5 m from water surface.

Introduction

Comprehensive limnological studies have been made for Indonesian reservoirs (MacKinnon *et al.*, 1996), deep alpine lakes (Mizuno, 1980) and crater lakes (Hehanussa, 1995). In Kalimantan, information is available for the Kapuas River (Roberts, 1989) and the lakes in the Mahakam River system (Mizuno, 1980). However, information is still poor for the lakes and rivers in the peat swamp forests which cover the vast area in the Central Kalimantan.

Since the start the JSPS-LIPI Core University Program "Environmental Management of Wetland Ecosystems in Southeast Asia", we seeked for the opportunity to make cooperative research on the lakes and rivers in the Central Kalimantan. In the research program, we agreed to identify the following 4 features of the aquatic systems in Central Kalimantan: 1) hydrological and geographical features partly using remote sensing technology, 2) ecosystem structure: community structure, fauna and flora, 3) ecosystem function, food-web and nutrient cycling, and 4) impact of land-use change and development on ecosystem structure and nutrient cycling.

During 22-25 February 1998, we made a preliminary field research in several lakes and rivers of different geological origins and different trophic levels. The present paper reports the physical and chemical parameters, especially their vertical profiles in the water columns, and the abundance of benthic and epiphytic invertebrates.

Study Sites

Water quality, zoobenthos and epiphytic invertebrates were surveyed for waters in the peat swamp area of Central Kalimantan, Indonesia. Lake Sabuah (02°3'19"S, 113° 56'37"E at the center of the lake) is located ca. 15 km north of Palangkaraya It is an oxbow lake along the Kahayan River with surface area of 1.2 km^2 and maximum depth of 6 m in the rainy season (February 1998).Two sites were selected at the northern tip (site SB1) and at the center (site SB2, depth 6 m, off Tuwung Village) of the lake (Fig. 1a). Lake Sembuluh (02°35'20"S, 112°24'20"E at the center of the lake) is located ca. 80 km east of Pangkalanbun. It is a floodplain lake forming a tributary of the Seruyan River, with surface area of 75km^2 and the maximum depth of 5 m. Two sites were selected at the northern inlet bay (site SM1, depth 3.3 m, off Terawan Village) and at the center (site SM2, depth 4.1 m, off Melang Village) of the lake. Several waters were surveyed in and adjacent to Tanjung Puting National Park, east of Pangkalanbun. We surveyed the Kumai River (site K1) and its tributary, the Sekonyer River flowing along the northwestern rim of the national park (sites SK1, SK2, SK3, SK4) and Lake Panjang, a swamp connecting with a tributary of the Sekonyer River (site P1, depth 1.0 m) (Fig. 1b).

Water samples were collected at additional sites for determining oxygen isotope compositions: rainwater at Bogor Botanical Garden and at Hotel Mina, Jl. Nias, Palangkaraya, well water at Tomban Tahai, a newly settled farmland, ground and surface water at Lahei site, northeast of Palankaraya and near the Mangkutub River (Kohayama *et al.*, 1997).

Materials and Methods

Observation and sample collection was performed mainly during 22-25 February 1998. The weather was fine throughout these days. Water temperature and dissolved oxygen concentration were measured in situ with a platinum resistor thermometer and a oxygen probe, respectively (YSI Model 55, Yellow Springs Instruments, USA) at every 0.5 m from surface to bottom. Quantum flux density was recorded at water depths of 0, 0.1, 0.2, 0.5, 0.75, 1.0 m and 0.5 m depth intervals furthermore with a data logger (LI-6000, LI-COR, USA) equipped with an underwater quantum sensor (LI-192S, LI-COR, USA) and a quantum sensor (LI-190S, LI-COR, USA) that was used for the measurement of reference incident solar radiation above water surface.

Water sample was collected at every 0.5 m from surface to bottom with a 1-l pyrex-glass Rigo snatch bottle sampler (100 mm in diameter and 200 mm high) with a vane at bottom. Specific conductivity and pH were measured for the sampled water with probes (ES-14, HORIBA, Japan). A subsample of 200-500 ml of the water was passed through a glass fiber filter (Whatman GF/F) precombusted at 450°C for 3 h. Filtration was performed in situ and the filter was placed in a 10-ml polypropyrene centrifuge tube with 8 ml of pure methanol to extract chlorophyll pigment, wrapped with aluminum foil and later stored in a refrigerator before analysis. The tube was centrifuged at 3000 rpm for 20 min and the absorbance was measured at 750 nm and 664 nm with a spectrophotometer (DU-65, Beckman, USA) for supernatant methanol solution. Chlorophyll *a* concentration (chl*a*, $\mu g\ l^{-1}$) was calculated by the following equation (Marker *et al.*, 1980).

$$\text{chl}a = 13.2\ (1000\ v_{\text{sol}} / v_{\text{water}})\ L\ (A_{664} - A_{750})$$

where v_{sol} is a volume of solvent (ml), v_{water}, volume of filtrated water (ml), L the optical path length of a cell (cm) and A_i the absorvance at i nm.

Total organic carbon (TOC) and dissolved organic carbon (DOC) concentrations were respectively determined for unfiltered and filtered waters stored in polypropyrene botles, with a TOC analyzer (TOC-5000, Shimadzu, Japan). Total carbon (TC) concentrations were also determined for the unfiltered water by the same analyzer.

For the determination of oxygen isotope compositions, water samples were collected with pyrex glass bottles at additional sites. Rainwater was sampled at Bogor Botanical Garden on 13 January 1998 and at Hotel Mina, Palangkaraya on 18 January 1998. Well water was sampled from a 20-m deep well of a farmhouse at Tomban Tahai on 20 January 1998. We sampled groundwater 40-50 cm from the peat surface as well as surface water at Lahei site on 17 January 1998. For lakes and rivers, water samples were collected and stored with polypropyrene bottles. Two ml of water sample was loaded in the CO_2-water equilibrater and kept shaked for overnight to achieve isotopic equilibrium between water and CO_2 Then CO_2 gas was seperated and introduced into a gas source isotope ratio mass spectrometer (Finnigan MAT delta-S, U.S.A.). Oxygen isotope composition of sample water was calculated from the isotpic composition of the CO_2 gas, considering isotopic fractionation. The result was given in delta notation ($\delta^{18}O$), which was per mil deviation from oxygen isotope composition of the international standard (Vienna Standard Mean Ocean Water, VSMOW) and was normalized to SLAP (Standard Light Arctic Precipitation) oxygen isotopic composition of –55.5 per mil consensus value. The whole processes were automatically carried out by the mass spctrometer system which accepted 24 samples at once and completed measurements within 5 h excluding equilibration time. The analytical precision was normally better than 0.05 per mils.

Two to 3 samples of bottom sediment were collected with an Ekman-Birge dredge. Each sample was washed in situ with a Surber sampler (0.3 mm mesh opening) and the zoobenthos retained on the mesh was fixed with 10% formalin solution.

Results and Discussion

Lake Sabuah

Water temperature was stratified markedly (2.8°C m^{-1}) at the layers of 0-1 m from the water surface. Dissolved oxygen concentrations ranged from 3.2 mg l^{-1} or 43% saturation at 0 m depth to 2.8 mg l^{-1} or 37% saturation at 0.5 m depth. The concentration decreased drastically to <0.3 mg l^{-1} at depths >1 m. At depths of 0-0.5 m, pH value ranged between 4.8-4.9 and DOC between 18-19 mg l^{-1} whereas at depths of 1-6 m, pH value ranged between 5.3-5.4 and DOC between 7-9 mg l^{-1}. Apparently peatland water affected surface water quality of Lake Sabuah. Chlorophyll *a* concentrations varied largely in the water column at the center of the lake (SB2): 20.6 μg l^{-1} (0 m depth) and 16.9 μg l^{-1} (1 m depth) in the surface layer and 4.2-8.0 μg l^{-1} at depths of 2-5 m.. These large differences of water quality parameters between surface (0-0.5 m) and deeper (1-6 m) layers suggested the poor vertical mixing in this lake.

The depth of euphotic zone estimated from the linear regression between water depth and log quantum flux density was 0.76 m at the center of the lake (SB2). Accordingly the transparency was as low as 0.36 m. This steep light attenuation was caused both by high DOC and high chlorophyll *a* concentrations in the surface layer.

Lake Sembuluh

Water temperature was stratified markedly in the top 0-0.5 m layers at both sites SM1 and SM2: 3.6°C m^{-1} at SM1 and 3.4°C m^{-1} at SM2. Vertical profile of oxygen concentration differed much between sites SM1 and SM2. At site SM1, dissolved oxygen concentration decreased sharply towards the lake bottom from 6.74 mg l^{-1} (0 m depth) to 0.5 mg l^{-1} (3.3 m depth) or 91% saturation at surface to 6% saturation at bottom, whereas at site SM2, oxygen depletion was not observed throughout the water column, ranging from 5.7 mg l^{-1} (79% saturation, 0 m depth) to 4.4 mg l-1 (57% saturation, 3.5 m depth). Chlorophyll *a* concentration ranged between 4.2-8.4 μg l^{-1} in the water column with peak value at 1-2 m depth (5.6-6.3 μg l^{-1}) and at 3.5 m depth (8.4 μg l^{-1}). DOC concentration in the water column ranged 6.4-6.5 mg l^{-1} at site SM1 and 4.5-6.3 mg l^{-1} at site SM2. Value of pH decreased slightly from surface to bottom, from 5.52 (0 m depth) to 5.12 (3.3 m depth) at SM1 and from 5.39 (0 m depth) to 5.29 (3.5 m depth) at SM2.

The depth of euphotic zone was 1.45 m at SM1 and 1.78 m at SM2. Transparency was: 0.71 m at SM1 and 0.66 m at SM2.

Sekonyer River, Kumai River and Lake Panjang

In the Sekonyer River and its tributary, water temperatures varied little within 0.1°C throughout the water column (sites SK1, SK2, SK4). Dissolved oxygen concentrations were very low, i.e., 0.64 (surface)-0.52 (bottom) mg l^{-1} at SK1, 0.65 (surface)-0.43 (bottom) mg l^{-1} at SK2 and 1.04 (surface)-0.53 (bottom) mg l^{-1} at SK4. TOC concentrations were 21.0 mg l^{-1} at SK2 and 17.5 mg l^{-1} at SK4. Values of pH for surface water ranged between 4.1-4.6. These values indicated that the river water was affected by peatland waters in the watershed although only TOC concentrations were determined for this river system.

The reason for the low oxygen concentration is not clear. The fact that specific conductivity was highest at the upstream site SK2 implied the existence of some contamination in the upstream region of the Sekonyer River.

In the Kumai River (site K1), dissolved oxygen concentration was higher than the Sekonyer River. From the surface to 2 m depth, dissolved oxygen concentrations were 3.1-3.2 mg l^{-1} or 41-43% saturation but at bottom (5 m depth), the value decreased to nearly 0 mg l^{-1}.

At site P1 in Lake Panjang, a swamp connected to a tributary of the Sekonyer River, dissolved oxygen concentrations were slightly higher than the main stream (site SK1): 1.85 mg l^{-1} at surface and 1.77 mg l^{-1} at bottom. TOC concentration (17.1 mg l^{-1}) and pH (4.3) of the surface water were similar to those at site SK1.

Oxygen Isotope Compositions

The $\delta^{18}O$ value of rainwater collected at Bogor was –2.37 per mils and that at palangkaraya was –3.46 per mils. The values of well or groung watar were much lower than the rainwater: -7.28 per mils for well water at Tamban Tahai and –7.06 per mils for groundwatere of peatswamp at Lahei. The value for surface water on peat swamp was close to the groundwater indicating that the water was originated from groundwater.

The $\delta^{18}O$ values of river and lake waters were between those of rainwater and groundwater: from -6.37 to -6.59 for Lake Sabuah, from -5.51 to -5.79 for Lake Sembuluh and from -5.41 to -5.50 for rivers and swamp in Tanjung Putting. The value for the Kumai River was lower than these waters (-4.14) (Fig. 2). There are 2 possible procecess explaining that the oxygen isotope compositions of lake and river waters showed intermediate values between rain and ground waters. One is the mixing of rain and ground waters and the other is the condensation of ^{18}O in open waters such as lakes and rivers by evaporation. To clarify the reason for this, we have to determine hydrogen isotope composition of water, to obtain D_{excess} parameter = $\delta D - \delta^{18}O$, which is an ambiguous indicator for evapolation.

Zoobenthos and Epiphytic Invertebrates

Densities of lake zoobenthos was low (0-104 individuals m^{-2}) except for the center of Lake Sembuluh (SM2, 504±228 individuals m^{-2}) where no oxygen depletion was observed at bottom water. Oligochaeta was dominant at sites with oxygen depletion (SB2 and SM1) whereas Chironomidae became dominant at site without oxygen depletion (SM2). In the Sekonyer River (SK1), however, zoobenthos density was 378±156 individuals m^{-2} although the oxygen content was not sufficient at bottom layer (Fig. 3).

Epiphytic or epipelic samples collected from the littoral zones consist of diverse groups of invertebrates: Chironomidae, Oligochaeta and Cladocera from Lake Sabuah, Chironomidae, Ephemeroptera, Odonata and Oligochaeta from Lake Sembuluh, Chironomidae and Oligochaeta from bottom sedge at Lake Panjang and Chironomidae, Ephemeroptera and Oligochaeta from the Sekonyer River.

Judging from the vertical profile of the oxygen conc and chlorophyll a concentrations and light attenuation, plankton and fish may inhabit in the top 1 m of the lake water column of Lake Sabuah. Zoobenthos density was extremely low in this lake. Primary production might also take place in the top layers. In Lake Sembuluh, depth of the biologically productive layer might slightly deeper as 1.5 m. Epiphytic or epipelic invertebrate in the littoral zone seemed to play an important role in the food web and function of aquatic ecosystems in the Central Kalimantan. Further detailed study is necessary both for rainy and dry seasons. The role of allocthonous matter from the surrounding peat swamp forest should also be clarified to understand the aquatic ecosystems.

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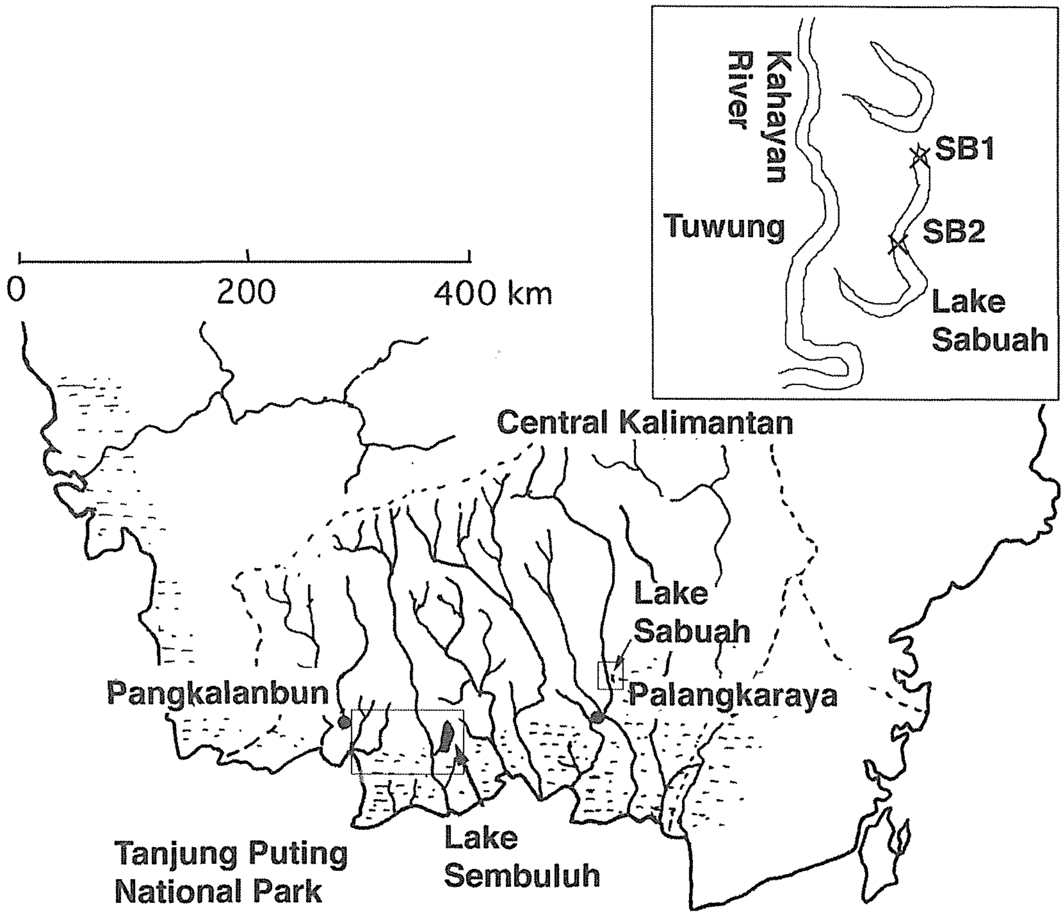

Fig. 1a. Map of Central Kalimantan showing sampling locations in Lake Sabuah.

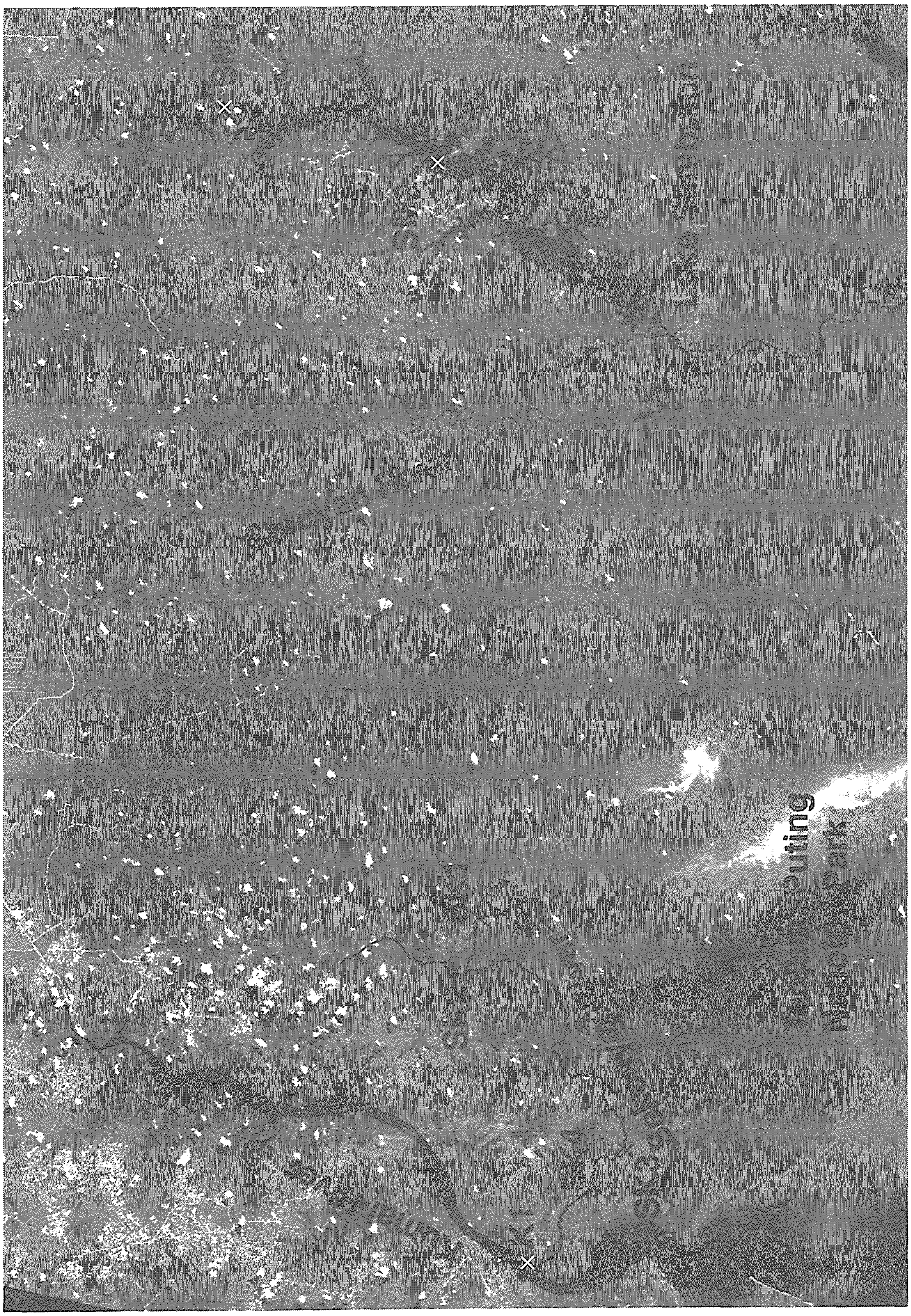

Fig. 1b. Sampling locations in Lake Sembuluh and in the Sekonyer and Kumai Rivers. Based on the red band data of a LANDSAT image obtained on 2 February 1993.

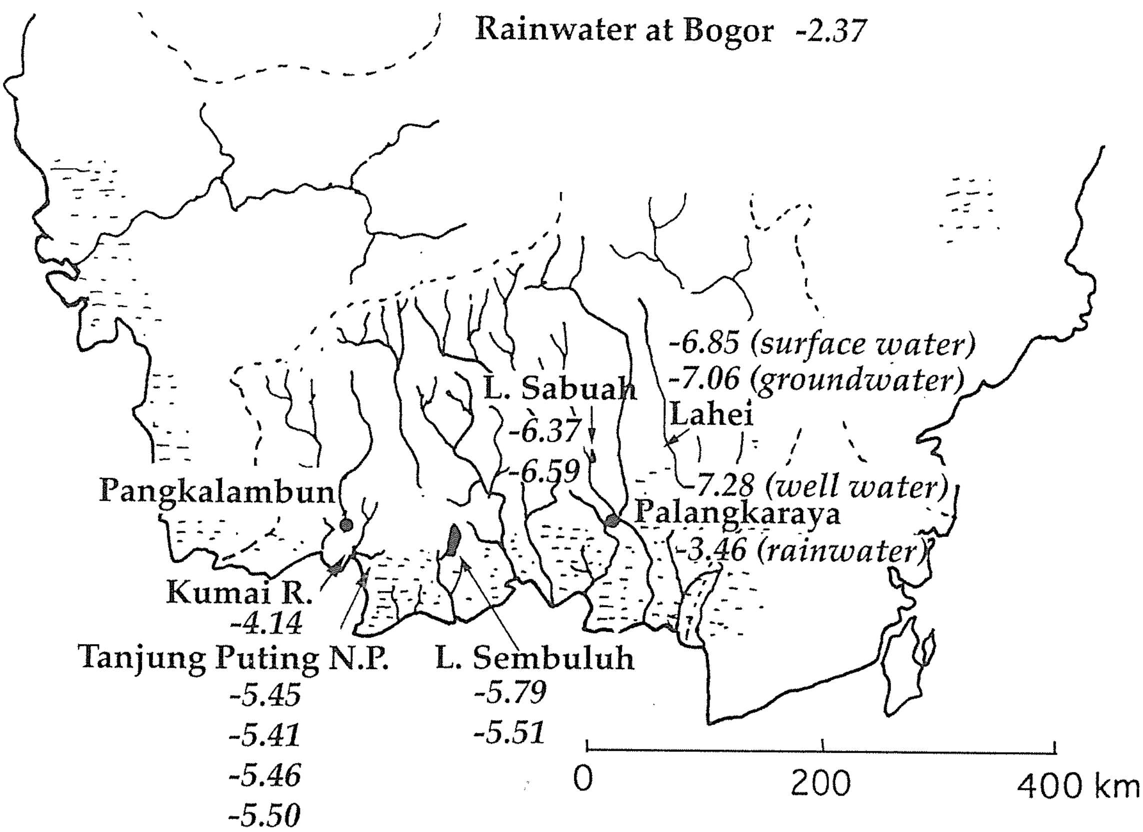

Fig. 2. Oxygen isotope compositions of rainwater, goundwater and lake and river water. Values are given in delta notation ($\delta^{18}O$), which was per mil deviation from oxygen isotope composition of the international standard, VSMOW, and was normalized to SLAP oxygen isotopic composition.

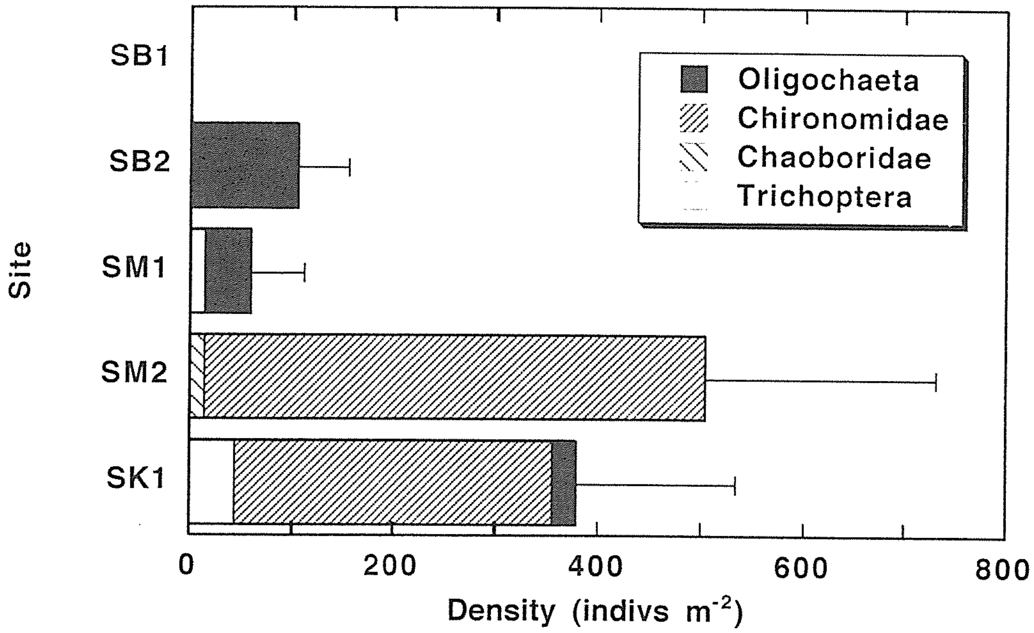

Fig. 3. Densities of zoobenthos collected from Lakes Sabuah and Sembuluh and the Sekonyer River. A bar indicate standard deviation for 3 samples (SB1, SB2, SM1, SM2) or half of the range for 2 samples (SK1).