PLANKTON DISTRIBUTION AND COMPOSITION OF OXBOW LAKES IN SABAH

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DECLARATION

The materials in this thesis are original except for quotations, excerpts, summaries and references, which have been duly acknowledged.

AZIMA BINTI AZMI
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بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

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ABSTRACT

PLANKTON COMPOSITION AND DISTRIBUTION OF OXBOW LAKES IN SABAH

The study aims to document and inventory the plankton composition and distribution of oxbow lakes in Sabah viz. Sugut, Klias Peninsula and Kinabatangan areas. Sugut was chosen as the main study area where four oxbow lakes were sampled in both the dry and wet seasons. These oxbow lakes were chosen based on different land use. In addition, three oxbow lakes were sampled respectively in the Klias Peninsula and Kinabatangan in the dry season for comparison of different locations. Phytoplankton was sampled using 20µm mesh size plankton net and enumerated using an Uthermohl counting chamber. The algal biomass (measured as mg/L chlorophyll-a concentration) was determined using the *Trichrometric Methods*. Zooplankton was sampled using 63µm mesh size plankton net and enumerated using Sedgwick-rafter (S-R) cells. The primary production was measured using the light and dark bottle technique. Fishes in the oxbow lakes were caught randomly for data inventory. A total of 159 phytoplankton species, a numbers of 10 species of zooplankton and 8 freshwater fishes were inventoried during the studies. These oxbow lakes were characterized by relatively high densities of phytoplankton (10.1-47.5 x 10^3 cells/L), compared to their parent river (10-22.3 x 10^3 cells/L). High algal biomass were also recorded ranging from 1.70 to 5.70 mg//L in these oxbow lakes. The primary productivity measurement ranged from 0.38-0.81 mg/L/hour. Based on phytoplankton species, there were differences between the oxbow lakes' and its parent river. The statistical analyses of correlation and Kruskal-wallis test shows there is a relationship between the composition and diversity of oxbow lakes' phytoplankton between dry and wet season and its surrounding effect.

ABSTRAK

KOMPOSISI AND TABURAN PLANKTON TASIK-TASIK LADAM DI SABAH

Kawasan kajian meliputi tiga kawasan utama iaitu Sugut, Semenanjung Klias dan Kinabatangan. Kajian ini bertujuan untuk melaksanakan dokumentasi dan inventori taburan dan komposisi plankton bagi tasik ladam. Sugut adalah kawasan kajian utama di mana empat buah tasik ladam telah disampel pada musim kering dan musim basah. Tasik-tasik ladam ini dipilih berdasarkan persekitaran dan guna tanah yang berbeza. Tiga buah tasik ladam disampel pada musim kering di Semenanjung Klias dan tiga buah lagi di Kinabatangan sebagai perbandingan bagi lokasi yang berlainan. Sampel fitoplankton diambil dengan menggunakan jaring plankton bermata jaring 20 µm dan pengiraan dilakukan secara kaedah enapan menggunakan silinder uthermohl. Biojisim alga (diukur sebagai kepekatan klorofil-a) ditentukan dengan menggunakan kaedah Trichrometric. Zooplankton disampel dengan menggunakan jarring plankton bermata jaring 63 µm dan pengiraannya dilakukan dengan menggunakan sel segdwick rafter (S-R). Produktivi primer diukur secara teknik botol terang dan botol gelap. Ikan di dalam tasik ldam ditangkap secara rawak untuk inventori data. Sebanyak 159 spesies fitoplankton, 10 spesies zooplankton dan 8 spesies ikan air tawar telah diinventori. Tasik ladam ini dicirikan oleh densiti fitoplankton yg tinggi (10.1-47.5 x 10^3 sel/L) berbanding dengan sungai utama masing-masing (10-22.3 x 10^3 sel/L) secara relatif. Biojisim alga yg tinggi dicatatkan dengan julat dr 1.70 hingga 5.70 mg/l. Produktiviti primer tasik ladam dicatatkan dengan julat dari 0.38-0.81 mg/L/jam. Berdasarkan Indeks kesamaan Sorensen, terdapat perbezaan dan persamaan didalam taburan spesies fitoplankton diantra tasik ladam dengan sungai utamanya,. Analisis satistik Korelasi dan Kruskal Wallis menunjukkan terdapat hubungan antara komposisi dan kepelbagaian spesies plankton tasik ladam terhadap musim kering dan musim basah serta kesan persekitarannya.

LIST OF ABBREVIATION

L	liter
ml	mililiter
g	gram
mg	miligram
m	meter
cm	centimeter
mm	milimeter
nm	nanometer
µm	micrometer
µg	microgram
%	percentage
&	and
>	more than
<	less than
DO	dissolved oxygen
BOD	biological oxygen demand
GF/C	glass fibre filter
s.e	standard error
sp.	species
°C	degree celcius
NO_3-N	nitrate
TP	total phosphorus

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CHAPTER 1

INTRODUCTION

Oxbow lakes are among the most productive aquatic systems in the world. They are known as 'billabongs' in Australia (Hart & McGregor, 1982), 'bayous' in United States of America (McFarlene, 1998) and 'lagunas' in Costa Rica, Mexico (Haberyan *et al.*, 2003). In Malaysia, they are known as 'Tasik Ladam' and in Sabah the terms used by the local people are 'danau', 'luagan' and 'sungai mati' (dead river).

The oxbow lake is created over time as erosions and deposits of soil change the river's course. The formation of oxbow lakes occurs when the river is in the flood stage. As flooding occurs, the floodwater will deposit sediment into the oxbow lakes. This allows for the erosion of the meander neck. The remaining loop that is left by this natural activity is called an oxbow lake.

The unique isolated nature of oxbow lake from its origin river creates a rich and dynamic biodiversity of aquatic organisms, especially plankton and fishes. The species in two neighbouring oxbow lakes, although only meters apart, can be very different. These lakes are important for replenishing populations of aquatic organisms species in the river and act as genetic banks, which help replenish the biology of the whole river system each time it is filled with floodwaters each time (Phillips, 1996).

Oxbow lakes have been rarely studied and so little information exists about their relationship to the river. Perhaps research has been limited on oxbow lakes because they are constantly changing and are destined for extinction or replacement

over time. In some years weather extremes, such as prolonged drought, hasten the end for an oxbow. They are very dynamic but have a limited life span. Eventually, sediment fills them in, and they disappear, though that may take centuries (Phillips, 1996).

Many of the floodplains of the larger rivers in Sabah are laden with oxbow lakes, which are among Malaysia's most treasured wetlands. These wetlands are very valuable aquatic breeding grounds, producing the richest freshwater fisheries where highly valued endemic fishes are found. Currently these oxbow lakes, some of which are renowned nature tourism destinations in Sabah, are declining due to numerous threats, such as sedimentation, urbanization and pollution from agricultural practices. These threatening factors challenge the effort to conduct more research on these unique oxbow lakes.

This study involves the inventory of physical, chemical and biological parameters of 10 valuable oxbow lakes, with the purpose of obtains baseline information for conservation and sustainable management the lakes. The following are the objectives of this study:

1. To inventory and document oxbow lakes in three areas in Sabah, viz. Sugut, Klias Peninsula and Kinabatangan.
2. To determine the physical and chemical parameter as well as plankton distribution and composition of the oxbow lakes in Sabah.
3. To compare the physical, chemical and biological parameters of four oxbow lakes in Sugut during dry and rainy seasons.
4. To document the depth profile of the physical (temperature), chemical (dissolved oxygen and pH) and biological (plankton density) parameters for oxbow lakes exceeding 5-meter depths.
5. To determine the land use effects on the oxbow lakes.

The plankton distribution and composition in this study includes the phytoplankton and zooplankton composition, primary productivity and algal biomass determination. The inventory of physical, chemical and biological data will reveal the characteristic and biodiversity richness of these oxbow lakes. The following hypotheses will be tested in this study:

a) The species diversity in the oxbow lakes is higher than their parent river's.
b) There is a significant difference in plankton distribution and composition of oxbow lakes during the dry and wet season in the Sugut oxbow lakes.
c) The physical, chemical and biological parameters studied in the deep oxbow lakes (those exceed 5 meters) vary with water depth.
d) The plankton distribution and composition of oxbow lakes are significantly affected by the surrounding land use.

CHAPTER 2

LITERATURE REVIEW

2.1 The formation of oxbow lakes

An oxbow lake is a crescent shaped lake lying alongside a winding river. The origin of oxbow lake is the natural lake that came from a river meander cut off (Dreyer *et al.*, 2003). As some rivers do not flow in a straight course, they meander forming an "S" shape, or half loops (Figure 2.1). As a meander neck forms (Figure 2.2), the loop becomes narrow, until an event called a cut-off takes place. A cut-off occurs when the river cuts through this loop through the narrow river meander surface. Finally, the openings to the loop are silted in, and the old meander is completely isolated from the new river course (Figure 2.3). The old meander is called an **oxbow,** because of its characteristic shape.

Oxbows can be wet or dry. When they are filled with water, they are called oxbow lakes. Over the time, these oxbow lakes become oxbow swamps or marshes. Eventually, the oxbow swamp loses its ability to hold water and completely fills with sediment. When this happens, it is referred to as a meander scar. Oxbow lakes and meander scars are important for the field of biology as they illustrate the evidence that rivers and streams do migrate, or change course (Dreyer *et al.*, 2003). The Geographic Information Systems (GIS) can be used to determine the location of oxbow lakes and meander scars. This will benefit in several ways as both features can help to determine past river channels. They can also be a source of fossils as organic material can become trapped in the oxbow lakes during periods of deposition (Dreyer *et al.*, 2003).

Oxbow lakes are very dynamic but have a limited life span as the outlet is deepened by erosion and the basin fills up with sediments. Over time, natural cycles of vegetation growth, death and decomposition, including riparian vegetation, sedimentation of dead plankton and macroinvertebrates, and siltation from soil surface erosion during floods, gradually fill the oxbow lakes. In nature, the oxbow lakes were filled in very slowly, with about 1mm of sediment being added each year (Shiel, 1994). The old, shallow oxbow lakes dry out periodically and these unstable environments favour small fishes. The young oxbow lakes are deeper and more frequently flooded by the river, therefore they contain a greater diversity and biomass of fishes. As most oxbow lakes reflect the morphology of the parent river, their depths are usually less than 5 meter, more often less than 2 meter (Phillips, 1996). Only the lakes in subsiding basins have existed for long periods of time, through the thickness and the composition of accumulated sediments. These lakes have more eventful and long biotic history, which has resulted in the evolution of many species, among them notable endemism (Margalef, 1994).

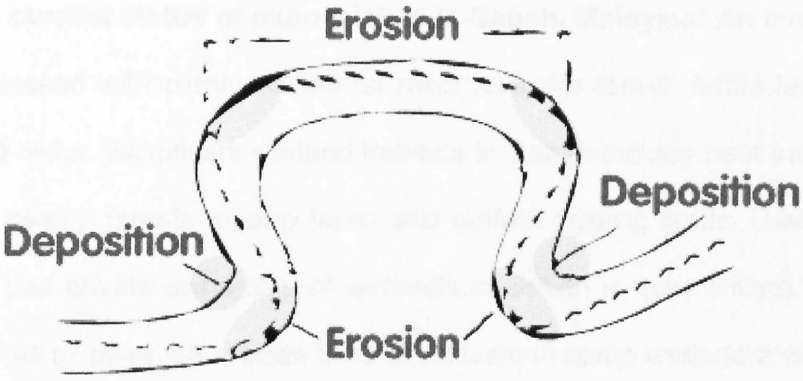

Figure 2.1: The river meander forming the 'S' shape. (Source: Dreyer *et al.*, 2003).

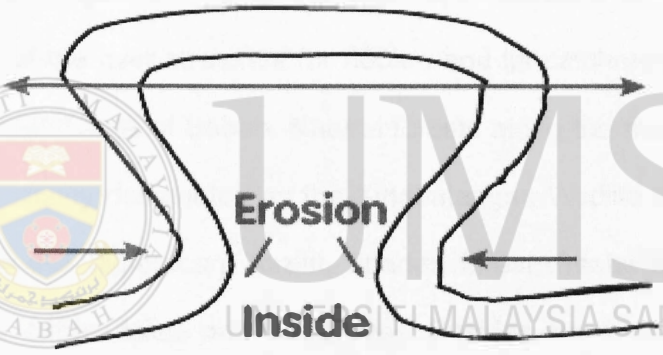

Figure 2.2: The river loop formed and the 'cut-off' occurs at the narrow river meander surface. (Source: Dreyer *et al.*, 2003).

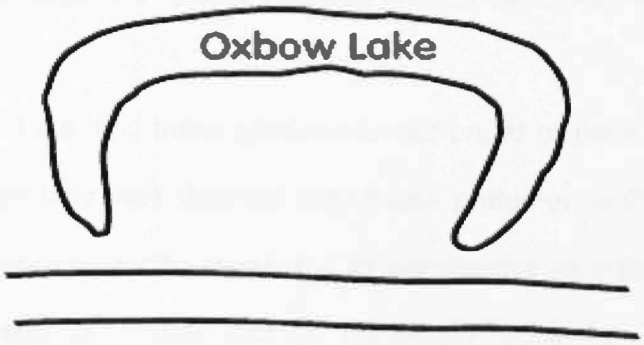

Figure 2.3: The old meander is completely isolated from the new river course and called an 'oxbow lake". (Source: Dreyer *et al.*, 2003).

2.2 The current status of oxbow lakes in Sabah, Malaysia: An overview

Sabah is blessed with plenty of natural resources like forest, fertile land, fisheries, wild life and water. Significant wetland habitats in Sabah include peat swamp forests, freshwater swamp forests, oxbow lakes and buffalo grazing lands. Davidson (2001) highlighted that private ownership of wetlands in Sabah is quite limited. The cultural crops, such as oil palm, have been tried to cultivate in some wetland areas, but it had not been fully investigated either the crop could withstand the hydrological constraints.

2.2.1 Kinabatangan Oxbow Lakes

The Lower Kinabatangan is among the important wetlands in Sabah, where its lowlands section of the river stretches for 560km and its catchment areas represent 23 percent of the land area of Sabah. Natural forests along the river bank includes a 27,000 ha strip recently designated as the Kinabatangan Wildlife Sanctuary and the river corridor includes dipterocarp forest, riparian forest, freshwater swamp forest, limestone forests, oxbow lakes and mangroves. Besides, the Kinabatangan River is also the source of water supply for villages and Sandakan town and also an important mode of transportation for the local settlements as well as the agriculture sector. However, much of the wetlands has been destroyed by unsustainable logging practices and land conversion for agricultural expansion, and contaminated by pesticides and discharge of industrial effluents (Sabah Structure Plan 2020, 2001).

The most of the land being privately owned under oil palm plantation and the run off from plantations was draining into these protected wetlands. Due to the characteristic of these protected areas and its significance as a tourist destination, it is important to monitor trends and to continually seek new opportunities for conservation work especially in collaboration with private landowners. Therefore, several bodies have tried to support government conservation initiatives. They

include the Partners for Wetlands project of WWF (World Wildlife Fund) Malaysia, the Kinabatangan Orang-Utan Conservation Project, and a joint memorandum of understanding on ecotourism research and development by Borneo Eco tours Sdn. Bhd., University Malaysia Sabah and WWF Malaysia (Davidson, 2001). In the same area, The Model Ecologically Sustainable Community Tourism Project (MESCOT) continues to develop community-based tourism in the upper region of the floodplains, with the river and oxbow lakes as key attractions.

2.2.2 Sugut Oxbow Lakes

Lower Sugut area refers to the lowland floodplain forest along the Sugut River in north-eastern Sabah. The area contains an array of forest types such as riverine, freshwater swamp forest, lowland dipterocarp forest and east coast peat swamp forest, many of which are disappearing fast in other parts of Sabah. Without concerted efforts to conserve biodiversity in these areas, many of these forest and wetland habitats are likely to be converted to plantations or become degraded by repeated logging. Other threats to conservation of biodiversity in the Lower Sugut area include forest fires, development of large scale oil palm plantations, timber extraction done not in accordance with a long-term forest management plan, unclear land policy and land alienation to non-residents, who have no interest in maintenance of forest and aquatic resources (Sabah Biodiversity Conservation Project, 1998b).

Apart from its botanical diversity, this region is also rich with wildlife. Oxbow lakes and steep sandstone ridges add to the natural beauty of this region. 'Orang Sungai' fishermen rely on the health of the freshwater swamps and waterways for fisheries resources (Sabah Structure Plan 2020, 2001). The freshwater fish fauna of Lower Sugut appears to be less rich than in Lower Kinabatangan in terms of species number, but fish are more abundant in Lower Sugut. It has been estimated that

fishing contributes 71% of the total value of household income in Sugut area (Sabah Biodiversity Conservation Project, 1998b).

2.2.3 Klias Peninsula Oxbow Lakes

Much of the Klias Peninsula is within the Padas River water catchment. Additional natural habitats are the rivers, streams and oxbow lakes. The wetland areas of the Klias Peninsula have potential for tourism and recreation development. In its natural state, the Klias wetlands provide valuable resources to local people and crucial habitat to native wildlife. Tourism seems to offer a sustainable alternative use of the wetlands while enabling it to continue to support local economic and subsistence needs and ecological/hydrological benefits. However, floods in Beaufort and the Klias Peninsula incur heavy damages to agriculture and public infrastructure. These floods will occur between 2 - 6 times a year but are more prevalent in years with heavy rainfall (Sabah Biodiversity Conservation Project, 1998a).

2.3 The review of oxbow lakes studies from the foreign countries

There is so little information exists about the oxbow lakes because they have rarely been studied (Phillips, 1996). The limited researches on oxbow lakes are probably because they are constantly changing and facing the extinction or replacement over time. However, there is some efforts to study and conserve these unique oxbow lakes ecosystem as been executed in several countries. In addition to document the oxbow lakes and identify the threats that they are exposed to, these studies also highlight the potentials of oxbow lakes and the importance to conserve its ecosystem.

2.3.1 Threats of oxbow lakes

The physical and chemical changes which occur in oxbow lakes formation provide conditions that are favourable for very rapid plant growth, particularly of phytoplankton, which frequently grows in an 'explosive' manner. Such explosive