

**RELATIONSHIPS BETWEEN GONAD MATURITY
AND SELECTED PHYSICO-CHEMICAL
CHARACTERISTICS OF WATER IN
FEMALE AIR-BREATHING FISHES
OF THE KLIAS BLACKWATER**

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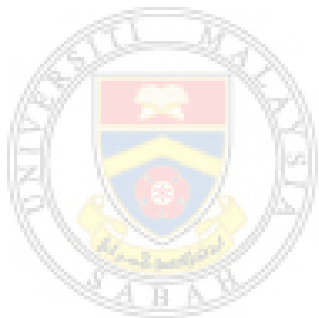
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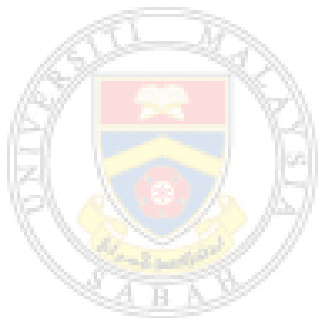
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ABSTRACT

Less is known about the reproduction of fish that inhabited the blackwater of the peat swamp forest. It was found that most of the fishes living in that area occupied with air-breathing organ to survive in acidic water with low oxygen levels. The main objective of this study was to determine the relationship between rainfall and physico-chemical characteristics of water (water depth, water temperature, pH, DO and conductivity) on the GSI of female air-breathing fishes in the blackwater of Klias Forest Reserve (Site 1) and Bukau Api-Api Forest Reserve (Site 2), in the Klias Peninsula of Sabah. The subsequent objective was to compare the composition, occurrence and similarity of fish fauna between blackwater (Site 1 and 2) and brownwater (Site 3) of the Klias Peninsula. The fishes were collected mainly with gill nets for one-year study period. Rainfall data was obtained from the nearest Meteorological Department and water physico-chemical characteristics were measured *in situ* every month. The frequency occurrence of gonad maturity stages and the GSI of the female air-breathing species were determined and the GSI were correlated with rainfall and water physico-chemical characteristics. Species composition, occurrence and similarity were compared between sites. There were 29 species, distributed in 17 genera and thirteen families recorded in blackwater and brownwater sites of the Klias Peninsula with Cyprinidae being the most dominant family with 9 species. Fish composition was found to be higher in blackwater compared to brownwater with 21 species and 17 species, respectively. There were eight species found exclusively in Site 1 compared with only seven species in Site 3, while only one species found exclusively in Site 2. Site 2 and Site 3 has the highest species similarity (0.6) whereas Site 1 and Site 3 has the lowest species similarity (0.3). The changes in water depth found to be closely associated with rainfall ($p < 0.05$). The frequency occurrence of female air-breathing fishes in mature stage showed that *Anabas testudineus* and *Channa lucius* has single and two reproductive peaks, respectively, while *Channa cf. melasoma* and *Clarias* sp. 1 have more than two reproductive peaks. When GSI correlated with rainfall, significant relationship only found for *Channa lucius* ($p < 0.05$). The correlation between water depth and GSI showed significant result for *Anabas testudineus* and *Channa lucius*. These results indicated that *Anabas testudineus* and *Channa lucius*

might have periodic reproduction while rest of the female air-breathing fishes reproduce all year round. Water temperature, pH and DO showed no significant effect towards the GSI of all of the female air-breathing fishes ($p > 0.05$) except conductivity that showed significant ($p < 0.05$) effect on the GSI of *Channa lucius*. Further study is suggested to enable a refinement about the effect of water physico-chemical characteristics on the reproduction of air-breathing fishes in the Klias Peninsula blackwater.



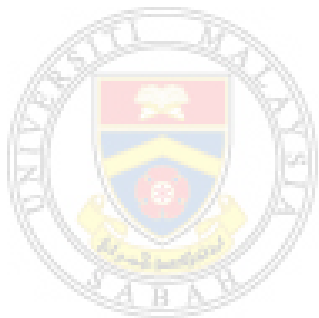
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ABSTRAK

Hubungan antara Kematangan Gonad dan Ciri-Ciri Fiziko-Kimia Air Terpilih pada Ikan Betina yang Bernafas di Udara dari Kawasan Air Hitam, Klias

Maklumat tentang pembiakan ikan yang mendiami kawasan air hitam pada hutan paya gambut adalah kurang. Didapati bahawa kebanyakan ikan yang ditemui di kawasan tersebut dilengkapi dengan organ pernafasan udara untuk hidup di air yang berasid dan rendah kandungan oksigen. Tujuan utama kajian ini dijalankan adalah untuk mengenalpasti hubungan antara faktor hujan dan ciri fiziko-kimia air (kedalaman air, suhu air, pH, DO dan konduktiviti) di kawasan air hitam Hutan Simpan Klias (Tapak 1) dan Hutan Simpan Bukau Api-Api (Tapak 2) di Semenanjung Klias, Sabah ke atas GSI ikan betina yang bernafas di udara. Objektif yang seterusnya ialah untuk mengenalpasti komposisi, kehadiran dan kesamaan fauna ikan di antara kawasan air hitam (Tapak 1 dan 2) dan air perang (Tapak 3) Semenanjung Klias. Ikan kebanyakannya ditangkap menggunakan pukot sepanjang tempoh setahun kajian dijalankan. Data hujan diperolehi dari Stesen Meteorologi yang terdekat manakala ciri fiziko-kimia air direkodkan di lapangan setiap bulan. Kekekapan kehadiran tingkat kematangan gonad dan GSI ikan betina yang bernafas di udara dikenalpasti dan GSI dikorelasikan dengan hujan dan ciri fiziko-kimia air. Komposisi, kehadiran dan kesamaan spesies antara tapak dibandingkan. Sebanyak 29 spesies tersebar dalam 17 genera dan 13 famili, dicatatkan di tapak kawasan air hitam dan air perang Semenanjung Klias. Cyprinidae merupakan famili paling dominan dengan 9 spesies. Komposisi ikan didapati lebih tinggi di tapak kawasan air hitam berbanding tapak kawasan air perang, masing-masing dengan 21 spesies dan 17 spesies. Lapan spesies ditemui secara eksklusif di Tapak 1 berbanding dengan hanya tujuh spesies ditemui di Tapak 3, manakala hanya satu spesies yang ditemui secara eksklusif di Tapak 2. Tapak 2 dan Tapak 3 mempunyai kesamaan spesies yang tertinggi (0.6) manakala Tapak 1 dan Tapak 3 mempunyai kesamaan spesies yang terendah (0.30). Perubahan paras air didapati berkait rapat dengan hujan ($p < 0.05$). Kekekapan kehadiran ikan betina yang bernafas di udara pada peringkat matang menunjukkan Anabas testudineus dan Channa lucius masing-masing mempunyai 1 dan 2 tempoh kemuncak pembiakan manakala

Channa cf. melasoma dan Clarias sp. 1 mempunyai lebih daripada dua kemuncak pembiakan. Apabila GSI dikaitkan dengan hujan, hubungan signifikan hanya didapati pada Channa lucius ($p < 0.05$). Korelasi antara kedalaman air dan GSI pula menunjukkan keputusan signifikan bagi Anabas testudineus dan Channa lucius. Keputusan ini menunjukkan bahawa Anabas testudineus dan Channa lucius mungkin mempunyai pembiakan berkala manakala ikan betina lain yang bernafas di udara mampu membiak sepanjang tahun. Ciri fiziko-kimia air iaitu suhu air, pH dan DO tidak mempunyai kesan signifikan ke atas GSI semua ikan betina yang bernafas di udara ($p > 0.05$), kecuali konduktiviti yang mempunyai kesan signifikan ($p < 0.05$) ke atas GSI Channa lucius. Kajian lanjut disarankan untuk membolehkan penjelasan terperinci tentang kesan ciri fiziko-kimia air ke atas pembiakan ikan yang bernafas di udara yang terdapat di kawasan air hitam Semenanjung Klias.



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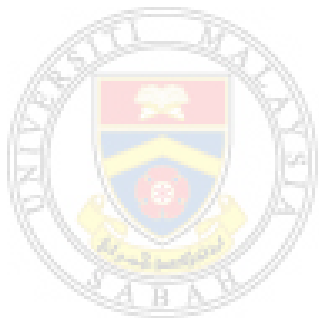
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LIST OF ABBREVIATIONS/SYMBOLS

%	percentage
°C	degree celsius
µS/cm	microsiemens per centimeter
a.m.	ante meridiem
ABO	air-breathing organ
cm	centimeter
DO	dissolved oxygen
FR	Forest Reserve
g	gram
GEF	Global Environment Facility
GSI	Gonadosomatic Index
ha	hectare
km	kilometer
m	meter
mg/L	miligram per liter
mm	millimeter
UD	unidentified
UNDP	United Nation Development Program
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency

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CHAPTER 1

INTRODUCTION

1.1 Background

Wetlands are wet ecosystems found throughout the world. It can be defined as land where water is the dominant determining factor for the nature of soil and the types of plants and animal communities living in this environment. Wetlands generally include a wide variety of habitats such as marshes, peatlands, floodplains, rivers, and lakes, and coastal areas such as saltmarshes, mangroves, and seagrass beds, but also coral reefs and other marine areas no deeper than six metres at low tide. It also includes human-made wetlands such as wastewater treatment ponds and reservoirs (Ramsar Convention Secretariat, 2013).

The Klias Peninsula is a wetland area situated in the district of Beaufort in the state of Sabah. It covers an area about 135,000 ha, encompassing an extensive network of river channels and diverse wetland habitats ranging from nipah, peat swamps, estuaries, and mangroves (Muhamad Saini, 1998). Presently, many part of the Klias Peninsula have been protected through the establishment of forest reserves (FR), which include Klias FR, Binsulok FR, Bukau Api-Api FR, Kampung Hindian FR, Nabahan FR, Padas-Damit FR, and Menumbok FR (Ong *et al.*, 1998).

The blackwater refers to the appearance of water body in the peat swamp forest that has dark brown to black colour, resembling tea or coffee. This colour is resulted from the contact of water with slowly decomposing organic litter and debris such as leaves and wood in various and at different stages of decomposition (Muhamad Barzani *et al.*, 2007), which gradually releases tannins, humic acid, and other organic acids that become the principal coloring matter of the blackwater. In terms of water chemistry, water draining out of the blackwater is generally acidic with low pH, inorganic ion and dissolved oxygen (DO) level (Khairul-Adha *et al.*, 2009). The acidity range of the blackwater is varies as reported by difference

and 3.0-4.5 (Silvius, 2005; Janzen, 1974). However, according to Johnson (1967), the ordinary Malayan blackwaters have pH less than 5.5.

The blackwater of the peat swamp forest has long been regarded as an inhospitable habitat for any organisms. This is because the humic acids in the blackwater are polyphenolic compounds which known to be toxic to wide variety of organisms. Thus, the organisms living in the blackwater are assumed to be low in diversity and limited to only those that are tolerant to the naturally acidic conditions. Most of the fishes living in a blackwater evolved to an adaptation known as "air-breathing". Johnson (1967) states that in Malayan blackwaters, nine of the 15 species of fish are air-breathers or surface swimmers. Aquatic hypoxia such as poor oxygen environment is believed to be the main selective pressure leading to the evolution of air-breathing in freshwater fishes. All freshwater air-breathing fishes are bimodal breathers where they possess gills but they can also rise to the surface to gulp air and some actually leaving the water (Moyle & Cech, 2004). These behaviors assisted by the presence of air-breathing organs that normally consist of a highly vascularised respiratory epithelium, which is specially developed for the absorption of oxygen from air (Hughes, 1963). The accessory air-breathing organs include skin, lungs and respiratory gas bladders, digestive tracts and structures derived from buccal, pharyngeal, and branchial cavities (Graham, 1997; Johansen, 1970).

Reproduction is a fundamental process that ensures the continuity and survival of a species. In fish population, the success of any fish species ultimately determined by the ability of its members to reproduce successfully in a fluctuating environment (Moyle & Cech, 2004). According to Rottmann *et al.* (1991), reproduction of fish is regulated by external environmental factors that trigger internal mechanisms into actions. In temperate areas, it was known that water temperature and photoperiod are the most important factors that regulate reproductive functions (Martinez-Palacios *et al.*, 2007; Shimizu, 2003; Lam, 1983). Whereas, in tropical and subtropical areas, the major causative factor that synchronizes reproduction is less clear but rain has been described as an important cue in regulating the reproductive function of fishes by triggering the spawning (Baran, 2006; Winemiller, 1993). The rainfall seasonality has produce cyclic

patterns in riverine discharge, which resulted in periods characterized by low and high water levels (Perga *et al.*, 2005) or hydrological variability. Changes in water levels affect both habitat quality and availability for aquatic organisms (Jenkins & Mailautoka, 2009), and thus influence population dynamics and species interactions (Reardon & Chapman, 2008). However, according to Baumgartner *et al.* (2008), each species may require a unique combination of abiotic factors to trigger spawning and determine its reproductive success.

In Malaysia, most of the studies on blackwater fish were focused on their taxonomy while research on the reproductive biology, ecology, and behavior of fish is still scarce. The unusual water properties of blackwater like low pH, limited DO, and low conductivity might be the prime indicators that differentiate it from other freshwater habitats and these parameters could have significant impact on the life of its inhabitants. These parameters may have significant role on the reproduction of peat swamp fishes like triggering spawning. Unfortunately, there was very limited information obtained regarding this matter. On the other hand, there were studies in other freshwater habitat in Malaysia that reported water level changes associated with rainfall seasonality affect the reproductive timing of fishes. As an example, study by Khaironizam & Zakaria-Ismail (2013) in Gombak River recorded that the spawning activity of cyprinid fish, *Neolissochilus soroides* was actively takes place during wet seasons. Study by Aizam *et al.* (1983) also reported the role of rainy period in triggering the onset of spawning in *Osteochilus melanopleura*.

Hence, this study was conducted in order to investigate whether changes in water level associated with rainfall do have effect on the gonad maturity of the air-breathing fishes in Klias blackwater. Besides, this study also aimed to know the relationship between other water quality parameters like water temperature, pH, DO and conductivity with the gonad maturity of the air-breathing fishes in Klias blackwater. The air-breathing fishes were chosen for this research as most of the fish species that recorded in previous study in Klias peat swamp have air-breathing capability and are economically important (Harnita, 2008). It should be noted that in this study, the assessment of gonad maturity focused only on the female air-breathing fishes in part because offspring production is limited to a greater degree by egg production than sperm production and partly because of the maternal origin

of the nourishment in the early life stage (Helfman *et al.*, 1997). Therefore, females serve as the estimators of reproductive potential in this research.

In this study, as the sample of air-breathing fishes for the assessment of relationship between gonad maturity and water physico-chemical characteristics collected directly from the natural habitat of Klias blackwater, hence it is felt that it is important to know other fishes that living in blackwater. Thus, the comparison of fish composition and occurrence between the blackwater and brownwater of Klias also become part of this study.

1.2 Significance of Study

The fishes that inhabited blackwater peat swamp usually have restricted distribution and sometimes different from those are living in other freshwater habitats. In Klias blackwater, most of the fish species demonstrates the ability to adapt in water with low DO levels and high acidic water. As found by Khairul-Adha *et al.* (2009), the catfish of the family of Clariidae can be found more in the blackwater than brownwater while more cyprinids occur in brownwater than blackwater and none eleotrids found in blackwater. Therefore, knowing the species that occur in blackwater and brownwater can fill the gap of knowledge of fish species that can be found in Klias Peninsula.

The studies on fish reproductive aspects are always related to the goal to increase fisheries production such as for stock assessment and conservation of commercial species. However, in this study, the gonad maturity aspect which is the Gonadosomatic Index (GSI) of the female air-breathing fishes in the Klias blackwater being studied as to relate it with the changes in water physico-chemical characteristics. This study is important, as it will provide baseline data and information on how the water physico-chemical characteristics of water depth, water temperature, pH, DO and conductivity can affect the reproduction of female air-breathing fishes in Klias blackwater. The finding will provide some information on the reproductive biology and reproductive strategy of air-breathing fishes as well such as the reproductive period and subsequently, improving the understanding on species reaction to the changes in the surrounding environment.

Furthermore, it should be noted that most of the air-breathing fishes inhabiting Klias blackwater have commercial values. For example, the climbing perch, *Anabas testudineus*, is highly valued food fish due to its high nutrition and taste (Alam *et al.*, 2006). It has high commercial demand in certain parts of India including North Eastern states and it became a traditional food source and protein provider in Asian countries (Jalilah *et al.*, 2011). Besides, *Anabas testudineus* is also believed to have medicinal properties such as disease prevention (Hussain, 2005). In Klias Peninsula, *Anabas testudineus* is one of the important fish foods for local communities, and it is acknowledged that fisheries are an important source of income to the Klias Peninsula communities (Muhamad Saini, 1998). Therefore, in circumstances, the data from this study is also essential for determining the vulnerability of species to pressures such as fishing and could be useful for managing specific species for conservation.

1.3 Objectives of Study

The study was conducted with the following objectives:

- a) To determine the relationship between rainfall and the GSI of the selected female air-breathing fishes in Klias blackwater
- b) To determine the relationship between water physico-chemical characteristics (water depth, water temperature, pH, DO and conductivity) and the GSI of the selected female air-breathing fishes in Klias blackwater
- c) To compare the composition, occurrence and similarity of fish fauna between Klias blackwater and brownwater