EVALUATING LAKE ECOSYSTEM HEALTH USING FISH AS A BIOINDICATOR AND ITS RELATION TO WATER QUALITY AT SUBANG LAKE, SELANGOR, MALAYSIA

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Subang Lake, Selangor is an endorheic lake that is surrounded by a forest area, however, rapid urbanization is being developed around Subang Lake. Biomonitoring act as an important technique to monitor the changes in the environment. The objectives of this study are to determine ecological and fisheries indices of Subang Lake, water physicochemical parameters of Subang Lake, and the relationship between fish assemblages and water physicochemical parameters of Subang Lake. In this study, seven sampling points have been selected in Subang Lake which is easily accessible and recommended by the staff from Pengurusan Air Selangor Sdn. Bhd. Five gill nets with different mesh sizes and two fish traps were set at each sampling point in the morning at 0800h and were checked every four hours until 1800h. The nets were set overnight on four consecutive days and the results of the captured freshwater fishes were recorded. The fish sampling was conducted within the month of July 2018, August 2018, June 2019, August 2019, and October 2019. The water physicochemical parameters were determined using the standard methods for the examination of water and wastewater. In-situ water parameters such as dissolved oxygen, pH, temperature, turbidity, and electrical conductivity were measured at Subang Lake. While the ex-situ water parameters such as ammoniacal nitrogen (NH_3N), nitrate (NO_3N), nitrite (NO_2N), phosphate (PO_4), biochemical oxygen demand (BOD_5), and chemical oxygen demand (COD) were measured by conducting a laboratory analysis. Water sampling was conducted within the month of June 2019, August 2019, and October 2019. A total of 1266 individuals of fish which belong to 9 families and 19 species were recorded in Subang Lake. There were five alien species that were recorded in this study. A higher number of species and individuals of fish were found in October 2019. However, there is nosignificant difference in the number of fish individuals and fish species in both spatial and temporal variation. Meanwhile, the length-weight relationship of *Cyclocheilichthys apogon* (b=2.884) and *Notopterus notopterus* (b=2.886) indicates that these fish species are negative allometric growth. However, the condition factor of *Cyclocheilichthys apogon* (Kn=1.184) and

Notopterus notopterus (Kn=1.010) indicate good general condition. Apart from that, the water quality of Subang Lake falls into category A where the water quality is suitable for conventional use but requires water treatment. The water quality is suitable for sensitive aquatic species. In this study, there is significant relationship between fish assemblages and water physicochemical parameters. The continuous measurement between the fish assemblages and water physicochemical parameters acts as an important factor in biomonitoring of Subang Lake. In conclusion, the ecosystem health of Subang Lake is currently varied, i.e., from moderate to good condition. However, improvement of the management and conservation of the aquatic and terrestrial ecosystem surrounded the need to be concerned about Subang Lake, so that the ecosystem health of Subang Lake can be protected and maintain.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Sarjana Sains

MENILAI KESIHATAN EKOSISTEM TASIK MENGGUNAKAN IKAN SEBAGAI PENUNJUK BIOLOGI DAN KAITANNYA DENGAN KUALITI AIR DI TASIK SUBANG, SELANGOR, MALAYSIA

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Tasik Subang, Selangor merupakan tasik endorheik yang dikelilingi oleh kawasan hutan, namun, pembandaran pesat tengah dibangunkan di persekitaran Tasik Subang. Pemantauan biologi merupakan teknik yang penting untuk memantau perubahan dalam persekitaran. Objektif kajian ini adalah untuk menentukan indeks ekologi dan perikanan di Tasik Subang, parameter fizikokimia air di Tasik Subang, dan hubungan antara parameter fizikokimia air dengan perhimpunan ikan di Tasik Subang, Selangor. Dalam kajian ini, terdapat tujuh titik persampelan telah dipilih di Tasik Subang yang mudah diakses dan dicadangkan oleh kakitangan Pengurusan Air Selangor Sdn. Bhd. Lima pukat dengan siaz jaring yang berbeza dan dua bubu telah dipasang pada setiap titik persampelan pada waktu pagi, jam 0800j dan diperiksa setiap empat jam hingga jam 1800j. Pukat dipasang semalaman selama empat hari berturut-turut dan hasil tangkapan ikan air tawar telah direkodkan. Pensampelan ikan dijalankan pada bulan Julai 2018, Ogos 2018, Jun 2019, Ogos 2019, dan Oktober 2019. Kaedah piawai pemeriksaan air dan air sisa digunakan untuk analisis parameter fizikokimia air. Analisis parameter air *in-situ* seperti oksigen terlarut, pH, suhu, kekeruhan, dan kekonduksian elektrik dijalankan di Tasik Subang. Selain itu, analisis parameter air *ex-situ* seperti nitrogen ammonia (NH_3N), nitrat (NO_3N), nitrit (NO_2N), fosfat (PO_4), permintaan oksigen biokimia (BOD_5), dan permintaan oksigen kimia (COD) telah dijalankan di makmal. Persampelan air dijalankan pada bulan Jun 2019, Ogos 2019, dan Oktober 2019. Sebanyak 1266 individu ikan yang tergolong dalam 9 keluarga dan 19 spesies direkodkan di Tasik Subang. Terdapat lima spesies asing telah direkodkan dalam kajian ini. Bilangan spesies dan individu ikan yang tertinggi direkodkan pada Oktober 2019. Walau bagaimanapun, tidak ada perbezaan yang signifikan terhadap jumlah individu ikan dan spesies ikan dalam variasi lokasi dan cuaca. Sementara itu, hubungan panjang-berat *Cyclocheilichthys apogon* (b = 2.884) dan *Notopterus notopterus* (b = 2.886) menunjukkan bahawa spesies ikan ini adalah pertumbuhan alometrik negatif. Walau bagaimanapun, faktor keadaan relatif *Cyclocheilichthys apogon* (Kn = 1.184) dan *Notopterus notopterus* (Kn = 1.010) menunjukkan

kesihatan ikan dalam keadaan yang baik. Selain itu, kualiti air mengelaskan Tasik Subang dalam kategori A yang mana kualiti air sesuai untuk penggunaan konvensional tetapi memerlukan rawatan air dan kualiti air sesuai untuk spesies akuatik yang sensitif. Dalam kajian ini, hubungan antara ikan dan parameter fizikokimia air adalah ketara. Pengukuran berterusan antara ikan dan parameter fizikokimia air bertindak sebagai faktor penting dalam permantauan segi biologi di Tasik Subang. Kesimpulannya, kesihatan ekosistem Tasik Subang kini menunjukkan keadaan kesihatan antara sederhana dan baik. Walau bagaimanapun, penambahbaikan pengurusan dan pemuliharaan ekosistem perairan dan persekitaran perlu dipantau supaya kesihatan Tasik Subang dapat dipulihara dan dipelihara.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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This is to confirm that:

- the research and the writing of this thesis were done under our supervision;
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LIST OF ABBREVIATIONS

<	Less than
>	Greater than
≤	Less or equal to
°C	Degree Celsius
APHA	American Health Public Association
ANOVA	Analysis of variance
BOD	Biochemical oxygen demand
CCA	Canonical communication analysis
chl-a	Chlorophyll *a*
COD	Chemical oxygen demand
CPUE	Catch per unit effort
D	Margalef diversity index
Ds	Simpson's dominance Index
DO	Dissolved oxygen
DOE	Department of Ecosystem
DOF	Department of Fisheries
GDP	Gross domestic product
H'	Shannon-wiener index
HCO_3^-	Bicarbonate
I.I	Ichthyological index
IBI	Index of Biotic Integrity
K	Condition factor
Kn	Relative condition factor

LUAS	Lembaga Urusan Air Selangor
LWR	Length-weight relationship
mg/L	Milligrams per liter
MLD	Millions of liters per day
NH_3N	Ammoniacal nitrogen
NO_2-N	Nitrite nitrogen
NO_3-N	Nitrate nitrogen
NLWQS	National Lake Water Quality Criteria and Standard
NWQS	National Water Quality Standards
ODL	Ordinary Datum Level
PCBs	Polychlorinated biphenyls
PO_4	Phosphate
PPCPs	Pharmaceuticals and Personal Care Products
TDS	Total dissolved solids
TP	Total phosphorus
TSI	Trophic state index
TSS	Total suspended solid
USEPA	United States Environmental Protection Agency
µS/cm	Microsiemens per centimeter
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Study background

Ecosystem health is defined according to different conceptual characteristics such as the presence of a disease in the system, diversity or complexity in the system, stability of the system, growth condition, and the balance between system components. Different approaches are used to assess the ecosystem's health, which is identifying characteristics of the ecosystem and ecosystem services. The characteristics of the ecosystem are categorized as eutrophication occurrence, biological diversity, and particular biotic score, whereas the ecosystem services are nutrient cycling and biodiversity maintenance. In addition, the functioning of the food web and different trophic levels that sustain an ecosystem are also able to reveal the ecosystem's health (O' Brien *et al.*, 2016). As such, in order to maintain the ecosystem's health, appropriate monitoring and management techniques are required.

There are several biomonitoring approaches which according to the indicator of taxa or guilds, indices of species diversity and richness, multivariate methods, and index of biotic integrity (IBI) determine the ecosystem health (O'Brien *et al.*, 2016). All the approaches are determined by the bioindicator such as plants, fish, birds, and benthic organisms that have been widely introduced by researchers (Parmar *et al.*, 2016). The fish community is a common bioindicator that is used to determine the condition of the watershed because they have (1) extensive life history information for most species, (2) they consist of different trophic levels, (3) they are easily identified, and (4) they are living in a broad-scale of habitat (Stojković *et al.*, 2011). According to Chong *et al.* (2010), from a total of 1,951 fish species in Malaysia, 470 species are freshwater species, and 70 species are found in lakes and ponds. However, freshwater habitat has the most threatened fish species, i.e., about 87% of all habitats is subjected to environmental changes, habitat modification, and anthropogenic activities. Any disappearance of fish species, especially sensitive fish species or those that play keystone roles in a particular ecosystem is irreversible. The loss of these species can lead to population declines of other species that have a strong connection to such species and to a breakdown in ecosystem services that depend on those connections. According to Wilkinson *et al.* (2018), land use for oil palm plantations and agricultural activities significantly impacts fish species; they have also recorded a significant reduction of fish species and functional fish species richness in all disturbed land uses.

Besides the land use problem, introduction of alien species is also known as one of the factors affecting the fish community structure. The introduction of alien fish species in Malaysia for various purposes which are aquaculture activities, fishing purpose, ornamental purpose, and biological control. However, alien fish species possess significant impacts on native fish species and the fish community structure. For instance, *Cyprinus carpio* is a robust invasive species because it can be stocked in extremely high density (Dwivedi & Nautiyal, 2013; Khan *et al.*, 2016). Hence, the introduction of

Cyprinus carpio stresses on the native species, and the high density of *Cyprinus carpio* caused the imbalance of fish community structure.

Environmental degradation not only affects on the fish composition and abundance, it is also affecting the growth condition of fish. The length-weight relationship (LWR) and condition factor (CF) of fish have been widely used to determine the growth pattern and condition of fish and provide an insight into the fish species condition in the ecology, which is essential in fisheries and fish biology (Radhi *et al.*, 2018). The CF and the LWR of fish are affected by environmental degradation and insufficient nutrients in the ecosystem (Getso *et al.*, 2017). According to Dodds and Whiles (2010), fish with high mass per unit length is considered excellent and healthy. The LWR and CF of fish help conserve and management of fish in the aquatic ecosystem (Radhi *et al.*, 2018).

According to Rocha *et al.* (2015), the physical and chemical parameters analysis for water quality monitoring has been conducted in Malaysian inland water bodies. Monitoring water quality is vital for future management because the current, ongoing, and emerging problems can be detected earlier, and the beneficial uses of water can be protected. Furthermore, changes in physicochemical water parameters such as temperature, total dissolved oxygen, and turbidity can affect fishes' growth, survival, and reproduction of fishes (Dodds & Whiles, 2010). Physicochemical water parameters such as pH, temperature, turbidity, biochemical oxygen demand (BOD), dissolved oxygen (DO), total phosphorus, total ammonia, nitrate, magnesium, sodium, potassium, bicarbonate, and phosphate are commonly used to determine water quality characteristics (Xiao *et al.*, 2016). The results of water characteristics were compared with the National Water Quality Standard (NWQS) and National Lake Water Quality Criteria and Standard (NLWQS) to determine the suitability of water resources for different usage such as agriculture, industrial and domestic usage (Naubi *et al.*, 2016). In Malaysia, the major pollutants in lakes and rivers are BOD, ammoniacal-nitrogen (NH_3N), and suspended solid (Huang *et al.*, 2015).

Subang Lake in Selangor, Malaysia is an endorheic lake with no surrounded inlet stream, and there is no outflow to the sea. Precipitation, surface runoff from the watershed, and groundwater seepage are the significant input for Subang Lake, and the water in this lake leaves as evaporation, groundwater seepage, and intermittent stream. Being an endorheic lake, Subang Lake is considered a unique ecosystem to study, primarily concerning the health of the fish and its surrounding habitats. The trophic state of Subang Lake is currently mesotrophic-eutrophic (Sharip *et al.*, 2016). Therefore, it is crucial to determine the condition of Subang Lake's ecosystem based on fish assemblages and the water quality, whether Subang Lake is under intense pressure from human activities or otherwise. Fish is a vital bioindicator that can determine the changes in Subang Lake's environment, which can further demonstrate the lake's water quality.

1.2 Problem statement

The sensitivity of an endorheic lake to the input of environmental pollutants is more significant than the open lakes system. The lake's processes from the surrounding watershed are inseparable and a slight change in the surrounding of Subang Lake possesses possible impacts on the water quality and the fish species distribution and assemblages at Subang Lake. Several interactions exist between the terrestrial and lake ecosystems such as food resources, energy resources, and riparian habitat. These interactions might cause effects to the lake's ecosystem when the terrestrial ecosystem is changing. According to Wilkinson *et al.* (2018), land use for different purposes has caused habitat disturbance and other effects on the ecosystem. In their study, they have recorded a substantial effect on species richness due to sedimentation that is caused by land uses.

The environmental degradation assessment and ecosystem health can be determined by utilizing fish as a bioindicator. However, a low number of research and studies that utilize fish as a bioindicator regarding fish assemblages, distribution, and conditions have been conducted in Subang Lake. The study of the lakes' health status using ecological and fisheries indices such as the index of biotic integrity (IBI) of fish is deficient in Malaysia. Besides, the application of biomonitoring has been widely introduced globally, and the biomonitoring technique in Malaysian aquatic ecosystems has mainly focused on bioaccumulation (Prabhakaran *et al.*, 2017). In contrast, other biomonitoring techniques in the Malaysian aquatic ecosystems are limited (Prabhakaran *et al.*, 2017). Hence, the development of biomonitoring practice is essential to protect and manage the current condition and ongoing ecosystem changes. Biomonitoring practices also can be applied to different studies in the future.

Subang Lake's trophic status changes from oligotrophic to mesotrophic-eutrophic indicate an increase of nutrients in Subang Lake. The increase in nutrients' levels may occur due to several factors. According to Chen *et al.* (2013), a higher nutrient release from the sediments will increase the water temperature. Further increase in nutrient levels in Subang Lake will cause eutrophication and affect the ecosystem simultaneously. Thus, the water quality needs to be identified for future monitoring of the water quality of Subang Lake.

The management and monitoring of water quality of Subang Lake are essential to reveal current, ongoing, and emerging problems of a lake so that problems that are detected can be solved immediately, and the benefit of the users can be protected while the monitoring of water quality is conducted. However, water quality monitoring using water chemistry analysis cannot ultimately reveal the actual toxicity of pollutants that affects the organisms and the combined effects on an ecosystem (Prabhakaran *et al.*, 2017). Hence, biomonitoring and assessment utilizing bioindicators concurrently with water quality analysis can provide a clearer insight into the ecosystem's health.

Furthermore, the release of alien species in Subang Lake causes several impacts on the ecosystem, such as changes in structure and assemblages of native fish groups and ecological damage. For instance, the common carp, *Cyprinus carpio* can cause water quality deterioration, disruption of the ecosystem, and shift biological assemblage structure. High fecundity, long lifespan, lack of predators, and adaptation capability under extreme habitats have caused the *Cyprinus carpio* to live longer than native species (Fischer *et al.*, 2013). As a result, the adaptation capability of the *Cyprinus carpio* may cause its domination in an aquatic ecosystem. The *Cyprinus carpio* can resuspend the sediments and associate nutrients in the water column (Fischer *et al.*, 2013). Besides that, Zakaria (2017) has reported that the native fish species are spotted to have a trend of reduction at Timah Tasoh Dam, Perlis, due to a tremendous increase of peacock bass, *Cichla ocellaris*, which is a ruthless predator of native species and have caused native species to land in Timah Tasoh Dam to reduce by 20 to 30% (Zakaria, 2017). Consequentially, alien species have significant effects on the environment as well as on other fish species. Therefore, monitoring the distribution of fish species and assemblages can determine the dominant fish species and further reveal the current ecosystem health.

1.3 Research questions

1. What is the current condition of the fish community well-being in Subang Lake, Selangor?
2. What is the current condition of the water physicochemical parameters in Subang Lake, Selangor?
3. What are the relationships between the water physicochemical parameters and fish assemblages in Subang Lake, Selangor?

1.4 Research Objectives

This study aims to achieve the following objectives:

1. To determine the ecological and fisheries indices of fishes in Subang Lake, Selangor.
2. To determine the water physicochemical parameters of Subang Lake, Selangor.
3. To determine the association of fish assemblages and water physicochemical parameters in Subang Lake, Selangor.

1.5 Research hypothesis

1. Ho: There is no significant difference in ecological and fisheries indices of fishes between spatial and temporal variation in Subang Lake, Selangor.
   Ha: There is a significant difference in ecological and fisheries indices of fishes between spatial and temporal variation in Subang Lake, Selangor.
2. Ho: There is no significant difference in water physicochemical parameters between spatial and temporal variation in Subang Lake, Selangor.
   Ha: There is a significant difference in water physicochemical parameters between spatial and temporal variation in Subang Lake, Selangor.
3. Ho: There is no significant relationship between fish assemblages and water physicochemical parameters in Subang Lake, Selangor.
   Ha: There is a significant relationship between fish assemblages and water physicochemical parameters in Subang Lake, Selangor.

1.6 Significance of the study

Subang Lake provides water supply to the industrial area and this study is essential because it identifies the current ecosystem health and water quality status of Subang Lake. According to Kuklina *et al.*, (2013), contaminated water is a source of disease in humans and other organisms. Hence, water quality management must have effective control and minimization of the harmful impacts on the aquatic environment. By undergoing this study, the application of biomonitoring uses fish as a bioindicator to indicate and monitor the environment degradation and condition. This study will increase the awareness of related agencies such as Lembaga Urusan Air Selangor (LUAS) and Pengurusan Air Selangor Sdn. Bhd. The relevant information provides the ecological and fisheries indices with water quality that can be used as a reference for related agencies such as Pengurusan Air Selangor Sdn. Bhd. and LUAS, who can constitute regulation for any developers before any projects are being conducted in the Subang Lake's surrounding, and to play their roles in preventing further degradation of the ecosystem. Furthermore, the biomonitoring's continuous effort utilizing bioindicators can conserve the environment and the water quality from degradation. Subang Lake is an endorheic lake that is sensitive to climate changes and responds rapidly to environmental changes. The application of biomonitoring via ecological and fisheries indices can provide a significant database for managing water quality in Subang Lake. The biomonitoring of Subang Lake via IBI can be widely executed in the freshwater ecosystem for monitoring and conservation of environmental changes.

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