UNIVERSITI PUTRA MALAYSIA

ANTHROPOGENIC ACTIVITIES IMPACT ON WATER QUALITY, FISH COMMUNITY AND BACTERIA PRESENCE IN DISTURBED AND UNDISTURBED NORTH SELANGOR PEAT SWAMP FOREST, MALAYSIA

SULE HUSSEIN ALIU

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By

SULE HUSSEIN ALIU

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in fulfilment of the requirement for the degree of Master of Science

December 2016

To my loving parents, for their immense support
To my beloved wife Rabiat Aliu, for her love, patience and wholehearted support
&
To my beautiful daughters Aqeelah Aliu & Hafeezah Aliu, for making everything worthwhile

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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December 2016

Chairman: Ahmad Ismail, PhD
Faculty: Science

This study is concerned with the impact of anthropogenic activities on the water quality, the fish community and the bacteria presence in disturbed and undisturbed north Selangor peat swamp forest (NSPSF). Field sampling and analyses were conducted during the months of June and October 2015, and January 2016. Environmental conditions, and water physicochemical data were measured in peat swamp, paddy field and oil palm plantation. Fish was collected and bacterial isolation and identification from fish, water and sediment using standard microbiological techniques. Statistical analyses employed include ANOVA and Turkey LSD, Kruskal-Wallis and Mann-Whitney tests, Principal Component Analysis (PCA) and Canonical Correspondence Analysis (CCA). In addition, fish community structure was calculated using Shannon-Weaver diversity, Pielou's evenness and Margalef's richness indexes.

Peat swamp recorded a significantly ($p < 0.05$) higher phosphate (1.937 ± 0.196 mg L^{-1}), sulphate (28.917 ± 20.398 mg L^{-1}) and chlorine (0.915 ± 0.361 mg L^{-1}), while low for pH (3.684 ± 0.251), dissolved oxygen (0.590 ± 0.169 mg L^{-1}) and ammonia-nitrogen (0.346 ± 0.081 mg L^{-1}) when compared to paddy field and oil palm plantation areas. However, there was no significant ($p > 0.05$) difference observed for water electrical conductivity, total dissolved solids, salinity and nitrite for at least two of the sampling habitats, and for all of the sampling habitats for water temperature. The phosphate and chlorine levels of all sites, the pH of peat swamp (3.684 ± 0.251) and paddy field (4.962 ± 0.462), and the dissolved oxygen level in peat swamps were above the standard level for support of aquatic life and fall into class V of the National Water Quality Standard (NWQS) of Malaysia.

Paddy field recorded a significantly ($p < 0.05$) lower score of accessibility (1.50 ± 0.548) and deforestation level (1.00 ± 0.000), while oil palm recorded the lowest score of pollution level (2.00 ± 0.000). There was no significant ($p > 0.05$) difference on level of human development, water depth and pollution in at least two of the sampling habitats, and for all of the sampling habitats in term of the distance from human settlement. With the exception of water depth, all of the measured environmental conditions showed their importance in determining the water quality of the NSPSF.

Statistical analyses revealed that pollution level is the most important environmental factor determining water quality in the NSPSF.

A total of 1382 individual fish belonging to 20 species were collected during this study. Of this, only 15 species were collected from peat swamp, compared to 19 and 20 species from paddy field and oil palm plantation respectively. In the same vein, peat swamp recorded the lowest species diversity (2.4243) and richness (2.4768), compared to paddy field and oil palm plantation. Family Cyprinidae has the highest number of representative species. A notable concern however is the absence of several endangered species such as *Betta livida* and *Parosphromenus harveyi*, which were previously recorded from the NSPSF, highlighting the need for a reassessment of their conservation status. Multivariate statistics reveal that the water physicochemical parameters such as water temperature, conductivity, ammonia, sulphate, chlorine and dissolved oxygen influence fish community.

A total of 3,421 isolates from 39 species of bacteria were obtained during this study. The most dominant bacterial species were *Escherichia coli*, *Salmonella* spp., and *Streptococcus agalactiae*. Paddy field and oil palm plantation had the highest number of isolates and species, due to higher anthropogenic inputs in these areas. Among the species isolated were several pathogens such as *Aeromonas hydrophila*, *Edwardsiella tarda*, *Staphylococcus* spp., and *S. agalactiae*. Water physicochemical parameters such as water temperature, conductivity, ammonia, sulphate, chlorine and dissolved oxygen were important in influencing bacterial composition.

This study identifies peat land conversion to agriculture, anthropogenic inputs such as domestic and industrial effluents discharge as the greatest threats to the resident biological communities in the NSPSF. Among others, the importance of inclusion of water quality improvement strategies in peatland conservation was highlighted.

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

PERKAITAN ANTARA AKTIVITI ANTROPOGENIK, KUALITI AIR, STRUKTUR KOMUNITI IKAN DAN KEHADIRAN BAKTERIA DI HUTAN PAYA GAMBUT UTARA SELANGOR.

Oleh

SULE HUSSEIN ALIU

Disember 2016

Pengerusi: Ahmad Ismail, PhD
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Kajian ini menitik beratkan perkaitan antara aktiviti antropogenik, kualiti air, dan struktur komuniti ikan serta kehadiran bakteria di kawasan hutan paya gambut Selangor utara (NSPSF). Persampelan di lapangan dan analisis telah dilaksanakan pada bulan Jun dan Oktober 2015, serta Januari 2016. Keadaan persekitaran dan dan fizikokimia air telah diukur di dalam kawasan paya gambut, sawah padi, dan ladang kelapa sawit. Pelbagai spesies ikan dikutip serta pengasingan dan pengenalpastian bakteria daripada ikan, air, dan juga sedimen mengggunakan teknik mikrobiologi piawai.Analisis statistik juga telah dijalankan menggunakan ANOVA dan Turkey LSD, Kruskal-Wallis dan ujian Mann-Whitney, Analisis Komponen Utama (PCA) dan Analisis Menyurat Canonical (CCA). Tambahan pula, struktur komuniti ikan telah dikira menggunakan kepelbagaian Shannon-Weaver, kesamarataan Pielou dan indeks kekayaan Margalef.

Paya gambut merekodkan jumlah fosfat yang signifikan (1.937 ± 0.196 mg L^{-1}), sulfat (28.917 ± 20.398 mg L^{-1}) dan klorin (0.915 ± 0.361 mg L^{-1}), manakala bagi nilai pH yang paling rendah (3.684 ± 0.251), oksigen terlarut (0.590 ± 0.169 mg L^{-1}) dan amonia-nitrogen (0.346 ± 0.081 mg L^{-1}) apabila dibandingkan dengan sawah padi dan juga ladang kelapa sawit. Walau bagaimanapun, tiada perbezaan yang signifikan diperhatikan bagi konduktiviti elektrik dalam air, jumlah pepejal terlarut, saliniti, nitrit bagi sekurang-kurangnya dua habitat persampelan, serta bagi semua kawasan persampelan untuk suhu air. Tahap klorin dan fosfat pada setiap kawasan, pH bagi kawasan paya gambut (3.684 ± 0.251) serta sawah padi (4.962 ± 0.462) dan juga tahap oksigen terlarut di dalam paya gambut adalah melebihi tahap piawai untuk menampung hidupan akuatik dan jatuh kedalam kelas V bagi Pawaian Kualiti Air Nasional (NWQS) Malaysia.

Sawah padi merekodkan jumlah signifikan skor yang lebih rendah bagi kebolehcapaian (1.50 ± 0.548) dan tahap pembasmian hutan (1.00 ± 0.000), manakala ladang kelapa sawit mencatatkan skor paling rendah bagi tahap pencemaran (2.00 ± 0.000). Terdapat tiada perbezaan yang signifikan bagi tahap pembangunan manusia, kedalaman air, serta pencemaran sekurang-kurangnya pada dua kawasan habitat persampelan, serta bagi semua habitat persampelan dalam erti kata lebih jauh daripada kawasan kediaman manusia. Dengan keberkecualian bagi kedalaman air, kesemua keadaan yang telah

diukur menunjukkan kepentingan dalam mengenalpasti tahap kualiti air bagi NSPSF. Analisis statistik memaparkan tahap pencemaran adalah faktor alam sekitar yang terpenting untuk mengenalpasti kualiti air didalam NSPSF.

Sejumlah 1382 individu ikan tergolong kepada 20 spesies telah dikutip sepanjang kajian ini. Hanya 15 spesies dikutip di kawasan paya gambut, berbanding dengan 19 dan 20 spesies daripada kawasan sawah padi serta ladang kelapa sawit. Pada masa yang sama, kawasan paya gambut, merekodkan jumlah kepelbagaian spesies paling rendah (2.4243) dan kekayaan (2.4768), berbanding sawah padi dan ladang kelapa sawit. Keluarga Cyprinidae mempunyai nombor tertinggi dalam perwakilan spesies. Pemerhatian perlu diambil bagi beberapa spesies yang menghadapi kepupusan sebelum daripada catatan NSPSF. Sebagai contoh, spesies *Betta livida* dan *Parosphromenus harveyi* telah disenarai sebagai menghadapi kepupusan oleh Senarai Merah Spesies Terancam IUCN tidak terdapat didalam kajian ini dan perlu dinilai semula status konservasinya. Statistik pelbagai menunjukkan parameter fizikokimia air seperti suhu air, konduktiviti, amonia, sulfat, klorin serta keterlarutan oksigen mempengaruhi kehadiran ikan.

Sejumlah 3421 pengasingan daripada 39 spesies bakteria diasingkan daripada kajian ini. Spesies paling dominan ialah *Escherichia coli*, *Salmonella* spp., dan *Streptococcus agalactiae*. Sawah padi dan ladang kelapa sawit mencatatkan pengasingan dan juga jumlah spesies tertinggi, berikutan terdapat input antropogenik yang tinggi dikawasan ini. Terdapat beberapa spesies patogen antaranya ialah *Aeromonas hydrophila*, *Edwarsiella tarda*, *Staphylococcus* spp., dan *Streptococcus agalactiae*. Parameter fizikokimia air seperti suhu air, konduktiviti, amonia, sulfat, klorin dan oksigen terlarut adalah penting dalam mempengaruhi komposisi bakteria.

Kajian ini mengenalpasti kawasan paya bertukar kepada pertanian, input antropogenik seperti baja, domestik serta pembuangan kumbahan industri sebagai ancaman terbesar kepada komuniti biologi didalam NSPSF. Selain itu, kajian ini juga mengangkat kepentingan penglibatan strategi pembaikpulih kualiti air dalam memelihara paya gambut.

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To my friends and colleagues at University Putra Malaysia, thank you for your support and time. Finally, I thank my colleagues in Kogi State College of Education who have assisted me in one way or the other.

I certify that a Thesis Examination Committee has met on 19 December 2016 to conduct the final examination of Sule Hussein Aliu on his thesis entitled "Anthropogenic Activities Impact on Water Quality, Fish Community and Bacteria Presence in Disturbed and Undisturbed North Selangor Peat Swamp Forest, Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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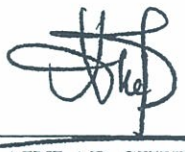

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Date: 26 January 2017

This thesis submitted to the Senate of the 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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CHAPTER 1

INTRODUCTION

1.1 Overview

Peat swamps are biotopes of great ecological importance. Like most brackish water habitats, there have a unique characteristic of being associated with a particular ecological community, with high biological diversity and trophic migrations, which could be in peril without appropriate management (Cognetti and Maltagliati 2000). Over the last decades, peat swamps in particular and aquatic systems in general have been globally impacted by a wide array of human factors (Allard et al. 1991; Dynesius and Nilsson 1994; Rahel 2000). Anthropogenic activities modify the physical, chemical and biological processes of water resources, which results in modification of the resident biological community. This modification could be in the form of reduced richness, diversity and extinction, or a replacement of the community with more resilient ones (Giam et al. 2012; Kuklina et al. 2013). As a result of the imperative biological response of communities to environmental changes, they serve as precise indicators of the status of the aquatic system as they are subject to the full range of chemical and physical influences, with additive and synergistic effects included (Adams et al. 1999; Schiemer 2000; Wolska et al. 2007).

In a delicate semi-closed ecosystem such as peat swamps, environmental and ecological factors clout organisms' response to environmental stressors (Adams et al. 1989; Adams et al. 1999). Ellis (1999) mentioned that such stressors predisposes organisms, especially fish to chronic immune suppression, thus stimulating bacterial invasion. Generally, fish are continuously exposed to the microorganisms present in water and in sediment (El-Shafai et al. 2004). These organisms change the microbial flora on external surfaces of the fish, including the gills, with high accumulation at sites of damage, such as missing scales or abrasions (Austin and Austin 2012). Similarly, food and water populated with microorganisms are delivered to the digestive tract via ingestion (Olafsen 2001), and they eventually colonise the digestive tract (Austin and Austin 2012).

Fisheries represent an important sector in a country's national income structure. According to Huq et al. (1983), swamps serve as natural water bodies for various fish species of deferring sizes, and an important source of income for small scale farmers. Swamp fish provides the cheapest protein, and involves small investment and little or no monitoring as the fish can grow easily without care. Peat swamps with its unique characteristics does not just provide fish for consumption or ornamental values but also serve as a reservoir of bio-indicator organisms of great research importance (United Nations Development Programe (UNDP) 2006; Yule 2010). Therefore, unregulated alteration to natural swamps, including peat swamps, can have its toll on a nation's economy.

The biological responses of animals and plants to environmental stressors have been well researched (Pounds et al. 2006; Whitfield et al. 2007; Dong et al. 2010). Also the bacterial community of several cultured and wild fishes (both freshwater and marine) have been well studied and documented (Austin and Austin 1999; Olafsen 2001;

Moustafa et al. 2010; Khan and Ghosh 2012; Saad 2013). But, only few studies have been conducted on the response of swamp fishes to human induced environmental stress, and on the bacterial communities of swamps. Such studies on peat swamp forest is completely fragmented, incomplete and mostly without a major focus on the response of biological communities (Mishra et al. 2014). In Malaysia especially, such studies on peat swamps and associated habitats are completely lacking.

The north Selangor Peat Swamp Forest (NSPSF), located on a plain coast in the northern part of the state of Selangor is home to diverse fish species, some of which are stenotopic to the peat swamp of the forest (Ng et al. 1994; Beamish et al. 2003). The desire for agricultural development and expansion in recent times, had resulted in destruction of a large part of the forest and its subsequent conversion to paddy fields and oil palm plantations (Giam et al. 2012). Consequently, the agricultural parts of the NSPSF is now characterized with intense anthropogenic activities (Posa et al. 2011). This has led to further deterioration of the environment, a scenario that can make it inhabitable to native fish species especially (Stoeckl et al. 2015), hence reducing their chance of survival, their richness and diversity.

As a result of the low pH and other unique water attributes, fish species that can survive and breed in peat swamps are limited (Ng et al. 1994). Many species found in peat swamps are not found in any other habitat. Thus fish resources in the NSPSF are exploited for the aquarium trade and consumption (Zakaria et al., 1999). A review of fish surveys reveal that 114 fish species belonging to 23 families have been recorded from the NSPSF (Davies and Abdullah 1989; IPT-AWB 1993; Ng et al. 1994; Beamish et al. 2003; Giam et al. 2012; Ahmad et al. 2013; Ismail et al. 2013; Siow et al. 2013). Some recent surveys had reported a decline in the fish community structure resulting from their displacement following peatland conversions in NSPSF (Beamish et al. 2003; Giam et al. 2012). Some of the fish species listed as endangered by the IUCN Red List of Threatened Species have been rarely sighted during recent surveys (Giam et al. 2012; Ahmad et al. 2013; Ismail et al. 2013; Siow et al. 2013). This trend of peatland conversion which has continued despite the associated risks could result in the extinction of already endangered species in the near future.

Water from the peat swamps is used in irrigating the paddy fields and oil palm plantations, and occasional overflow occurs especially during high rainfall. Hence, fish is suspected to migrate from the adjacent paddy fields and oil palm plantations into the peat swamps of the NSPSF and vice versa, especially during seasons of high rainfall (Irvine et al. 2013). By implication therefore, there is the possibility of bacteria being introduced from the highly impacted anthropogenic agricultural areas into the peat swamps, especially through trophic migrations of fish. This could increase the incidence of bacterial infections, which are one of the causative agents of fish diseases, and the primary cause of mortality in wild and cultured fishes (Posa et al. 2011; Coll et al. 2016). It could also lead to or increase the risk of infection of humans by human pathogenic bacteria in and around fish. Such scenario of intense human activities, deterioration of the environment and migrations of fish, could pose a risk to the brackish water environment without appropriate management and risk assessment.

1.2 Objectives of the study

This study has three principal objectives, summarized as follows:

1. To determine the influence of anthropogenic activities on the water physicochemical parameters in peat swamp, paddy field and oil palm plantation of the NSPSF.
2. To determine the fish community structure in peat swamp, paddy field and oil palm plantations of NSPSF, and their relationship to the water physicochemical parameters.
3. To determine the bacterial presence in fishes, water and sediments of peat swamps, paddy fields and oil palm plantations of NSPSF, and their relationship to the water physicochemical parameters.

1.3 Approach of study

The approach in implementing this study involved a focused preliminary observation, identification of human activities and resultant environmental conditions, study sites selection, physicochemical analyses of water, fish sampling for fish identification and community structure, bacteriological examination of water, sediment and fish samples (Fig. 1.1). The methods adopted in selection of sampling sites, the duration and period of sampling, collection of fish, water and sediment, techniques in isolation and identification of bacteria, and the statistical methods in analysing data obtained are based on the insights and experiences derived from review of literatures and a careful scrutiny of the strengths and weaknesses of various available techniques. In addition, a preliminary study was conducted in the study area prior to the actual research to identify habitat characteristics, inhomogeneity in space or time, and possible complications to aid in stratification of sampling sites, and selection of best-fit sampling techniques.

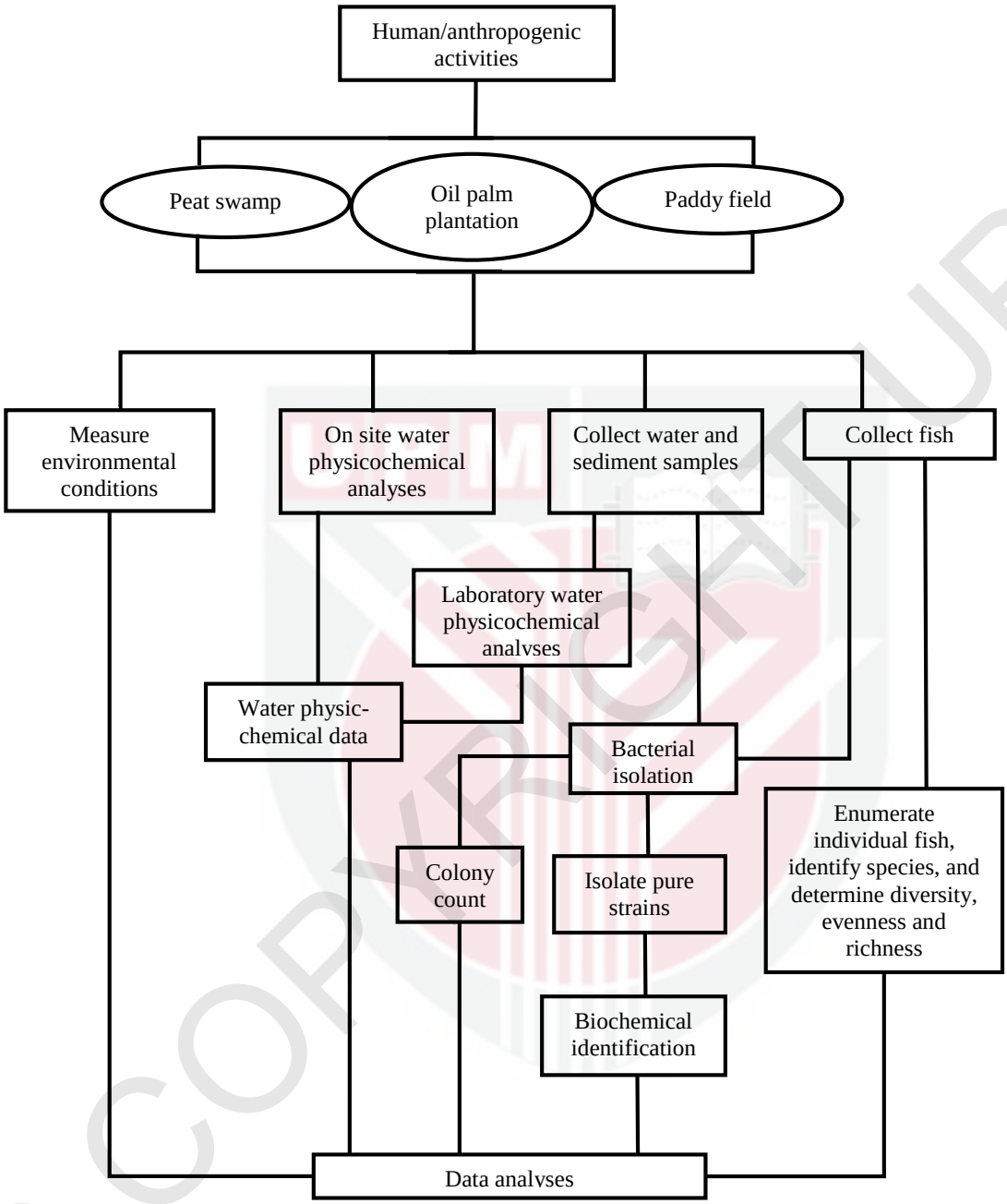

Figure 1.1: Flowchart of the study

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The student was born on 12th September 1987 in Igalamela/Odolu Local Government Area of Kogi State, Nigeria. He attended his primary education at Ayegba LGEA Primary School II, from 1992 to 1998, where he obtained his Certificate of Primary Education. He later continued his secondary education at St. Peter's College, Idah, Kogi State, Nigeria, from 1998 to 2004, where he sat for the West African Senior Secondary School Certificate (WASSC) examination, and obtained three distinctions and five credits. He then proceeded to Ahmadu Bello University Zaria, Nigeria from 2005 to 2010, where he obtained a Bachelor of Science degree, with honours, in Biology.

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After his undergraduate studies, the student completed a one-year compulsory National Youth Service Corps (NYSC) program, where he was posted to Auchi, Edo State, Nigeria, to teach biology and execute other community service projects. The student joined Kogi State College of Education, Ankpa, Nigeria, as an Assistant lecturer in 2012 where he had lectured courses in biology, provided supervisory support to final year students, and carried out collaborative researches published in peer-reviewed journals, before proceeding to Universiti Putra Malaysia in 2014 for a Master of Science degree in Ecology. With a research focused on biological conservation, fish and bacterial ecology, migration and ecosystem health, the student completed his Master of Science program with a thesis entitled "Anthropogenic activities impact on water quality, fish communities and bacterial presence in disturbed and undisturbed Selangor peat swamp forest, Malaysia".

LIST OF PUBLICATIONS

Journal

Sule HA, Ismail A, Amal MNA (2016) A review of the ichthyofauna of Malaysian peat swamp forests. Pertanika J Trop Agric Sci. 39(4):421-458

Sule HA, Ismail A, Amal MNA, Zulkifli SZ, Mohd Fauzul AMR (2016) Influence of anthropogenic activities on water physicochemical parameters in peat swamp, paddy field and oil palm plantation of north Selangor peat swamp forest. Environ Monit Assess, *Submitted.*

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Proceeding

Sule HA, Ismail A, Amal MNA, Syaizwan ZZ and Aidil MF (2016) The influence of water physicochemical parameters on fish occurrence in peat swamp, paddy field and oil palm plantation of north Selangor peat swamp forest, Selangor, Malaysia. Abstract presented at Malaysia International Biology Symposium '16 (i-SIMBIOMAS), held in Putrajaya International Convention Centre, Putrajaya, Malaysia, 26–27th October 2016.

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Sule HA, Ismail A, Amal MNA, Zulkifli SZ (2015) Human activities increase bacterial composition of North Selangor Peat Swamp Forest. In: Ismail A, Zulkifli SZ, Hanapiah M, Aziz FZA (eds) Proceedings of Seminar Ekologi Malaysia '15 held in Putrajaya International Convention Centre, Putrajaya, Malaysia, 19th October 2015. Department of Biology, Universiti Putra Malaysia, Serdang, Selangor Darul Ehsan, pp 101–103

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