UNIVERSITI PUTRA MALAYSIA

ECO-PHYSIOLOGY AND MESOCOSM STUDY ON MICROALGAE IN OLIGOTROPHIC AND MESOTROPHIC MUNICIPAL MANMADE LAKES IN DIFFERENT WEATHER CONDITIONS

MUNAY ABDULQADIR OMAR ABDULQADIR ALTEERAH

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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 Doctor of Philosophy

July 2017

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Dedicated to my father's soul

my precious mother

and

my husband

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree of Doctor of Philosophy

ECO-PHYSIOLOGY AND MESOCOSM STUDY ON MICROALGAE IN OLIGOTROPHIC AND MESOTROPHIC MUNICIPAL MANMADE LAKES IN DIFFERENT WEATHER CONDITIONS

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July 2017

Chairman : Hishamuddin Omar, PhD
Faculty : Science

Numerous weather records from all over the world indicated that climate changes are happening including in Malaysia. Climate change influences daily weather conditions and the biotic component in water bodies. Unlike the subtropics and temperate regions, Malaysia has no distinct seasons. Most studies are on microalgae diversity and water quality parameters but few studies were available on the impact of changing weather conditions on microalgae species composition, diversity and productivity. Therefore the objectives of this study are to evaluate the effect of variable weather conditions on water quality, diversity, succession of microalgae, primary productivity of the mix microalgae in two urban manmade lakes and mixed microalgae study in floating mesocosms. Daily weather conditions monitored three times daily at morning (8.0-9.0), noon (12.0-13.0) and afternoon (16.0-17.0). The weather is classified into mix, wet and dry conditions based on weather scoring. Lake study comprised of weekly sampling for 22 weeks was carried out for water physico-chemical parameters, microalgae species composition and diversity, microalgae biomass and productivity. A set of mesocosms outdoor experiment was performed to evaluate the productivity of mix microalgae in semi controlled conditions with sampling every two days. Mesocosms were divided into four treatments: non-sheltered with fertilizer, non-sheltered without fertilizers, sheltered with fertilizers, sheltered without fertilizers. Triple supper phosphates and urea (2g: 20 g) were used as fertilizers. Statistical analysis were done using one way ANOVA, Canonical corresponding analysis (CCA), Principal Component Analysis (PCA) and Factorial ANOVA for microalgae culture parameters. The mean water quality parameters of the lake during all weather conditions were: water temperature (28.95 & 29.43˚C), pH (7.14 & 7.11), electrical conductivity (0.15 & 0.41 mS/cm), dissolved oxygen (5.5 & 4.5mg/L), alkalinity (43.8 & 148.2 mg$CaCO_3$/L), orthophosphates (0.02 & 0.42 mg / L), nitrate-nitrogen (0.2 & 0.07 mg/L), ammonium-nitrogen (0.06 & 0.96 mg/L), trophic status index (20.6 & 37.5) in Engineering lake and Seri Serdang Lake respectively. A total of 65 species from five divisions (Chlorophyta, Euglenophyta, Cyanophyta, Bacillariophyta and Dinophyta) and 51

species belonging to six divisions (Chlorophyta, Cyanophyta, Bacillariophyta, Euglenophyta, Cryptophyta & Charophyta) were recorded from Engineering Lake and Seri Serdang Lake respectively. Division Chlorophyta was the most dominant in Engineering Lake comprising of 67.6% and in Seri Serdang lakes comprising of 67.3% during all sampling weeks. In dry weather conditions, the microalgae density was low in both lakes. Engineering lake and Seri Serdang Lake showed the highest means chlorophyll a concentration of 0.65±0.028 & 4.83±0.96 µg/L respectively in dry weather conditions. Engineering lake and Seri Serdang Lake also showed highest mean of temporal fluctuations of primary production with 0.43±0.03 & 2.14 ± 0.85 mg C/ L/ h respectively. Reduction of light intensity during mix weather conditions was the main factor behind the reduction of primary productivity in both lakes. Increase light intensity and nutrient concentration during dry weather conditions led to improve microalgae primary productivity. Small mesotrophic manmade lake (Seri Serdang) showed its importance in producing O_2 and CO_2 sequestration. Weather conditions in mesocosms study period were scored and categorized to ensure each cultivation cycle was under one type of weather conditions. Water quality parameters in all treatments cultures was monitored for 10 days in three cycles and showed significant variations among the variables. Nutrients decreased during cultivation period and the growth performance of the mix microalgae in fertilized and non-fertilized mesocosms from three culture cycles slightly increased with culture time. Primary productivity was higher in the fertilized non-sheltered mesocosms (Treatment 1). On the 10^{th} day of culture primary productivity in treatment 1, 2, 3 & 4 were lower in the dry cycle (0.7±0.1) (0.2±0.0) (0.2±0.0) (0.5±0.0) g/l dry wt and higher in the mix cycle (2.2±0.3) (0.4±0.0) (0.7±0.5) (0.4±0.0) respectively. In different mesocosms treatment, the diversity of microalgae did not differ much. Twenty-six species were recorded in mixed and wet cycle and twenty-nine dry cycles. Chlorophyta due to its versatile adaptability was the main dominant group during all cycles comprising 80%, 83%, and 85% during mix, dry and wet cycles respectively. Different weather conditions and different treatments including sheltered & non- sheltered significantly influenced microalgae species composition. This was probably due to the sensitivity in some of them to different light intensities. This study concluded that light intensity, and temperature were the main factors that can impact microalgae growth and morphological features. Malaysian weather conditions are variable that can be categorized as wet, mixed and dry. The weather conditions exert its influence on water physico-chemical water parameter, microalgae diversity and productivity. Mesocosms study also confirmed the findings in oligotrophic and mesotrophic lake on the impact of weather condition on water quality parameters, microalgae diversity and productivity.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan ijazah Doktor Falsafah

KAJIAN EKO-FISIOLOGI DAN MESOKOSM MIKROALGA DALAM TASIK PERBANDARAN OLIGOTROFIK DAN MESOTROFIK BUATAN MANUSIA DALAM KEADAAN CUACA BERBEZA

Oleh

MUNAY ABDULQADIR OMAR ABDULQADIR ALTEERAH

Julai 2017

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Kebanyakkan rekod cuaca di seluruh dunia menunjukkan perubahan iklim telahpun berlaku termasuk di Malaysia. Perubahan iklim mempengaruhi keadaan cuaca harian dan komponen biotik dalam jisim air. Tidak seperti di kawasan subtropika dan kawasan temperat, Malaysia tidak mempunyai musim yang ketara. Kebanyakkan kajian yang dijalankan adalah mengenai diversiti mikroalga dan parameter kualiti air tetapi tidak banyak kajian yang dijalankan terhadap impak keadaan perubahan cuaca terhadap komposisi spesis mikroalga, diversiti dan produktiviti. Sehubungan dengan itu objektif kajian ini ialah untuk menilai kesan keadaan cuaca yang berubah-ubah terhadap kualiti air, diversiti dan perubahan spesis mikroalga mengikut masa, produktiviti mikroalga campuran dalam dua tasik munisipal buatan manusia dan dalam mesokosm terapung. Keadaan cuaca harian dicerap tiga kali sehari iaitu pada waktu pagi (8.0-9.0), tengah hari (12.0-13.0) dan petang (16.0-17.0). Cuaca dikelaskan mengikut keadaan iaitu cuaca bercampur-campur, cuaca basah dan cuaca kering berdasarkan skor cuaca. Persampelan mingguan dijalankan di tasik untuk selama 22 minggu telah dijalankan untuk parameter fiziko-kimia air, komposisi spesis mikroalga dan diversiti, biojisim mikroalga dan produktiviti. Eksperimen menggunakan kaedah mesokosm di luar juga dijalankan untuk menilai produktiviti mikroalga dalam kadaan separa terkawal. Persampelan dijalankan setiap dua hari. Mesokosm dibahagikan kepada empat rawatan: tanpa lindungan dengan baja, tanpa lindungan tanpa baja, lindungan dengan baja dan lindungan tanpa baja. Baja "*triple super phosphates*" dan urea dengan nisbah (2g:20g) digunakan. Analisis statistik menggunakan ANOVA satu hala, "*Canonical corresponding analysis*" (CCA), "*Principal component analysis*" (PCA) dan ANOVA faktorial digunakan untuk parameter pengkulturan mikroalga. Min parameter kualiti air tasik dalam semua keadaan cuaca masing-masing adalah: suhu air (28.95 & 29.43˚C), pH (7.14 & 7.11), konduktiviti elektrikal (0.15 & 0.41 mS/cm), oksigen terlarut (5.5 & 4.5mg/L), alkaliniti (43.8 & 148.2 mg$CaCO_3$/L), ortofosfat (0.02 & 0.42 mg / L), nitrat-nitrogen (0.2 & 0.07 mg / L), amonia-nitrogen (0.06 & 0.96 mg/L), indeks status trofi (20.6 & 37.5) masing-masing di Tasik Fakulti

Kejuruteraan dan Tasik Seri Serdang. Sejumlah 65 spesis dari lima kelompok mikroalga iaitu (Chlorophyta, Euglenophyta, Cyanophyta, Bacillariophyta and Dinophyta) dan 51 spesis dari 6 kelompok mikroalga (Chlorophyta, Cyanophyta, Bacillariophyta, Euglenophyta, Cryptophyta & Charophyta) dicatatkan di Tasik Fakulti Kejuruteraan dari Tasik Seri Serdang. Kelompok mikroalga yang dominan adalah Chlorophyta yang terdiri dari 67.6% di Tasik Fakulti Kejuruteraan dan 67.3% di Tasik Seri Serdang sepanjang tempoh persampelan. Ketumpatan mikroalga adalah rendah semasa keadaan cuaca kering di kedua-dua tasik. Tasik Fakulti Kejuruteraan dan Tasik Seri Serdang masing-masing mencatatkan min kepekatan klorofil a tertinggi dengan bacaan (0.65±0.028) & (4.83±0.96) µg/L dalam keadaan cuaca kering. Tasik Fakulti Kejuruteraan dan Tasik Seri Serdang juga menunjukkan min turun-naik temporal pengeluaran primer tertinggi dengan bacaan masing-masing (0.43±0.03) & (2.14 ± 0.85) mg C/L/h. Penurunan keamatan cahaya semasa keadaan cuaca bercampur merupakan faktor utama pengurangan produktiviti primer di kedua-dua tasik. Pertambahan keamatan cahaya dan kepekatan nutrien semasa keadaan cuaca kering meningkatkan produktiviti primer mikroalga. Tasik kecil buatan manusia mesotrofik di Seri Serdang menunjukkan kepentingannya dalam penghasilan O_2 dan pengikatan CO_2. Keadaan cuaca semasa kajian mesokosom dijalankan juga diskorkan dan dikategorikan di mana setiap kitar pengkulturan mengikut jenis keadaan cuaca. Kualiti parameter air dalam setiap kultur rawatan dicerap selama 10 hari dalam tiga kitaran. Didapati kualti parameter air berbeza mengikut kitar pengkulturan dalam keadaan cuaca yang berbeza. Paras nutrien menurun mengikut masa pengkulturan selari dengan prestasi pertumbuhan mikroalga campuran dalam mesokosom berbaja dan tanpa baja yang meningkat sedikit dalam tiga kitaran pengkulturan yang berbeza. Produktiviti primer adalah lebih tinggi dalam mesokosom tanpa lindungan dengan baja (Rawatan 1). Pada hari ke 10, produktiviti primer untuk rawatan 1, 2, 3 dan 4 adalah rendah untuk kultur dalam keadaan cuaca kering masing-masing dengan bacaan (0.7±0.1) (0.2±0.0) (0.2±0.0) (0.5±0.0) g/L berat kering dan tinggi dalam keadaan cuaca bercampur-campur dengan bacaan (2.2±0.3) (0.4±0.0) (0.7±0.5) (0.4±0.0) g/l berat kering. Tiada banyak perbezaan dari segi diversiti mikroalga dalam kajian mesokosom dengan rawatan yang berbeza. Diversiti mikroalga dalam keadaan cuaca bercampur dan dalam kadaan cuaca basah adalah 26 dan 29 dalam keadaan cuaca kering. Chlorophyta merupakan grup yang dominan kerana kebolehannya untuk beradaptasi dalam keadaan cuaca yang berbeza dan masing-masing terdiri dari 80%, 83% dan 85% daripada keseluruhan komposisi mikroalga dalam keadaan cuaca bercampur-campur, kering dan basah. Keadaan cuaca yang berbeza dan rawatan yang berbeza seperti lindungan dan tanpa lindungan mempengaruhi komposisi mikroalga dengan signifikan, mungkin disebabkan oleh kepekaan sesetengah mikroalga kepada keamatan cahaya yang berbeza. Keadaan cuaca Negara Malaysia adalah berubah-ubah, dan boleh dikategorikan sebagai keadaan cuaca basah, keadaan cuaca bercampur-campur dan keadaan cuaca kering. Keadaan cuaca juga menyumbang dalam mempengaruhi parameter fiziko-kimia air, diversiti mikroalga dan produktiviti. Kajian mesokosm juga mengesahkan penemuan dalam tasik oligotrofik dan tasik mesotrofik mengenai impak keadaan cuaca terhadap parameter mutu air, diversiti mikroalga dan produktiviti.

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I certify that a Thesis Examination Committee has met on 11 July 2017 to conduct the final examination of Munay Abdulqadir Omar Abdulqadir Alteerah on her thesis entitled "Eco-Physiology and Mesocosm Study on Microalgae in Oligotrophic and Mesotrophic Municipal Manmade Lakes in Different Weather Conditions" 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 Doctor of Philosophy.

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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 Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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This is to confirm that:

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INTRODUCTION

1.1 Background

The state of our environment has been deteriorating since the last two centuries when the industrial revolution was started. A significant damage was done to the natural resource and that is continuing. One of the biggest problems facing the world today is global warming. Many scientists believe that our production of carbon dioxide and other greenhouse gases formed a blanket, preventing heat from escaping to outer space thus heating the atmosphere (Heng, 2016) and this could be very dangerous for human life.

Many problems could result from global warming such as changes in weather patterns (Krasko, 2014; Lang, 2014). Many areas of the world are experiencing increased floods, and other unusual weather. In addition, biodiversity loss can be caused by alteration of ecosystems and loss of the habitats (Cardinale et al., 2012) and because of climate change, heating of the Earth's surface affects biodiversity because it endangers all the species that adapted to the colder weathers (Cowles et al., 2016; Kano, 2016). Water quality degradation of freshwater are directly caused by changes in land use and urbanization (Wang et al., 2016).

Freshwater bodies act as sink for various chemicals including carbon (Adewopo et al., 2014; Costantini et al., 2013), so freshwater bodies reflecting climate change and challenges were taken toward freshwater resources as environmental degradation solution (Naiman & Dudgeon, 2011). Physical, chemical and biological aspect of freshwater bodies interacts dynamically and has profound effect on the overall wellbeing of the water bodies. Carbon dioxide and oxygen are the important component of aquatic ecosystem (Ayyanna et al., 2016). Respiration and photosynthesis are reverse process and they are controlling keys of CO_2 and oxygen concentration in aquatic ecosystem, so the length of day light periods fluctuation lead to changing in CO_2 and oxygen concentrations.

There are many approaches have been taken to reduce CO_2 emission such as biofuel production and recycling (Hof et al., 2016). CO_2 can be sequestered by using photosynthetic organisms such as microalgae (Moheimani, 2016), and then microalgae biomass can be converted to environmental friendly biofuels.

The biological component of the lakes includes primary producers such as microalgae, aquatic macrophytes and consumer such as zooplankton, nekton, insects and invertebrates (Hondula et al., 2014). Freshwater lake housed numerous microalgae which is one of the most important biological component. Microalgae as Primary

producer, form the base of the food chain, major carbon fixer, major O_2 producer, involve in nutrient cycling and remediation of water quality.

1.2 Justification and objectives of the study

In the past and present, most of the studies carried out on lakes were focused on zooplankton and microalgae diversity, Lake Limnology, primary productivity and nutrient dynamics. Monthly or bimonthly samplings were obtained but very rarely obtained on weekly basis. There are about 90 natural and man-made lakes in Malaysia with total area 1,001.821 km² (Sharip et al., 2014). Most of the studies were done on big manmade and natural lakes in Malaysia, but small manmade lake has been largely ignored. Therefore the aim of present study is to show daily weather and weekly limnological changes in small manmade municipal lakes. Although there are studies about microalgae in water bodies such as lakes but the studies are limited to species composition, species diversities, and succession in a particular condition but very few studies which relate microalgae to physical and chemical factors as results of changing weather conditions. Therefore, the objectives of this study are:

1. To measure physico-chemical water parameters in an oligotrophic lake and mesotrophic lake under different weather conditions.
2. To monitor changes in microalgae communities in term of diversity and succession in an oligotrophic lake and mesotrophic lake under different weather conditions.
3. To correlate microalgae productivity with water quality and weather conditions.
4. To record growth and species composition of microalgae in mesocosms in semi-controlled condition under variable weather conditions.

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