UNIVERSITI PUTRA MALAYSIA

PHYSICAL, CHEMICAL AND BIOLOGICAL CHARACTERIZATION OF SIBUTI MANGROVE FOREST ESTUARY, SARAWAK, MALAYSIA

A. S. M. SAIFULLAH

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By

A.S.M.SAIFULLAH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy
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DECEMBER 2015

Supervisor: Dr. Abu Hena Mustafa Kamal

Faculty: Agriculture and Food Sciences

Estuaries are the areas of complex interaction between fresh and saline water. The mangrove estuaries are claimed to be the most productive and considered as the breeding ground for fishery resources. Though, Malaysia is blessed with number of mangrove estuaries, however not adequate research findings are reported about their potentialities. Thus, this study was conducted to investigate the characteristics, plankton diversity and feeding habit of fishes in Sibuti mangrove estuary. Monthly sampling for ecological and biological parameters was conducted from January 2013 to December 2013 and data were pooled into seasons *viz*., intermediate, dry and wet. The summarised indices from Estuarine Water Quality Index (EWQI), Shannon- Wiener Diversity Index (SWDI) and Estuarine Resource Importance Index (ERII) claimed this estuary as high quality (total index 10.83). The hydro-biological parameters of the estuary followed a seasonal rhythm. The surface water temperature of the estuary ranged from 27.1 to 32.2^{o}C and revealed mesohaline on the basis of salinity ranged from 0.3 to 27.1 PSU. Water of the estuary revealed acidic to alkaline where dissolved oxygen (DO), total dissolved solids (TDS) and light extinction coefficient (LEC) were observed ranging from 1.94 to 6.71 mgL^{-1}, 0.5 to 43.9 mgL^{-1} and 1.71 to 6.71 respectively. The chlorophyll *a* concentration of the surface water ranged from 0.002 to 0.348 mg m^{-3}. Primary productivity (PP) ranged from 0.20$gCm^{-3}hr^{-1}$ to 0.74$gCm^{-3}hr^{-1}$ (0.53±0.15$gCm^{-3}hr^{-1}$) with its higher mean in the intermediate season (0.60±0.08 $gCm^{-3}hr^{-1}$) and the lower in the wet season (0.35±0.12 $gCm^{-3}hr^{-1}$). Nitrate, phosphate, ammonium and silica concentrations ranged from 0.40 to 3.53 mgL^{-1}, 0.01 to 1.92 mgL^{-1}, 0.06 to 1.24 mgL^{-1} and 1.7 to 3.47mgL^{-1} respectively. Seasonality exerted significant variation in surface water temperature, salinity, TDS, conductivity and ammonium. One hundred two (102) species of phytoplankton under 43 genera were recorded from Sibuti mangrove estuary including 6 species of Cyanophyta, 4 species of Chlorophyta, 63 species of Diatom and 29 species of Dinoflagellate. Mean abundance of phytoplankton ranged from 5694 to 88890 $cellsL^{-1}$ over the study period with its higher value in the dry season. Species recorded from the estuary, were dominated by *Pleurosigma normanii*, *Coscinodiscus* sp, *Coscinodiscus centralis*, *Coscinodiscus granii*, *Dinophysis caudata*, *Ceratium carriense*, *Ceratium fusus* and *Ceratium lineatum*. Abundance of phytoplankton demonstrated positive

correlation with chlorophyll *a* (r=0.69, p=0.01), ammonium (r=0.64, p=0.01) and silica (r=0.64, p=0.01).

A total of 54 forms of zooplankton belonging to diverse groups *viz*., copepod (35), chaetognatha (1), decapoda (1), amphipoda (1), mysid (1), cladocera (1), ostracoda (1), rotifer (1), tintinnid (1), apendicularia (1), doliolid (1), medusa (1), mollusc (2) and larvae, nauplii and fish eggs (6) were recorded form the estuary. The majority of zooplankton was occupied by copepod (73.58%) and was dominated by *Acartia* spp.(calanoida), *Oithona* spp. (cyclopoida) and *Euterpina* spp. (harpacticoida). Abundance of zooplankton ranged from 1419.58- 3121.59 ind. m^{-3} and maximum was observed in the intermediate season while minimum in the wet season. Species diversity (H̓) of zooplankton ranged from 1.62-2.61 and there was revealed no seasonal or site specific variation. Zooplankton abundance showed positive correlation with phytoplankton (r=0.66, p=0.01) and chlorophyll *a* (r= 0.73, p=0.01).

A total of 997 stomachs of 12 species of fishes under 9 genera namely *Arius maculatus*, *Arius caelatus*, *Arius truncatus*, *Hexanematichthys sagor*, *Setipinna melanochir*, *Setipinna breviceps*, *Setipinna taty*, *Coilia dussumieri*, *Opisthopterus tardoore*, *Ilisha elongata*, *Nibea saldado* and *Otolithes ruber* were investigated for the purpose of getting insight of feeding habits of the fishes of the estuary. Empty stomach consisted of the largest portion of investigated stomachs and poor feeding was common all over the study period. Crustacean dominated by shrimps were found as the most preferred food of the fishes followed by miscellaneous (appendages, detritus, plant parts) and molluscs. Feeding habit of fishes was found different in various length group as well as seasons. A cluster analysis based on dietary overlaps and dominant food consumption criteria, revealed four feeding guilds *viz*., shrimp feeder, gastropod and bivalve feeder, fish and shrimp feeder and detritus (plant part and sand-mud) and shrimp feeder. The results depicting estuarine characteristics, diverse primary consumer (phytoplankton), secondary consumer (zooplankton) and feeding habit of fishes and the correlation among them exerted an interlocking pattern, which demonstrated the interdependency of the variables towards functioning of the estuary.

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

PENCIRIAN FIZIKAL, KIMIA DAN BIOLOGI MUARA HUTAN BAKAU SIBUTI, SARAWAK, MALAYSIA

Oleh
A.S.M. SAIFULLAH

DISEMBER 2015

Penyelia: Dr. Abu Hena Mustafa Kamal

Fakulti: Sains Pertanian dan Makanan

Muara sungai ialah kawasan yang mempunyai interaksi kompleks di antara air tawar dan air masin. Muara sungai di kawasan paya bakau dianggap sebagai satu sumber yang sangat produktif dan merupakan tempat pembiakan ikan. Malaysia dilimpahi diberkati dengan pelbagai hutan paya bakau. walaupun begitu, tidak banyak penyelidikan dijalankan mengenai kelebihannya. Oleh yang demikian, kajian dijalankan untuk mengkaji ciri, kepelbagaian plankton dan sifat pemakanan ikan di muara paya bakau Sibuti. Persampelan parameter ekologi and biologi telah dijalankan pada setiap bulan dari Januari 2013 sehingga Disember 2013 dan data di dibahagikan mengikut musim iaitu pertengahan, kering and lembab. Ringkasan indeks daripada Indek Kualiti Air Muara (EWQI), Indek Diversiti Shannon-Wiener (SWDI) dan Indek Kepentingan Sumber Muara (ERII) menunjukkan kawasan muara paya bakau ini mempunyai kualiti yang tinggi (jumlah indek 10.83). Parameter hidro-biologi di kawasan muara mengikut keadaan pola musim. Suhu permukaan air di muara adalah 27.1 hingga 32.2°C dan kemasinan di antara 0.3 hingga 27.1 PSU. Air di muara paya bakau menunjukkan perubahan asid kepada alkali dimana oksigen terlarut (DO), jumlah pepejal terampai (TDS) dan "light extinction coefficient" (LEC) di antara 1.94 hingga 6.71 mgL^{-1}, 0.5 hingga 43.9 mgL^{-1} dan 1.71 higga 6.71. Kepekatan klorofil a di permukaan air adalah di antara 0.002 hingga 0.348 mg m^{-3}. Produktiviti Primer (PP) di antara 0.20$gCm^{-3}jam^{-1}$ hingga 0.74$gCm^{-3}jam^{-1}$ (0.53±0.15$gCm^{-3}jam^{-1}$) dimana purata tertinggi adalah pada musim pertengahan (0.60±0.08 $gCm^{-3}jam^{-1}$) dan yang terendah adalah pada musim lembab (0.35±0.12 $gCm^{-3}jam^{-1}$). Kepekatan nitrat, phosphat, ammonium dan silika di antara 0.40 to 3.53 mgL^{-1}, 0.01 hingga 1.92 mgL^{-1}, 0.06 to 1.24 mgL^{-1} dan 1.7 to 3.47mgL^{-1}.Variasi pada suhu permukaan air, kemasinan, jumlah pepejal terampai, konduktiviti dan ammonium adalah signifikan pada setiap musim.

Seratus dua (102) spesis fitoplankton merangkumkumi 43 genus di rekodkan di muara paya bakau Sibuti termasuk 6 spesis Cyanophyta, 4 spesis Chlorophyta, 63 spesis Diatom dan 29 spesis Dinoflagellata. Purata kelimpahan fitotoplankton di antara 5694 hingga 88890 selL-1 sepanjang kajian dengan nilai tertinggi pada musim kering. Spesis yang di rekodkan didominasi oleh *Pleurosigma normanii*, *Coscinodiscus* sp., *Coscinodiscus centralis*, *Coscinodiscus granii*, *Dinophysis caudata*,*Ceratium carriense*, *Ceratium fusus* dan *Ceratium lineatum*. Kelimpahan fitoplankton mempunyai perkaitan positif dengan klorofil a (r=0.69,p=0.01), ammonium (r=0.64, p=0.01) dan silika (r=0.64, p=0.01).

Sebanyak 54 jenis zooplankton di bawah kumpulan yang pelbagai., kopepod (35), chaetognatha (1), dekapoda (1), amphipoda (1), mysid (1), cladocera (1), ostracoda (1), rotifer (1), tintinnid (1), apendicularia (1), doliolid (1), medusa (1), moluska (2) dan larva, nauplii dan telur ikan (6) direkodkan. Majoriti zooplankton terdiri daripada kopepod (73.58%) dan di dominasi oleh *Acartia* spp. (calanoida), *Oithona* spp. (cyclopoida) and *Euterpina* spp. (harpacticoida). Kelimpahan zooplankton di antara 1419.58- 3121.59 ind. m^{-3} dan nilai maksimum adalah pada musim pertengahan sementara nilai minimum pada musim lembab. Indek Kepelbagaian Spesis (H′) zooplankton di antara 1.62-2.61 dan ini menunjukkan tiada pengaruh musim atau or variasi pada tempat yang spesifik. Jumlah kelimpahan zooplankton menunjukkan perkaitan positif dengan fitoplankton (r=0.66, p=0.01) dan klorofil *a* (r=0.73, p=0.01).

Sebanyak 997 perut dari 12 spesis ikan di bawah 9 genera iaitu *Arius maculatus*, *Arius caelatus*, *Arius truncatus*, *Hexanematichthys sagor*, *Setipinna melanochir*, *Setipinna breviceps*, *Setipinna taty*, *Coilia dussumieri*, *Opisthopterus tardoore*, *Ilisha elongata*, *Nibea saldado* dan *Otolithes ruber* di kaji untuk tujuan mendalami sifat pemakanan ikan di muara paya bakau. Perut kosong merupakan yang tertinggi diantara perut yang di kaji dan menunjukkan sifat pemakanan yang rendah didapati sepanjang kajian dijalankan. Krustasia di dominasi oleh udang diikuti oleh yang lain-lain (anggota badan, lumpur, bahagian tumbuhan) dan moluska. Sifat pemakanan ikan didapati berlainan mengikut kepelbagaian kumpulan panjang dan juga musim. Kluster analisis berdasarkan pertindihan diet dan kriteria makanan yang dominan, menunjukkan empat jenis pemakanan iaitu pemakan udang, pemakan gastropod dan dwicenkarang, pemakan ikan dan udang, pemakan sampah pemakan lumpur dan tumbulan) dan udang. Hasil kajian menunjukkan ciri-ciri muara, kepelbagaian pengguna primer (fitoplankton), pengguna sekunder (zooplankton) dan sifat pemakanan ikan serta corak perkaitan di antara mereka di mana menunjukkan variasi kebergantungan ke arah keberhasilan kawasan muara sungai.

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I certify that a Thesis Examination Committee has met on 31/12/2015 to conduct the final examination of A.S.M.Saifullah on his thesis entitled "PHYSICAL, CHEMICAL AND BIOLOGICAL CHARACTERIZATION OF SIBUTI MANGROVE FOREST ESTUARY, SARAWAK, 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 Doctor of Philosophy.

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ANOSIM	Analysis of Similarities
ANOVA	Analysis of Variance
CCA	Canonical Correspondence Analysis
CAP	Community Analysis Package
Chl *a*	Chlorophyll *a*
DO	Dissolved Oxygen
DSP	Diarrhetic Shelfish Poisoning Species
ERII	Estuarine Resource Importance Index
EWQI	Estuarine Water Quality Index
GPP	Gross Primary Production
HAB	Harmful Algal Bloom
$ind.m^{-2}$	Individual Per Square Meter
$ind.m^{-3}$	Individual Per Cubic meter
Kph	Kilometer Per Hour
nMDS	Non-metric Multidimensional Scaling
mL	Mili Liter
mgL^{-1}	Miligram Per Liter
m^{-3}	Per Meter Cube
NPP	Net Primary Production
PAST	PAleontological Statistics
PSU	Practical Salinity Unit
PP	Primary Productivity
PRIMER	Plymouth Routines In Multivariate Ecological Research
SAS	Statistical Analysis System
SPSS	Statistical Package for the Social Sciences
SM	Suspended Matter
SME	Sibuti Mangrove Estuary
SWDI	Shannon-Weaver Diversity Index
TDS	Total Dissolved Solids
UVS	Ultraviolet Spectrophotometer

DEDICATION

Dedicated To My Family

CHAPTER 1

GENERAL INTRODUCTION

1.1 Background

Estuaries act as transitional zone between the land and the sea (Badarudeen *et al*., 1996) and economically important ecosystems for fishery resources worldwide (Kawabata *et al*., 1993). As a transition zone, the inflows of both marine and fresh water provide high levels of nutrients both in the water column and in sediment, making estuaries among the most productive natural habitats in the world (McLusky and Elliott, 2004).

The role of estuaries has been profoundly appreciated on a global scale by Costanza *et al*. (1997) who ranked estuaries in the top position among the world's most important ecosystems in terms of ecological services provided. Along with the function of nutrient cycling and transformation, estuaries are essential habitats in the life history of many species and in particularly for fish (Breine *et al*., 2007). They are considered as important nurseries for the juveniles of many marine, estuarine and freshwater fishes since they promote growth and offer shelter from predators (Elliott *et al*., 1990; Maes, 2000). Furthermore, estuaries are crucial resting areas for transient fish species; in particular diadromous fish populations, many of which are threatened. In this context, mangrove estuarine ecosystems are considered as highly productive with the capacity to efficiently trap suspended material from the water column and act as nutrient traps, receiving high organic and inorganic inputs from rivers, resulting in high primary productivity (Radi *et al*., 2007).

Litter from mangroves (leaves, propagules and twigs) and subsurface root growth provide significant inputs of organic carbon to mangrove sediments (Alongi, 1998). A range of other sources may also provide important organic carbon inputs; including allochthonous riverine or marine material, autochthonous production by benthic or epiphytic micro or macro algae, and local water column production by phytoplankton (Bouillon *et al*., 2004). It is also apparent that mangrove estuaries form zooplankton-rich ecosystems which could potentially be exploited by small fish as their source of energy (Van Damme *et al*., 2005). Chong (2007) reported some evidence of the contribution of phytoplankton to the trophodynamics of the largest

mangrove forest in Peninsular Malaysia based on the large expanse of open water in the lower Matang estuary, high chlorophyll *a* concentration and high consumption of planktonic fauna by mangrove fishes. In the estuarine ecosystem, phytoplankton acts as initial biological component from which the energy is transferred to higher organisms through food chain (Ananthan *et al*., 2004; Sridhar *et al*., 2006).

Despite all the potentialities of estuaries, being a transition zone between land and ocean, estuaries are subject to the input of high loads of nutrients leading to water quality impairment (Breine *et al*., 2006). Land claim of valuable intertidal areas for industrial development or agriculture cause further deterioration of estuarine ecosystems. Consequence of which could be eutrophication, algal bloom and finally the obnoxious condition for aquatic organisms. Estuaries and adjoining coastal waters receive inputs of various substances from a wide range of human activities and for this reason very often they are categorized as 'receiving water'.The estuary bound rivers can carry substantial loads of nutrients, organic matter and other materials that originate from upstream sources. In many cases, large urban populations are located close to estuaries with the result that substances arising from municipal and industrial sources are often discharged directly to these tidal waters.

Towards restoration of potential estuaries, it is very important to develop and implement integrated monitoring and conservation system. According to Lassen *et al*. (2004), the assessment of the status of estuarine ecosystems for the proper management of estuarine resources, it requires the collection of physical, chemical and biological data, and knowledge about the interaction of different components. Such information usually require translation into a simple value or index, which evaluates the current state in relation to a pristine state and which can be presented and used for further decision making. Ferreira (2000) also mentioned a clear need for a more comprehensive approach to estuarine environmental quality classification, which takes into account of physical, chemical and biological study on the one hand, and the water column and sediment aspects on the other. The physical, chemical and biological profile altogether can depict the health of an estuary.

Generally, water characteristics play significant role in maintaining the aquatic diversity as well as possesses control on the ecosystem.

The quality of water refers to the physical, chemical and biological parameters of water and all these characteristics directly or indirectly influence the survival and production of aquatic species (Boyd and Tucker, 1998). Physico-chemical parameters and concentration of nutrients in estuarine ecosystem play significant role in the distributional patterns and species composition of plankton (Saifullah *et al*., 2014a). Previous studies revealed a clear variation of water characteristics in relation to seasonal changes (Rajkumar *et al*., 2009; Perumal *et al*., 2009). Phytoplankton species distribution shows wide spatio-temporal variations due to the differential effect of hydrographical factors on individual species and they serve as good indicators of water quality including pollution (Gouda and Panigrahy, 1996). Thus, it is important to consider seasons as driving force when conducting research on water characteristics or diversity of biological parameters in an estuary. Other than the temporal variation, the spatial variation is also profound in case of distribution and composition of plankton. In this context, water quality plays vital role on the distribution and abundance of plankton through its polluted and unpolluted nature in the estuary.

The biological parameter like phytoplankton and zooplankton have key role in the aquatic productivity as primary and secondary producer respectively. In the aquatic trophic level both the parameters staying on the lower level and initiate the food web. Thus, the abundance and diversity of plankton in the aquatic regime is important for the sustenance of other organisms like fish. Naturally, high biomass values of plankton indicate high fish production (Mahar, 2003). The high zooplankton biomass offers enhanced feeding and growth conditions leading to higher survival and recruitment of young fish.

1.2 Problem Statement

Estuaries in Malaysia harbour critical ecosystems (mangroves, seagrasses, intertidal reefs and mudflats) that provide habitat for a unique assortment of plants and animals. They also support commercial and recreational fisheries, aquaculture, comprise important waterways for commercial shipping and recreational boating, tourism and other recreational activities. However, different uses and users of this ecosystem also impose various pressures on the ecosystem and for this reason frequently the estuarine environment suffers. Dominance of mangrove in the coastal region of the country added new dimension to the adjacent estuary through providing

shelter and food for the organisms living in the ecosystem. Mangrove estuaries are considered as unique and significant ecosystem from ecological point of view. In this line, Malaysian coasts are blessed with numerous mangrove estuaries however, very little is known about the ecology of those estuaries.

According to Ibrahim *et al*. (1995), several problems related to estuary management are reported in Malaysia and the primary problem is that there is no recognition of the estuarine regime; there is only recognition of the riverine or marine regime which leads to misunderstanding of the physical, chemical and biological processes occurring in the estuary. So, for the purpose of conservation and management it is necessary to delineate estuarine regime from other aquatic ecosystem.

Prior to develop the management system and designing the conservation program, it is important to gather the ecological knowledge of the respective estuary. The estuaries are reported as enriched with fisheries resources where a number of fishing folks are dependent for their livelihood. Thus, management of fisheries resources demands prime attention. The knowledge of feeding habit, trophic organization and food web structure of fisheries community altogether can lead towards a sustainable fisheries resource management for an estuary. Such integrated studies are required for estuarine management which is still not widely practiced in Malaysia.

Realizing those shortcomings, this research has been designed in such a way that integrates the investigation of the water characteristics and resource importance of estuary, faunal diversify and their seasonal variations and interaction of fishes of the estuary with different feeding guilds. Towards achieving the objectives, some research questions were developed *viz.* How productive the estuary is in relation to its water characteristics and resources? What is the temporal and spatial diversity of planktons and how seasonality and water parameters govern plankton composition at Sibuti mangrove estuary? How fishes in the estuary interact with food items and form feeding guild in Sibuti mangrove estuary. It is expected that answers of the above mentioned questions would give an understanding of mangrove estuarine ecosystem, its food chain pattern, energy flow and richness of biodiversity.

1.3 Rationale of the Study

Understanding the ecosystem ecology of a mangrove dominated estuary is important as it encompasses aquatic biota *viz*., composition of phytoplankton and zooplankton, the productivity of different trophic level, food chain with primary producer (phytoplankton) and influence of physico-chemical parameters. Better understanding of the ecology of estuary debts into its water characteristics along with the abundance and diversity of primary producers (phytoplankton) secondary consumer (zooplankton) and finally the tertiary consumers (fishes) and feeding habit of fishes which in an integrated manner can depict the functioning of the estuary. Plankton diversity and dynamics of an estuary is essential to know for evaluating contribution of biological parameters into the food chain specially into the feeding guild.

The extensive studies on the ecology of estuarine environment in the equatorial tropics are few (Chua,1973). Exisitng studies on estuarine ecology of the Malaysia are also very few (Mokhtar *et al.* 1994; Ibrahim *et al.*, 1995 and Tahir *et al*. 2008). None of the mentioned research either included comprehensive seasonal data on hydrographical factors or consider the physiological adaptation of estuarine flora and fauna or the interrelationship of the biota and the environmental factors.

Sibuti mangrove estuary, the present study area is reported as pristine and undisturbed on the basis of its water quality, fisheries diversity and plankton diversity (Gandaseca *et al*., 2011; Saifullah *et al*., 2014a and Hoque *et al*., 2015). The estuary is margined by diverse mangrove vegetation which is believed to contribute to the higher productivity of the estuary. Some descrete researches reported for this estuary can not draw a complete ecological scenario. Considering the mentioned points, present study attempted an ecological analysis through integration of the physical, chemical and biological characterisitcs of the Sibuti mangrove estuary.

It is hypothesized that being pristine ecosystem, the Sibuti mangrove estuary would demonstrate its good standing in terms of water quality, characteristics of typical tropical estuary, diverse planktonic composition and a gradient of feeding pattern of fishes in relation to seasonal variability. The end product of this study will be useful to better understand the dynamic process of a tropical estuary,

its faunal and floral diversity and finally feeding habit and feeding giuld of the estuary. Thus, an integarted ecological feature obtained from this study could be a base for the better management of Sibuti mangorve estuary(SME).

This study investigated the water characteristics, biotic community structure encompassing seasonal assemblage, composition and diversity of phytoplankton and zooplankton and their influence towards food and feeding habit of fishes in the estuary. As mentioned earlier also that ecological knowledge is must for developing a management for an ecosystem, the outcome of the research would be a baseline for tropical estuarine ecosystem manager as well as for further researchers who will work on complex ecology of a mangrove estuary. Considering those points, following objectives were selected to check throughout the study.

1.4 Objectives

Objectives of the study were

1. To characterize the Sibuti mangrove estuary with assessment of physico-chemical and biological parameters;
2. To investigate the community composition and seasonal variation of phytoplankton in the Sibuti mangrove estuary;
3. To investigate the composition and diversity of zooplankton in the Sibuti mangrove estuary in relation to seasonal changes and
4. To determine the food and feeding habit of some fishes in the Sibuti mangrove estuary.

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LIST OF PUBLICATIONS
Published and Accepted Papers

Saifullah, A.S.M., Abu Hena, M.K., Idris, M.H.,Halimah, A.R. and Johan, I. 2014. Composition and diversity of phytoplankton from mangrove estuaries of Sarawak. *Journal of Biological Science* 14(5): 361-369. (**ISI** and **Scopus** cited).

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Saifullah, A.S.M., Abu Hena, M.K., Idris, M.H.,Halimah, A.R. Seasonal pattern of phytoplankton composition and abundance in Sibuti mangrove estuary, Sarawak, Malaysia.

Saifullah, A.S.M., Abu Hena, M.K., Idris, M.H., Halimah, A.R. Zooplankton diversity and abundance in mangrove waters from Sibuti mangrove estuary, Miri, Malaysia.

Saifullah, A.S.M., Abu Hena, M.K., Idris, M.H., Halimah, A.R. Feeding habit of common fishes and their trophic linkage in mangrove estuary of Sibuti, Sarawak, Malaysia.

Saifullah, A.S.M., Abu Hena, M.K., Idris, M.H., Halimah, A.R. Feeding habit of common fishes and their trophic linkage in mangrove estuary of Sibuti, Sarawak, Malaysia.

Saifullah, A.S.M., Abu Hena, M.K., Idris, M.H., Halimah, A.R. Classifying estuary using multi approaches in Miri, Sarawak.

Saifullah, A.S.M., Abu Hena, M.K., Idris, M.H., Halimah, A.R Review of zooplankton and related study in the coastal waters of Malaysia.