UNIVERSITI PUTRA MALAYSIA

# *PHYSICAL HABITAT ASSESSMENT FOR DOMINANT FRESHWATER FISH SPECIES IN GALAS RIVER BASIN, KELANTAN, MALAYSIA*

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FPAS 2016 9

# PHYSICAL HABITAT ASSESSMENT FOR DOMINANT FRESHWATER FISH SPECIES IN GALAS RIVER BASIN, KELANTAN, MALAYSIA

By

**NORFADILAH BINTI AINI**

**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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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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**September 2016**

**Chair: Nor Rohaizah Jamil, PhD**
**Faculty: Environmental Studies**

This study elucidates the relationship of different flow regimes as a function of physical microhabitat changes, besides determining the optimum flow required to maintain suitable habitat for three target freshwater fish species. These species namely *Mystacoleucus obtusirostris (Sia), Barbonymus schwanenfeldii (Lampam sungai)* and *Cyclocheilichthys apogon (Temperas*) were selected based on five criteria; most sensitive, transferability, economic and social interest, vulnerability and extent available information. The issue need to be tackle in this study is river basin significantly causes alteration to the flow regime as well as deterioration of water quality, which subsequently causes alteration to the fish population in terms of its wellbeing and population growth. Any alteration by human activities put the integrity of the river ecosystem at risk in study area especially sedimentation problem. The increasing on human activities gives negative impact to the freshwater fish in the river. Moreover, it more challenge when these freshwater fishes are regarded as an economic source to the local residents along the river. Regarding this issue, hydrological index method (7Q35 analysis) and physical habitat simulation (Physical Habitat Simulation Model) are adopted for an environmental flow assessment. Besides that, in this study is analysing the hydrological factor that affected the flow regimes for example water quality analysis, land use changes and soil loss.  From the calculation of minimum annual mean (MAM) has recorded 7-day low flow for every 50-year period is about 5.786 $m^3$/s for low flow event. Otherwise, from the simulation water levels need to cater for these three freshwater fish species to survive in certain reach along the Galas River species are at 0.40 m (*Mystacoleucus obtusirostris*), 0.60 m (*Barbonymus schwanenfeldii*) and 0.40 m (*Cyclocheilichthys apogon*). The recommended flow regimes in the study area are based on the surface area of usable habitat calculation for three targeted species respectively is at 6.42 $m^3$/s,10.89 $m^3$/s and 7.26 $m^3$/s. Lastly, the recommended flow regime for the Galas River is 10.89 $m^3$/s and it derived for this study as one of propose input to the assessment of alternative stream flow management in the future.

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

**PENILAIAN HABITAT FIZIKAL UNTUK SPESIS DOMINAN IKAN AIR TAWAR DI LEMBANGAN SUNGAI GALAS, KELANTAN, MALAYSIA**

Oleh

**NORFADILAH BINTI AINI**

**September 2016**

**Pengerusi: Nor Rohaizah Jamil, PhD**
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Kajian ini menghuraikan hubungan aliran rejim yang berbeza sebagai fungsi perubahan fizikal mikrohabitat, di samping menentukan aliran optimum yang diperlukan untuk mengekalkan habitat yang sesuai untuk tiga sasaran spesies ikan air tawar. Spesies iaitu *Mystacoleucus obtusirostris* (Sia), *Barbonymus schwanenfeldii* (Lampam sungai) dan *Cyclocheilichthys apogon* (Temperas) telah dipilih berdasarkan lima kriteria; paling sensitif, dipindah milik, kepentingan ekonomi dan sosial, kelemahan dan tahap maklumat yang ada. Isu ini perlu ditangani dalam kajian ini adalah lembangan sungai ketara menyebabkan perubahan kepada aliran rejim serta kemerosotan kualiti air, yang kemudiannya menyebabkan perubahan kepada populasi ikan dari segi pertumbuhan dan kesejahteraan penduduknya. Sebarang perubahan oleh aktiviti manusia meletakkan integriti ekosistem sungai berisiko di kawasan kajian terutama masalah pemendapan. Aktiviti manusia yang semakin meningkat memberi kesan buruk kepada ikan air tawar di sungai. Selain itu, ia lebih memberi cabaran apabila ikan-ikan air tawar dianggap sebagai sumber ekonomi kepada penduduk tempatan di sepanjang sungai. Mengenai isu ini, kaedah hidrologi indeks (7Q35 analisis) dan simulasi habitat fizikal (Physical Habitat Simulasi Model) yang digunakan untuk penilaian aliran alam sekitar. Selain itu, dalam kajian ini adalah menganalisis faktor hidrologi yang menjejaskan aliran rejim untuk analisis kualiti air contoh, perubahan guna tanah dan kehilangan tanah. Dari pengiraan purata tahunan minimum (MAM) telah mencatatkan 7 hari rendah aliran bagi tempoh setiap 50 tahun adalah kira-kira 5,786 $m^3/s$ untuk acara aliran rendah. Jika tidak, dari simulasi paras air perlu untuk menampung tiga spesies ikan air tawar untuk terus hidup dalam jangkauan tertentu di sepanjang spesies Sungai Galas di 0.40 m (*Mystacoleucus obtusirostris*), 0.60 m (*Barbonymus schwanenfeldii*) dan 0,40 m (*Cyclocheilichthys apogon*). rejim aliran yang dicadangkan di kawasan kajian adalah berdasarkan kepada kawasan permukaan pengiraan habitat boleh digunakan untuk tiga spesies yang disasarkan seperti berikut pada 6.42 $m^3/s$, 10.89 $m^3/s$ dan 7.26 $m^3/s$. Akhir sekali, rejim aliran yang disyorkan untuk Sungai Galas adalah 10.89 $m^3/s$ dan ia diperolehi untuk kajian ini sebagai salah satu cadangan input kepada penilaian pengurusan aliran aliran alternatif pada masa akan datang.

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I certify that a Thesis Examination Committee has met on 28 September 2016 to conduct the final examination of Norfadilah binti Aini on her thesis entitled "Physical Habitat Assessment for Dominant Freshwater Fish Species in Galas River Basin, Kelantan, 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 (insert the name of relevant degree).

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Name of Member of Supervisory Committee: ______________________________

## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF ABBREVIATIONS

| | |
|---|---|
| UP | Ulu Pulai |
| GM | Gua Musang |
| KT | Kampung Terah |
| LK | Limau Kasturi |
| BB | Bertam Baru |
| DBG | Dabong |
| BB | Bertam Baru |
| KG | Kuala Geris |
| DS | Downstream |
| GEC | Global Environment Centre |
| WUA | Weighted Usable Area |
| PHABSIM | Physical Habitat Simulation Model |
| IFIM | In-stream Flow Incremental methodology |
| HSC | Habitat Suitability Curve |
| EFA | Environmental Flow Assessment |
| EF | Environmental Flow |
| NLRP | National River Linking Project |
| EIA | Environmental Impact Assessment |
| DEIA | Detailed Environmental Impact Assessment |
| IUCN | The World Conservation Union |
| US | United States |
| JRI | JPS River Index |
| DID | Department of Irrigation and Drainage |
| TSS | Total Suspended Solids |
| TDS | Total Dissolved Solids |

| | |
|---|---|
| JICA | Japan International Cooperation Agency |
| WQI | Water Quality Index |
| DOE | Department of Environment |
| INWQS | Interim National Water Quality Standard |
| DO | Dissolved Oxygen |
| SS | Suspended Solids |
| BOD | Biological Oxygen Demand |
| COD | Chemical Oxygen Demand |
| DOAM | Department of Agriculture Malaysia |
| RUSLE | Revised Universal Soil Loss Equation |
| GIS | Geographical Information System |
| ADCP | Acoustic Doppler Current Profiler |
| HDPE | High-density polyethylene |
| USGS | United States Geological Survey |
| MAM | Mean Annual Minimum |
| µS/cm | micro-Siemens per centimeter |
| mg/l | milligrams/liter |
| °C | degree Celsius |
| m/s | meter per second |
| $m^2/s$ | meter square per second |
| $m^3/s$ | meter cubic per second |
| WSL | Water Surface Level |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

River has been known to be essential to all forms of growth and development for humans, plants, and animals (Lim, 2014). Due to the importance of river as food producer and water resource, the sedimentation problem attributed by dense development resulted to physical habitat loss for various aquatic life forms, thus affecting the ecological balance of river ecosystem, proves to be an emerging issue. Physical characters of river include channel and floodplain morphology, sediment size and heterogeneity and other geomorphic features (Poff, 2009). The impacts of rapid development involving man-made alterations to river particularly its ecosystem have deteriorated (Shazili *et al.*, 2006). In a natural river ecosystem, the dynamic processes between the biotic and abiotic component are crucial in determining the fate of river integrity. Any alteration to these components will directly or indirectly cause impact on the dependent species, especially the fish. Fish commonly be used as the immediate indicator of flow regime changes have gained a lot of concern since last few two decades. Thus, due to any changes to its original habitat will cause alteration to its population, thus will influence directly on the food source availability. Flows, the master variable that determine the fate of all processes of the river are recognized by the determined factors in most river related issues. Flow regime is one of the central importance in sustaining the ecological integrity of flowing water systems.

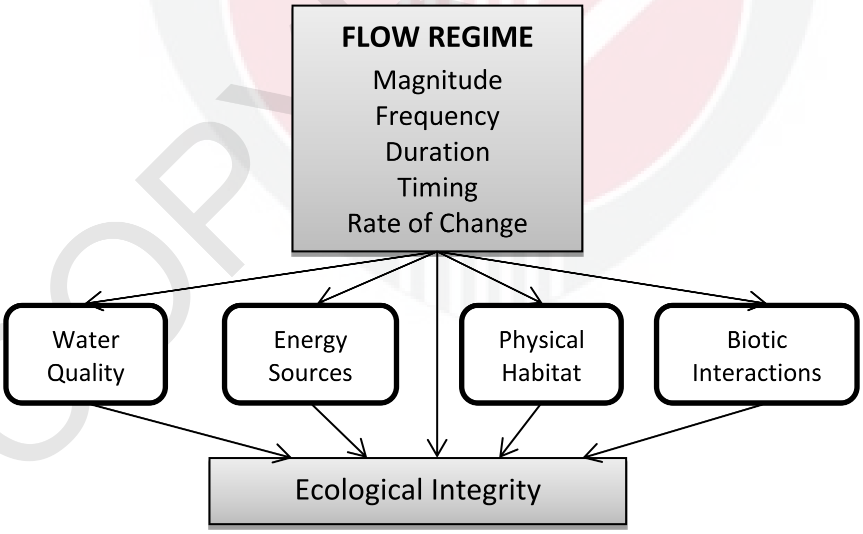


**Figure 1.1: Conceptual Model of Major Driving Forces Influencing Freshwater Ecosystems**

(Source: Karr, 1991)

In Figure 1.1 shows the conceptual models that contribute the flow regime components, which includes duration, timing, magnitude, frequency and rate of change. For the five components influence ecological integrity, directly and indirectly, through their effects on other primary regulators of integrity. Besides that, these fish species have evolved, which influences the ecosystems, adjusting the annual cycles. They have also developed strategies for survival and often require periodic hydrologic extremes caused by floods and droughts that exceed the normal annual high or low in flows, temperature, and other factors. Low flow reduces stream amount and wetland habitat area, which causes disconnection of a river from its floodplain. These phenomena can lead to lower populations of fish and wetland wildlife, invasion of exotic species; and reduces the possibilities for pollution assimilation and protection of downstream water quality (Baron and Poff, 2004). Flow of unnaturally high magnitude can overrun shallow water habitat such as stream riffles, alters geomorphological characteristics of streams such as channel course and substrate, and increases flood risks (Katz, 2006).

The timing and frequency of different flow events often play various roles in seed dispersal, signalling mating periods, preventing invasion of exotic species, flushing out sediments, and cycling nutrients. High water in-stream can also be harmful to the river ecosystem because many species of plant and aquatic animals have limited time to adjust to the sudden changes in the ecosystem. Water withdrawals create a challenge to balance water uses between various human activities and ecological values, as both reduce the stream flow. The environment has a natural self-cleaning capacity and resilience to water shortages but when extremes occur, it causes biodiversity loss, affecting livelihoods, and damages the natural food sources such as fishes and other aquatic life forms. Eventually, it requires high costs for clean up and rehabilitation process (Richter *et al.*, 1997).

Based on Tharme (2003), environmental flow assessment and maintenance are relatively new practices for the water sector, particularly in developing countries. There is still lack of awareness regarding this concept and its application. Most countries especially in developing countries do not have any environmental flow legislation or accepted approaches for the assessment of these flows. In this case, Malaysia is one of the countries that new implant the environmental flow. As known, Integrated Water Resource Management (IWRM) is started implantation only in 2000s. In 2016s only a few water systems has fully integrate IWRM in the management. Integrated River Basin Malaysia (IRBM) as the subsection of IWRM and environmental flow is under the IRBM.

Thus, EFA is considered to fulfil the objective of meeting human demand on water resources and at the same time, maintaining ecological integrity (Tharme, 2003). Thought, water is an important medium for any ecosystem in the world, both in qualitative and quantitative terms. As known, the sources of water are the rivers, lakes, and sea. Reduce in water quantity and deteriorating water quality pose serious negative impacts on the ecosystems, especially to humans and aquatic life forms (Richter *et al.*, 1996). Therefore, the need to preserve and be aware of the significance of water sources is essential. Table 1.1 shows the list of river functions in Malaysia with different purposes; for navigation and transport, fisheries, and hydrological cycle.

**Table 1.1 List of river functions in Malaysia**

| Functions | Description |
|---|---|
| Drinking water | Designated for human consumption; must be fit for drinking, cooking food, and other domestic purposes. A raw water criterion (water before treatment) is dependent upon the technology level at the potable water treatment plant. |
| Industry | May be used by industries such as pulp and paper plants, chemical, and steel manufacturers, for processing non-food products, and for cooling purposes. |
| Navigation | Water may be used for the commercial transfer of humans, animals, and goods. |
| Livestock | Water may be consumed by livestock and poultry, and used for cleansing purposes. |
| Aquatic life support | Water may be used to maintain the ecological integrity of rivers including the sustained growth and propagation of aquatic organism (fish, invertebrates, aerophytes, and plankton), semi aquatic organisms, and terrestrial wildlife dependent on surface water for survival. |
| Irrigation | Water may be used supplement rainfall for growing crops. |
| Fishing | May be used for legal fishing for the purpose of human consumption. |
| Recreation | Usage is divided into two categories; primary and secondary contact. Primary contact refers to body immersion in water, e.g. swimming. Secondary contact refers to body contact with water, e.g. rafting and canoeing. |

Source: Parish, 2011

## 1.2 Problem Statement

In naturally functioning river ecosystems, unaltered in any way by human activities, each environmental driver has a natural range of variability that depends on the geomorphic characteristics of the catchment, the climatic regime, as well as local factors. IRBM is the important component in IWRM to manage the river basin. Based on previous studies that related indicated that the rapid development at the Galas River basin significantly causes alteration to the flow regime as well as deterioration of water quality, which subsequently causes alteration to the fish population in terms of its wellbeing and population growth. Any alteration by human activities put the integrity of the river ecosystem at risk.

Therefore, considering the sedimentation problem that causes alteration to the physical morphology of the river channel, thus affecting the flow regime and physical habitat, this study undertakes to identify the main factors to this issue that affects the population of these fishes. Protecting the natural habitat of these fishes is becoming a challenge when these freshwater fishes are regarded as an economic source to the local residents along the river.

Many regulated streams are characterized by high variable and unpredictable flow regimes. Since changes in stream flow directly modify the physical habitat, streams with high variable flows provide highly unstable aquatic habitats. The natural variable flows create and maintain the dynamics of in-channel and floodplain conditions, as well as habitats that are essential to aquatic and riparian species. Hydrologic variability has direct impact on the river ecosystem through the creation of habitat mosaic or simply maintains the channel morphology. The flow regimes, which is strongly correlated with many critical physicochemical characteristics of river such as water quality, channel geomorphology as well as the habitat diversity, is considered as the main limiting factor in distribution and abundance of riverine species through the regulation of ecological integrity of flowing waters.

Additionally, the Department of Irrigation Malaysia (2013) recorded water level of certain river reach particularly around Dabong section has shown drought flow (low flow) for various return periods; for seven consecutive days for the last five years. Significant drop in the number of fish catch and population of fishes are also reported simultaneously during the same period of time (Peck Yen T. and Rohasliney H., 2010), which explains the need of this study to determine the low flow event for future mitigation by local authorities. So, if insufficient allocation of water augmented in the river, the possibility of further declined fish population can be expected.

## 1.3 Research Objectives

The general objective of the study is to determine the correlation between the stream flow changes along Galas River in three different seasons (low flow, normal flow, and high flow) and the favorability of the stream channel, to serve as an optimized habitat for the targeted fish species throughout the year. There is a critical need to identify the main factors that affect the population growth of targeted fish species in the river system. The specific objectives of this study are as follows:

1) To elucidate the relationship of different flow regime as a function of physical microhabitat changes towards the targeted fish species.
2) To model the impact of different flow regime on the targeted fish species at critical reach with the hydrological properties and selected water quality parameters.
3) To recommend optimum environmental flow regime for three targeted fish species at Galas River, Kelantan based on weighted usable area (WUA index).

## 1.4 Scope of Study

This study aims to identify the relationship between the flow regimes and the favorability of the stream channel to serve as an optimized habitat for the targeted fish species. The floe regimes, which is strongly correlated with many critical physicochemical characteristics of river such as water quality, channel geomorphology as well as the habitat diversity, is considered as the main limiting factor in distribution and abundance of riverine species through ecological integrity of flowing waters regulation.

By adopting the Physical Habitat Simulation Model (PHABSIM) is one of the most commonly used models in habitat simulation method since 1970's. This study aims to identify the main factor that limits the fish population growth by focusing on the physical microhabitat analysis in conjunction to flow dependent function. The recommended flow regime is derived from weighted usable area (WUA index) end of this study. It is proposed to be an input to one of assessment alternative stream flow management in the future. Habitat suitability criteria are necessary in the In-stream Flow Incremental Methodology (IFIM) as input to the PHABSIM. Therefore, the Habitat Suitability Curve (HSC), which is one of important input in PHABSIM method, is developed for the three pre-identified fish species namely *Mystacoleucus obtusirostris* (Sia), *Barbonymus schwanenfeldii* (Lampam Sungai), and *Cyclocheilichthys apogon* (Temperas). These three species are selected based on several factors, most sensitive, transferability, economic and social interest, vulnerability and extent available information.

Apart from that, this study considers the specific HSC for these three species as a benchmark or optimum level for the WUA optimization in the recommended seasonal flow regime at Galas River. The HSC and information related to the flow regime recommendation are of significant importance in the future management of Galas River, as well as providing information transferability potential to other river systems of similar level and mode of alteration. This study provides evidence that an environmental flow assessment is critically needed in Malaysia. This study incorporates hydrological analysis and modeling processes, which can be used as a management tool in environmental flow assessment for watershed.

## 1.5 Environmental Flow Assessment (EFA)

Environmental flow which also commonly being addressed as midstream flow is referred to the allocated amount of water to be maintained in the river channel. The five main components of environmental flow are durations, time, rate of change, magnitude and frequency.

The environmental flow assessment maintains and reserves water in the river, ensuring the continuous functions of ecological processes that provides much needed goods and services for human use and maintenance of biodiversity. Based on Gordon *et al*. (2004), the study of environmental flow analysis for river management is highly demanded; it is defined as the allocation of water made available for maintaining ecological processes in a desirable state (Mazvimavi *et al.,* 2007). On a global scale, existing and projected future increases in water demands have resulted in an intensifying, complex conflict between the development of rivers as well as other freshwater ecosystems, water and energy sources, and their conservation as biologically diverse, integrated ecosystems (GCI, 2000). A growing field of studies dedicated to assess requirements of rivers for their own water, to enable satisfactory trade-offs in water allocation among all users of the resources and available resources in the river, has been stimulated by this ongoing conflict.

Although historically, the United States has been at the forefront of the development and application of methodologies for prescribing environmental flow, using 37% of the global pool of techniques, parallel initiatives in other parts of the world have increasingly provided the impetus for significant advances in the field. In a recent review of international environmental flow assessment, Tharme (2003) recorded 207 different methods within 44 countries.

Furthermore, these environmental flow assessments are divided into four categories, which are Hydrological Index Methods, Habitat Discharge Methods, Habitat Simulation Methods, and Holistic Approaches. The selections of method based on the three categories are data availability, duration of study and validation of the outcomes. For this study, Habitat Simulation Methods has been adopted using the PHABSIM which were established since late 1970s. This is because the methods compatible with the duration of study take only one to two years and the data availability included hydraulic data and habitat data. The validation of the outcomes is high reliability than other method.

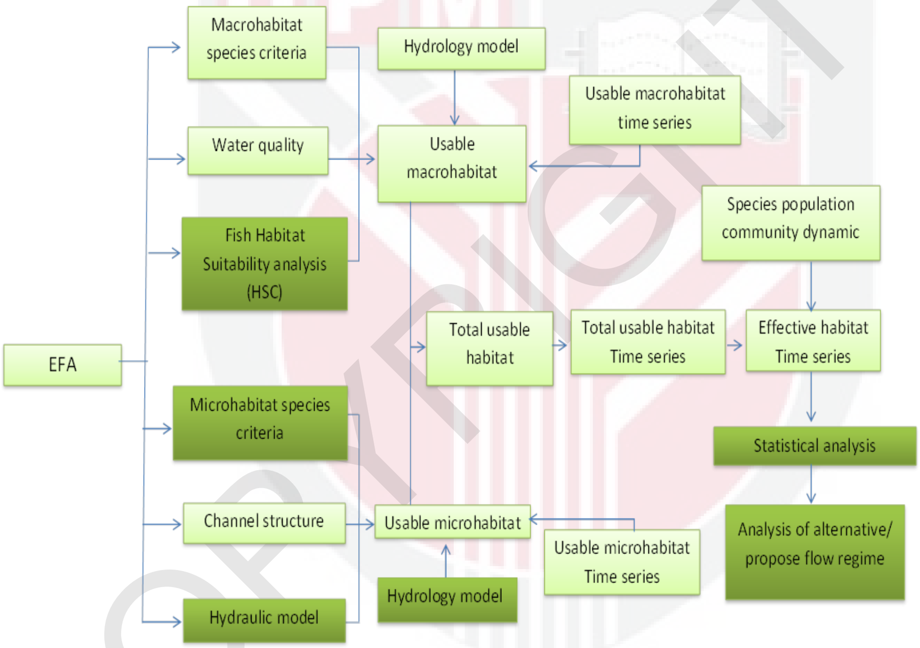


**Figure 1.2: Framework of Environmental Flow Assessment (EFA)**

In Figure 1.2 shows the framework of environmental flow assessment using in this study. This is suitable for interpretation among aquatic ecologists, hydrologists, and water resources engineers. EFA discussed about the advantages and limitations of this method, and subsequently concluded with recommendation of a longer-term environmental flow research program. Rather than being considered to provide solution for environmental water demand estimation, this study should be regarded as a pivotal step towards the development of the future national environmental flow tools and policies. EFA has always been considered to monitor human activities such as impoundment, diversions, groundwater exploitation, and use of water for hydropower generation, and catchment land-use, which will change the flow regime (Baron *et al.*, 2002). In some other countries such as New Zealand, Australia, United States, and Canada, EFA is already made compulsory in their environmental impact assessment (EIA) for project development involving water withdrawal in aquatic ecosystems (Dyson *et al.*, 2003). Thus, a very specific and strategized environmental flow planning was integrated in the water resource management since the year beginning.

Furthermore, the issues of environmental flow assessment and management are high on the world agenda at present. At the same time, it remains a new research field. In many countries, a crude nationwide assessment of water requirements of rivers and their associated aquatic ecosystems does not exist. It is prudent to start addressing these issues; for example, in India, these issues have become particularly relevant in the view of the major inter-basin water transfers planned under the National River Linking Project (NRLP) (Smakhtin and Anputhas, 2006).

## 1.6 Significance of Study

Currently, studies on the EFA in Malaysia particularly river are limited. This study aims to bridge such information gap as well as to provide insights on the physical habitat characteristics and abundance level for these three targeted freshwater fish species in Galas River Basin. Therefore, a combined EFA approach namely hydraulic modeling analysis and habitat modeling analyses are carried out to determine the environmental flow level that should be maintained in the river based on the three indicator species. Unlike the strict conservative perspective, the selection of fish species not only consider the species conservation value, but also pay equal attention on the species significant contribution source of food and economic, have sufficient info that make this assessment replicable, and to more consideration. The species selection, however are not limited to fish only as there are other riverine species can use as bioindicator in EFA studies. For this study, fish was selected as boiindicator as this riverine inhabitant are among the first to be directly impacted when there is changes in flow regimes. Such approach provides robust explanation and greater understanding on the intrinsic factors responsible for the changes on physical habitat characteristics including flow regime, water quality, and energy output that are applicable to tropical rivers.

Quantitative outputs from this study include: (i) the recommended flow regimes that are to be maintained at the study area (based on calculating the surface area of usable habitat for the three targeted species); and (ii) prediction of whether the wellbeing and population growth of the targeted fish species increase with the suitability of physical microhabitat in term of flow-dependent system. The recommended flow regimes derived at the end of this study is proposed as an input to an assessment of alternative stream flow management in the future. It is predicted that the wellbeing and population growth of the target fish species will increase with the suitability of physical microhabitat in term of flow dependent system. Additionally, appropriate recommendations and references are to be provided to the local authorities and selected agencies in managing and maintaining the river ecosystem in good condition.

## 1.7 Thesis Organization

This thesis consists of five chapters, which provides hydraulic data and habitat data for the simulation model as well as their potential flow regime in the study area. The chapters in this thesis have been organized as follows.

**CHAPTER 1** discusses briefly on the background of this study, problem statement, and the objectives of this study. Scope and significance of study are provided to provide better insights of this study**.** This chapter further introduces the physical habitat for freshwater fish species and the importance of freshwater fish. Besides that, this chapter discusses on the definition, method of environmental flow assessment and river functions in Malaysia and other countries.

**CHAPTER 2** provides comprehensive literature review in relevance to this study. The review on related studies and current practices obtained from relevant previous studies provide a background to develop theory, methodology, and research tools for this study. It focuses on the environmental flow assessment and the physical habitat characteristics influencing the target species population in this context the fish. Besides that, it further describes about the Physical Habitat Simulation Model (PHABSIM) based on previous studies. This chapter also highlights the strengths and weaknesses that contribute to the field of knowledge in this study.

**CHAPTER 3** discusses on the principle of method applied in the study, which specific emphasize was given on Physical habitat simulation approach, where the PHABSIM model was adopted to enhance the result interpretation of the end of the study, data collection which are primary and secondary data analysis are equally important in completing each stage of the study. The assumption and principle behind each approach in the method application or modification were also being discussed in this chapter. Some limitation and attempt to solve specific issues within the simulation stage also is being sufficiently addressed in this section. Therefore, this chapter provides detailed explanation on the methodology applied in this study.

**CHAPTER 4** contains the results and discussion in this study. The hydraulic data and habitat data for the fishes from three sampling activities are provided with the results from statistical analysis and simulation model. The results obtained are presented in graphs and tables such as longitudinal profile, length-weight relationship, habitat suitability curve, and weighted usable area. Furthermore, this chapter provides findings with respect to the three objectives presented in this study.

**CHAPTER 5** serves as a conclusion to this thesis. It summarizes the results from Chapter 4 with respect to the research objectives. This chapter includes recommendations to improve the quality of this study for future studies. This chapter proposes several recommendations, which might be useful in design and optimal sampling strategy for future monitoring purposes, as well as further actions to conserve and protect these freshwater fish species and the river quality.

## REFERENCES


Abowei, J.F.N., (2010). Salinity, Dissolved Oxygen, pH and Surface Water Temperature Conditions in Nkoro River, Niger Delta, Nigeria. Adv. *Journal Food Science Technology*, 2(1): 16-21.

Afzal Khan, M., Jafri, A. K. and Chadha, N. K.. (2004). Growth and body composition of rohu, Labeo rohita(Hamilton), fed compound diet: winter feeding and rearing to marketable size. *Journal of Applied Ichthyology*, 20: 265-270.

Allan, J.D. and M.M. Castillo. (2007). *Stream ecology: structure and function of running waters*. 2nd edition. Chapman and Hall, New York, N.Y.

Ambak, M.A., Mansor, M.I., Mohd-Zaidi, Z. & Mazlan, A.G. 2010. Fishes of Malaysia. Kuala Terengganu: Publisher Universiti Malaysia Terengganu. p. 344.

Ahmad A K, Mushrifah I and Shuhaimi-Othman M. (2009). Water quality and heavy metalconcentrations in sediment of Sungai Kelantan, Kelantan, Malaysia: A baselinestudy. Sains Malaysiana38(4): 435–442.

Ambak M A, Isa M M, Zakaria M Z and Ghaffar M A. (2010). Fishes of Malaysia. KualaTerengganu: Universiti Malaysia Terengganu. Ambak M A and Zakaria M Z. (2010). Freshwater fish diversity in Sungai Kelantan. Journal of Sustainability Science and Management 5(1): 13–20

Amneera, W. A., Najib, N. W., Yusof, S. R., & Ragunathan, S. (2013). Water Quality Index of Perlis River, Malaysia. *International Journal of Civil & Environmental Engineering IJCEE-IJENS*, Vol 13; 55-59.

A.P. Fialho, L.G. Oliveira, F.L. Tejerina-Garro, L.C. Gomes. (2007). Fish assemblage structure in tributaries of the Meia Ponte river, Goias, Brazil Neotrop. *Journal of Applied Ichthyology*, 5, pp. 53–60.

Ayoade, A.A., Ikulala, A.O.O. (2007). "Length-weight relationship, condition factor and stomach contents of *Hemichromis bimaculatus*, *Sarotherodon melanotheron* and *Chromidotilapia guentheri* (Perciformes: Cichlidae) in Eleiyele Lake, Southwestern Nigeria", Revista de Biologia Tropical, 55(3-4), 969-977.

Baron, J. S., Poff, N. L., Angermeier, P. L., Dahm, C. N., Gleick, P. H., Hairston, N. G. Jr, Jackson, R. B., Johnston, C. A., Richter, B. D. and Steinman, A.D. (2002). Meeting ecological and societal needs for freshwater. *Ecological Applications*, 12(5):1247–1260

Bishop, K.A. & Forbes, M.A. (1991). The freshwater fishes of northern Australia in Haynes, C.D., Ridpath, M.G. & Williams, M.A.J. (eds) Monsoonal Australia, Landscape, Ecology and Man in the Northern Lowlands. A. A. Balkema, Rotterdam & Brookfield, pp 79 – 107.

Bovee, K. D., Lamb, B.L., Bartholow, J. M., Stalnaker, C.B., Taylor, J. and Henriksen, J. (1998).Stream habitat analysis using the instream flow incremental methodology. U.S Geological Survey, Biological Resources Divisions Information and Technology Report USGS /BRD -1998-0004.

Bovee, K. D. (1986). Development and evaluation of habitat suitability criteria for use in the instream flow incremental methodology. U.S. Fish and Wildlife Service, Washington, D.C., Instream Flow Information Paper 21, Biological Report, 86(7).

Bovee K D. (1982). A Guide to Stream H abitat Analysis Using the Instream Flow Incremental Methodology.Instream Flow Information Paper 12.FWS/OBS-82/26. USDI Fish and Wildlife Services, Of Ice of Biology Services: Washington, DC.

Bovee, K.D., B.L. Lamb, J.M. Bartholow, C.B. Stalnaker, J. Taylor, and J. Henriksen.(1998). Stream habitat analysis using the instream flow incremental methodology. Information and Technology Report 1998-0004. Fort Collins, CO: U.S. Geological Survey. 130 p.

Brookes A. (1995). River channel restoration: theory and practice. In Changing River Channels, Gurnell A, Petts GE (eds). John Wiley & Son, Inc.: Chichester; 369–388Bunn SE, Arthington AH. (2002). Basic principles and consequences of altered hydrological regimes for aquatic biodiversity. Environmental Management 30(4): 492±507.

Brookes, A. (1988). Channelized Rivers: Perspectives for Environmental Management. John Wiley & Sons, Chichester.

Brussock, P.P., Brown, A.V. and Dixon, J.C. (1985). Channel form and stream ecosystem models. Water Resources Bulletin 21:859–866.

Cowx, I.G. & Welcomme, R.L. (1998).Rehabilitation of Rivers for Fish.FAO, Fishing News Books, Oxford, UK & Malden, MA.

David L. Rosgen. (1996). Applied river morphology. 2nd ed. Colarado: Wildland Hydrology Books.

DID 2009. *The Development Related to River and Reserve*. Department of Irrigation and Drainage, Ministry of Natural Resources and Environment, Kuala Lumpur, Malaysia.

DID 2011. *Reviewof the National Water Resources Study (2000-2050) and Formulation of National Water Resources Policy*. Final Report, Volume 10-Kelantan. Department of Irrigation and Drainage, Ministry of Natural Resources and Environment, Kuala Lumpur, Malaysia.

Dyson, M.; Bergkamp, G.; and Scanlon, J. eds. (2003).Flow. The essentials of environmental flows. Gland, Switzerland and Cambridge, UK: IUCN. xiv + 118 pp.

Echelle, A. A., A. F. Echelle, and L.G. Hill. (1972). Interspecific interactions and limiting factors of abundance and distribution in the Red River pupfish, *Cyprinodon rubrofluviatilis*. American Midland Naturalist 88:109-130.

Efitre, J., Chapman, L.J., Murie, D.J. (2009), "Fish condition in introduced tilapias of Ugandan crater lakes in relation to deforestation and fishing pressure", Environmental Biology of Fishes doi: 10.1007/s10641-009-9461-z (Jan 5, 2012).

Farzana, Y., Saira, K. (2008), "Length-weight relationship and relative condition factor for the halfbeak Hemiramphus far Forsskal, 1775 from the Karachi coast", University Journal of Zoology, Rajshahi University 27, 103-104.

Fishbase.org. http://www.fishbase.org/ [Assessed online 12 September 2014]

Fishbase.org. http://www.fishbase.org/ [Assessed online 28 November 2014]

Fishbase.org. http://www.fishbase.org/ [Assessed online 15 January 2015]

Fishbase.org. http://www.fishbase.org/ [Assessed online 10 February 2015]

Fishbase.org. http://www.fishbase.org/ [Assessed online 5 May 2015]

Fishbase.org. http://www.fishbase.org/ [Assessed online 8 June 2015]

Fox, M. G. and A. Keast. (1990). Effects of winterkill on population structure, body size, and prey consumption patterns of pumpkinseed in isolated beaver ponds. *Canadian Journal of Zoology*, 68, 2489–2498.

Froese, R. (2006), "Cube law, condition factor and weight-length relationship: history, meta-analysis and recommendations", *Journal of Applied Ichthyology*, 22, 241-253.

Gadowaski, D. M. and S. M. Caddell, (1991). Effects of temperature on early life history stages of California halibut Paralichthys californicus. Fish Bull., 89: 567-576.

Gordon,N.D. (1996). The hydraulic geometry of the Acheron River, Victoria, Australia. Centre for Environmental Applied Hydrology report, University of Melbourne, Australia, February, 1996.

H. Rohasliney, J. Siti Amirah, A. S.Nurul Izzati, A. Mohd Rezza Petra, M. Y. Miti Fateema Yusliza and M.S. Amir Shah Ruddin. Fish diversity in unpolluted and polluted river, Kelantan, Malaysia. In: Devagi K., Meekiong K., Isa I., Lim C.K., Lim P.T., Hairul A.R., Y E., Azaima R., Ho W.S., Samsur M., Jamilah J., Cheksum T. & Fasihuddin A., (eds). Proceeding of Conference on

Natural Resources in the Tropics 3. Universiti Malaysia Sarawak, Samarahan, Sarawak. 2010, pp. 476-491.

H. Rohasliney, and D.C. Jackson. Fish assemblages in streams subject to anthropogenic disturbances along the Natchez Trace Parkway, Mississippi. Journal Tropical Life Sciences. 2009,20(2):29-47

Hardy, T.B. (1998). The future of habitat modelling and instreamflow assessment techniques.Regulated Rivers: Research & Management, 14: 405–420.

Hydrological Procedure No. 12 (HPI2) .Magnitude and Frequency of Low Flow in Peninsular Malaysia. Kuala Lumpur: Drainage Irrigation and Department Malaysia.

Hortle, K.G. and P.S. Lake. (1983). Fish of channelized and channelized sections of the Bunyip River, Victoria. *Australian Journal of Marine and Freshwater Resources*, 34: 441-450.

Izagirre O, Serra A, Guasch H, Elosegi A. (2009). Effects of sediment deposition on periphytic biomass, photosynthetic activity and algal community structure. *Science of the Total Environment*, 407: 5694–5700.

Jager, H. I., Cardwell, H.E., Sale, M. J., Bevelhimer, M. S., Coutant, C.C., Winkle, W. V. 1997. Modelling the linkages between flow management and salmon recruitment in rivers. *Ecological Modelling* 103:171-191

Jamabo, N.A., Chindah, A.C., Alfred-Ockiya, J.F. (2009), "Length-weight relationship of a mangrove prosobranch Tympanotonus fuscatus var fuscatus (Linnaeus, 1758) from the Bonny Estuary, Niger Delta, Nigeria", *World Journal of Agricultural Sciences* 5(4), 384-388.

Karr, J .R. and D.R. Dudley.(1978). A Primer on the Biological Integrity of Running Waters.Unpublished ms. 12pp.

Karr JR. (1991). Biological integrity: a long-neglected aspect of water resource management. Ecological Applications 1: 66-84.

Katz, D. (2006). Going with the Flow: Preserving and Restoring Instream Water Allocations. The World's Water: 2006-2007. Gleick, P. (Ed.), Island Press: 27-49.

Kausar, R., & Salim, M. (2006). Labeo rohita, *26*(3), 105–108.

Koehn, J.D., O'Connor, W.D. (1990) Threats to Victorian Native Freshwater Fish.Vic. Nat. V.107 (1).

Koehn, J.D. (1992). Freshwater fish habitats: key factors and methods to determine them. In Hancock, D.A. (ed) Sustainable fisheries through sustaining fish habitat. Proceedings of the Aust. Soc. Fish Biol. Workshop held at Victor Harbor, S.A., 77-83.

Liu, W. C., Liu, S. Y., Hsu, M. H., Kuo, A. Y. 2005. Water quality modeling to determine minimum instream flow for fish survival in tidal rivers. *Journal of Environmental Management* 76: 293–308

Lopes, L. F. G., Carmo, J.S.A.D., Cortes, R.M.V., Oliveira, D. 2004. Hydrodynamics and water quality modelling in a regulated river segment: application on the instream flow definition. *Ecological Modelling* 173: 197–218

Maddock I., (1999). The importance of physical habitat assessment for evaluating river health. Freshwater Biolology, 41, 373–391
.

Maidment, D. (1993).Handbook of Hydrology. McGraw Hill Publisher, United Kingdom.

Malaysia, J. P. D. S., & Sekitar, K. S. A. D. A. (2012). *Pengukuran Kualiti Air Sungai Berdasarkan Jps River Index (Jri) Di Lembangan Sungai Klang Air Dan*

Martin-Smith, K. M. (1998). Relationships between fishes and habitat in rainforest streams in Sabah, Malaysia. *Journal of Fish Biology*,52: 458-482.

Matthews, W.J. (1998). Patterns in freshwater ecology.Chapman and Hall, New York, New York.

Mazvimavi, D., Madamombe, E., &Makurira, H. (2007).Assessment of environmental flow requirements for river basin planning in Zimbabwe.Physics and Chemistry of Earth, 32, 995-1006.

MK Mitchell; Stapp WB.(1992). Field Manual for Water Quality Monitoring.

Mohsin, A.K.M. and M.A. Ambak.(1983). Freshwater Fishes of Peninsular Malaysia. *PenerbitanUniversitiPertanian Malaysia*. 284 pp

Moyle, P., (1993). Fish;An Enthusiast's Guide. Berkley.University of California Press.

Nagaya, T., Shiraishia, Y., Onitsuka, K., Higashino, M., Takami, T., Otsuka, N., Akiyama, J., Ozeki H. 2008. Evaluation of suitable hydraulic conditions for spawning of ayu with horizontal 2D numerical simulation and PHABSIM. *Ecological Modelling* 215: 133–143

Niehoff D, Fritsch U, Bronstert A. (2002). Land-use impacts on storm-runoff generation: scenarios of land-use change and simulation of hydrological response in a meso-scale catchment in SW-Germany. *Journal of Hydrology*, 267: 80–93.

Nik AR. (1988). Water yield changes after forest conversion to agricultural landuse in Peninsular Malaysia. *Journal of Tropical Forest Science*, 1(1): 67–84.

Offem, B.O., Samsons, Y.A., Omoniyi, I.T. (2009), "Length-weight relationship, condition factor and sex ratio of forty six important fishes in a tropical flood river", *Research Journal of Fisheries and Hydrobiology*, 4(2): 65-72.

Omar, C. (2010). Geographic Information System Manual.Tenaga National Berhad.

Oscoz, J.; Campos, F.; Escala, M. C., (2005): Weight–length relationships of some fish species of the Iberian Peninsula. *J. Appl. Ichthyol*, 21, 73–74.

Parson, A. (1991). 'The Conservation & Ecology of Riparian Tree Communities in the Murray Darling Basin, NSW A Review' NSW NPWS Hurstville.

Pauly, D. (1983), "Some simple methods for the assessment of tropical fish stock", FAO Technical Paper 234, 52pp.

Peck Yen T, Zulfarina F S and Rohasliney H. (2010). Comparison of the zooplankton community in Kelantan River and its tributary, Pengkalan Chepa River: A preliminary study. In S Harith, H Abdullah, R Suppian and H A Rahman. (eds.). National Conference on Environment and Health 2010. Kota Bharu, Kelantan: School of Health Sciences, Universiti Sains Malaysia, 1–6.

Peck Yen T. and Rohasliney H. 2013. Status of Water Quality Subject to Sand Mining in the Kelantan River, Kelantan. Tropical Life Sciences Research, 24(1), 19–34.

Persat H, Olivier JM, Pont D. (1994). Theoretical habitat templets, species traits, and species richness: fish in the Upper Rhone River and its floodplain. Freshwater Biology 31: 439–454.

Platts, W.S. (1983). Vegetation requirement for fisheries habitats.InMonsen, S.B. and Shaw, N. compilers.Managing intermountainrangelands-improvement of range and wildlife habitats.U.S. Forest Service General Technical Report INT-157, pp.184–188.

Rainboth, W.J. (1996). Fishes of the Cambodian Mekong.FAO Species Identification Field Guide for Fishery Purposes. FAO, Rome. p. 265.

Renard, K., Foster, G., Weesies, G., McDool, D., & Yoder, D. (1997). Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). Agricultural Handbook 703, USDA-ARS.

Richter BD, Baumgartner JV, Wigington R, Braun DP. (1997). How much water does a river need? Freshwater Biology 37: 231- 249.

Richter BD, Baumgartner JV, Powell J, Braun DP. (1996). A method for assessing hydrological alteration within ecosystems. Conservation Biology10 (4): 1163±1174.

Scarnecchia, D.L. (1988). The importance of streamlining in influencing fish community structure in channelized and unchannelized reaches of a prairie stream. Regulated Rivers: Research and Management 2:155-166.

Schlosser IJ, Kallemeyn LW. (2000). Spatial variation in fish assemblages across a beaver-influenced successional landscape. *Ecology* 81: 1371-1382.

Smith, K.M.M. (1996), "Length/weight relationship of fishes in a diverse tropical freshwater community, Sabah, Malaysia", *Journal of Fish Biology* 49, 731-734.

Stalnaker, C.B., B.L. Lamb, J. Henriksen, K. Bovee, and J. Bartholow. (1995). The Instream Flow Incremental Methodology: A Primer for IFIM. Biological Report 29. Washington, DC: U.S. Geological Survey. 45 p.

Strakosh, T. R., R. M. Neumann, R. A. Jacobson. (2003). Development and assessment of habitat suitability criteria for adult brown trout in southern New England rivers. Ecology of Freshwater Fish, 12: 265-274.

Sutton, Ron, and Morris, Chelsie, (2004). Flow characterization study instream flow assessment Big Timber Creek, Idaho: U.S. Department of the Interior, Bureau of Reclamation, Snake River Area Office, Boise, Idaho, p 119.

Sweeney, B.W., (1993). Effects of Streamside Vegetation on Macroinvertebrate Communities of White Clay Creek in Eastern North America. Proceedings of the Academy of Natural Sciences of Philadelphia 144:291-340.

TerBraak, C. J. F., and C. W.N. Looman. In press (1986).Weighted averaging, logistic regression and the Gaussian response model. Vegetation 65:3-11.

Tharme, R. E. (2003). A global perspective on Environmental Flow Assessment: emerging trends in the development and application of environmental flow methodologies for rivers. *River Research and Application*, 19, 397-441.

Toriman, M. E. (2010). Assessing Environmental Flow Modeling For Water Resources Management : A Case of Sg . ( River ) Pelus , Malaysia, *8*(4), 69–76.

Turner, M., Vietz, G., Boon, P. and Doeg, T. (2008). Final Recommendations: Determination of environmental flow requirements for the Powlett River. Report prepared by Alluvium Consulting for South Gippsland Water and West Gippsland Catchment Management Authority. September 2008.

Wang S, Kang S, Zhang L, Li F. (2008). Modelling hydrological response to different land-use and climate change scenarios in the Zamu River basin of northwest China. Hydrological Processes 22: 2502–2510.

Weber-Scannell, P.K., Duffy, I.K. (2007).Effects of total dissolved solid on aquatic organisms: A review of literature and recommendation for salmonid species. Am. J. Environ Sci., 3:1-6.

White I, Howe J. (2004). *The mismanagement of surface water*. Applied Geography 24: 261–280.

Winkle, W. V., Jager, H. I., Railsback, S. F., Holcomb, B. D, Studley, T. K., Baldrige, J. E. 1998. Individual-based model of sympatric populations of brown and rainbow trout for instream flow assessment: model description and calibration. *Ecological Modelling* 110: 175–207

Wipfli, M.S., J.S. Richardson and R.J. Naiman. (2007). Ecological linkages between headwaters and downstream ecosystems: Transport of organic matter, invertebrates, and wood down headwater channels. *Journal of the American Water Resources Association* 43(1):72–85 (doi: 10.1111/j.1752-1688.2007.00007.x).

Wood, P.J. and P.D. Armitage. (1997). Biological effects of fine sediment in the lotic environment. Environmental Management 21:203-217.

Wooldridge S, Kalma J, Kuczera G. (2001). Parameterisation of a simple semi-distributed model for assessing the impact of land-use on hydrologic response. *Journal of Hydrology* 254: 16–32.

Wurts, W. A. and Durborow, R. M. (1992).Interactions of pH, carbon dioxide, alkalinity, and hardness in fish ponds.SRAC Publication, 464.Retrieved November 3, 2014 from Southern Regional Aquaculture Center. Stable URL: http://www2.ca.uky.edu/wkrec/InteractionspHEtc.PDF

Zakaria-Ismail, M. (1994).Zoogeography and biodiversity of the freshwater fishes of Southeast Asia. Hydrobiologia 285: 41-48.

**LIST OF PUBLICATIONS**

**Norfadilah Aini**, Nor Rohaizah Jamil, Hasrul Hazman Hasan, Fasihah Mohd Yusof. (2016), River Hydro Morphology Characteristic Influenced by Seasonal Changes: A Case Study in Galas River, Kelantan. *Research Journal of Applied Science*. (Accepted)

**Norfadilah Aini**, Nor Rohaizah Jamil, Hasrul Hazman Hasan. (2016) Land use changes and Soil erosion risk assessment using Geospatial Information System (GIS): A case study in Galas River Basin, Kelantan. *Sains Malaysiana.*(Submitted)

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