POPULATION PARAMETERS, FEEDING AND REPRODUCTIVE BIOLOGY OF BEARDLESS BARB, *Cyclocheilichthys apogon* (Valenciennes, 1842) FROM SELECTED TRIBUTARIES OF MUDA RESERVOIR, KEDAH, MALAYSIA

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by

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LIST OF SYMBOLS AND ABBREVIATIONS

b	Growth coefficient
BW	Body weight
CCA	Canonical correspondence analysis
C.flow	Current flow
cm	Centimeter
Cond	Conductivity
DO	Dissolved oxygen
E	Exploitation rate
ELEFAN I	Electronic length-frequency analysis I
E_{max}	Maximum allowable limit of exploitation
F	Fishing mortality
FiSAT II	FAO-ICLARM stock assessment tools II
g	Gram
K	Growth constant
Kn	Relative condition factor
L	Litre
Lc	Length at first capture
LWR	Length-weight relationship
$L\infty$	Asymptotic length
M	Natural mortality
m	Meter
mg	Miligram
mm	Milimeter

NH_3	Ammonia
NO_2^-	Nitrite
NO_3^-	Nitrate
PCA	Principal component analysis
PO_4^{3-}	Phosphate
R^2	Regression coefficient
s	Second
SD	Standard deviation
SPSS	Statistical package for social science
TDS	Total dissolved solids
Temp	Temperature
TSS	Total suspended solids
TL	Total length
vBGF	von Bertalanffy growth function
W.dep	Water depth
Y'/R	Relative yield per recruit
Z	Total mortality
Ø'	Growth performance index
μS	Micro Siemens

PARAMETER POPULASI, BIOLOGI PEMAKANAN DAN PEMBIAKAN IKAN TEMPERAS, *Cyclocheilichthys apogon* (Valenciennes, 1842) DARI ANAK SUNGAI TERPILIH DI EMPANGAN MUDA, KEDAH, MALAYSIA

ABSTRAK

Sedikit maklumat yang diketahui mengenai aspek biologi *Cyclocheilichthys apogon* dan oleh itu, satu kajian mengenai biologi spesies ini telah dijalankan di lima anak sungai di Empangan Muda selama 18 bulan dari Mac 2014 hingga Ogos 2015. Persampelan bulanan telah dijalankan untuk mengumpul sampel-sampel air dan spesimen-spesimen ikan. Kajian ini merangkumi penentuan parameter kualiti air fiziko-kimia, hubungan panjang-berat dan faktor keadaan relatif *C. apogon*, parameter populasi, pemakanan dan biologi pembiakan *C. apogon*. Tiada perbezaan signifikan ($p > 0.05$) yang diperhatikan antara stesen persampelan pada pH, nitrit, nitrat dan ammonia serta tiada perbezaan signifikan ($p > 0.05$) yang diperhatikan pada suhu air, konduktiviti, kedalaman air, oksigen terlarut, jumlah pepejal terlarut, aliran air, kepekatan nitrat dan fosfat antara bulan-bulan persampelan. Semua nilai-nilai dari analisis kualiti air fiziko-kimia di anak-anak sungai di Empangan Muda adalah dalam tahap yang selamat dalam Kelas I dan IIA. *C. apogon* didapati membesar dalam corak pertumbuhan isometrik berdasarkan hubungan panjang-berat. Nilai-nilai faktor keadaan relatif *C. apogon* adalah lebih tinggi daripada satu menunjukkan keadaan *C. apogon* adalah lebih baik di anak-anak sungai ini. Daripada kajian parameter populasi, *C. apogon* dianggarkan mencapai panjang infiniti ($L\infty$) pada 21.5 cm, dengan kadar pertumbuhan sederhana (K) 0.42 tahun^{-1}. Panjang pada penangkapan pertama (*Lc)* *C. apogon* dianggarkan pada 8.67 cm. Jumlah kematian (Z) *C. apogon* adalah tinggi (3.17 tahun^{-1}) dengan kematian semasa penangkapan (F) pada kadar

1.95 tahun^{-1} adalah lebih tinggi daripada kematian semula jadi (*M*) pada kadar 1.22 tahun^{-1}. Kadar eksploitasi (*E*) *C. apogon* pada kadar 0.62 tahun^{-1} adalah sedikit tereksploitasi daripada tahap eksploitasi optimum ($E_{0.1}$) pada kadar 0.61 tahun^{-1}. Pengeksploitasian spesies ini harus diurus dengan betul menggunakan cara yang mampan untuk kelangsungan sumber ikan sebelum ianya mencapai anggaran tahap eksploitasi maksimum yang dibenarkan (E_{max}) pada kadar 0.76 tahun^{-1}. *C. apogon* merekrut dalam dua corak rekrut setiap tahun pada bulan April dan September. Dari kajian biologi pemakanan, *C. apogon* di anak-anak sungai di Empangan Muda adalah omnivor-eurifagus dengan memakan makanan campuran daripada makanan berasaskan tumbuhan dan haiwan dengan keutamaan pada makanan berasaskan haiwan. Kandungan makanan utama adalah Basillariofita, Krustasia, Insekta dan cacing (Nematoda & Annelida). Makanan lain seperti Klorofita, Sianofita, zarah makrofit yang tidak dapat dikenalpasti, rumpai yang tidak dapat dikenal pasti, sisik ikan dan telur adalah kurang ditemui menunjukkan bahawa kepentingannya adalah rendah untuk ikan atau tersalah makan. Variasi dalam jenis pemakanan *C. apogon* diperhatikan di antara ikan tidak matang dan matang, bulan kering dan basah, kelas saiz panjang dan stesen persampelan. Peralihan pemakanan daripada tumbuhan kepada haiwan diperhatikan daripada ikan yang tidak matang kepada ikan dewasa. Peralihan pemakanan yang sama daripada tumbuhan kepada haiwan diperhatikan daripada ikan yang bersaiz lebih kecil kepada ikan yang bersaiz lebih besar. *C. apogon* lebih banyak memakan haiwan di Stesen 1, 2 dan 3 berbanding dengan tumbuhan dan lebih banyak memakan tumbuhan di Stesen 4 dan 5 berbanding dengan haiwan. Dari kajian biologi pembiakan, nisbah jantina bagi *C. apogon* jantan dan betina adalah 1.08: 1.00 (jantan: betina). Peringkat kematangan bagi *C. apogon* jantan dan betina dikelaskan kepada enam peringkat kematangan. *C. apogon* adalah ‘kumpulan peneluran serentak’ berdasarkan analisis histologi and taburan kekerapan saiz oosit. *C. apogon* betina mencapai kematangan jantina pada saiz yang lebih kecil (10.0 cm) daripada *C. apogon* jantan (11.3 cm). Musim peneluran utama *C. apogon* berkait erat dengan bulan hujan atau basah pada bulan September. Fekunditi *C. apogon* adalah dari 135 hingga 2260 telur per gonad dan ianya lebih berkait dengan berat gonad berbanding berat badan dan panjang keseluruhan. Maklumat-maklumat yang diperolehi daripada kajian ini berguna untuk mengisi jurang pengetahuan mengenai parameter populasi, pemakanan dan biologi pembiakan *C. apogon* di anak-anak sungai di Empangan Muda serta untuk perbandingan masa hadapan mengenai spesies ini.

POPULATION PARAMETERS, FEEDING AND REPRODUCTIVE BIOLOGY OF BEARDLESS BARB, *Cyclocheilichthys apogon* (Valenciennes, 1842) FROM SELECTED TRIBUTARIES OF MUDA RESERVOIR, KEDAH, MALAYSIA

ABSTRACT

Scanty information is known about the biological aspects of *Cyclocheilichthys apogon* and as such, a study on the biology this species was conducted in five tributaries of Muda Reservoir for 18 months from March 2014 untill August 2015. Monthly sampling was conducted to collect the water samples and fish specimens. This study includes the determination of the physico-chemical water quality parameters, length-weight relationships and relative condition factor of *C. apogon*, population parameters, feeding and reproductive biology of *C. apogon*. No significant differences ($p > 0.05$) were observed among sampling stations in pH, nitrite, nitrate and ammonia concentration and no significant differences ($p > 0.05$) were observed in water temperature, conductivity, water depth, dissolved oxygen, total dissolved solid, current flow, nitrate and phosphate concentration among sampling months. All the values of the physico-chemical water quality analysis in tributaries of Muda Reservoir were in safe level in Class I and IIA. *C. apogon* was found to grow in isometric growth pattern using the length-weight relationships. The values of relative condition factor of *C. apogon* was higher than one shows the better condition of *C. apogon* in this tributaries. From the population parameters study, *C. apogon* was estimated to reach length infinity ($L\infty$) at 21.5 cm, with moderate growth rate (K) of 0.42 year^{-1}. The length at first capture (Lc) of *C. apogon* was estimated at 8.67 cm. The total mortality (Z) of *C. apogon* was higher (3.17 year^{-1}) with the fishing

mortality (F) of 1.95 year^{-1} was higher than the natural mortality (M) of 1.22 year^{-1}. The exploitation rate (E) of 0.62 year^{-1} of *C. apogon* was slightly exploited than the optimum exploitation level ($E_{0.1}$) of 0.61 year^{-1}. The exploitation of this species should be managed properly in sustainable way for fish resources continuity before it reaches the estimated maximum allowable limit of exploitation (E_{max}) of 0.76 year^{-1}. *C. apogon* recruit in two recruitment pattern per year in April and September. From the feeding biology study, *C. apogon* in tributaries of Muda Reservoir was euryphagous-omnivores by consuming mixed diet of animal and plant-based food with the preferences to the animal-based food. The main food contents were Bacillariophyta, Crustacea, Insecta and worms (Nematoda & Annelida). Other food materials such as Chlorophyta, Cyanophyta, unidentified macrophyte particles, unidentified weeds, fish scales and eggs were less encountered indicating their low importance to fishes or mistakenly consumed. The variations in the type of diet consumed by *C. apogon* were observed between immature and mature fish, dry and wet months, length size classes and sampling stations. A diet shift from plant materials to animal materials was observed from immature fish to mature fish. The same diet shift from plant materials to animal materials was observed from smaller size fish to bigger size fish. *C. apogon* consumed more on animal materials in Stations 1, 2 and 3 compared to plant materials and consumed more on plant materials in Stations 4 and 5 compared to animal materials. From the reproductive biology study, the sex ratio of male and female *C. apogon* was 1.08: 1.00 (male: female). The maturity stages of male and female *C. apogon* were classified into six maturity stages. *C. apogon* was a ‘group synchronous spawner’ according to histological analysis and oocyte size frequency distribution. Female *C. apogon* reach sexual maturity at smaller size (10.0 cm) than the male *C. apogon* (11.3 cm). The major spawning season of *C.*

apogon was tightly related to the rainy or wet month in September. Fecundity of *C. apogon* ranged from 135 to 2260 eggs per gonad and it is more related to gonad weight rather than body weight and total length. Informations obtained from this study would be useful to fill in the gap of knowledge on the population parameters, feeding and reproductive biology of *C. apogon* in tributaries of Muda Reservoir as well as for future comparisons regarding this species.

CHAPTER 1

GENERAL INTRODUCTION

1.1 Man-made lakes or reservoirs in Peninsular Malaysia

In Malaysia, there are many reservoirs and lakes, either natural or man-made. The examples of natural lakes are Chini Lake and Bera Lake whereas for man-made lakes or reservoir are Muda, Pedu, Temengor and Kenyir Reservoirs. According to Sharip & Zakaria (2008), more than 73 man-made lakes or reservoirs were built in Malaysia, mainly for the purpose of irrigation, water supply, flood mitigation and hydroelectric power generation. The reservoirs and lakes become essential storage areas for the water resources of the country. They are also providing habitat to diverse biological species. There are five main reservoirs in the northwestern coast of Peninsular Malaysia namely Timah Tasoh, Ahning, Pedu, Muda and Beris Reservoirs.

Muda Reservoir lies at northeastern part of Kedah. This reservoir, together with Ahning and Pedu Reservoirs were constructed under the Muda Irrigation Scheme aims to provide irrigation to the Muda areas covering 96 000 hectares in order to enable double cropping of rice per year (MADA, 2015). The Muda Reservoir has a large catchment area (984 km^2) with the storage capacity of 160 million m^3 and covering an area of 25.6 km^2. The water from this reservoir is flowed and discharged to Pedu Reservoir (MADA, 2015).

1.2 Importance of Muda Reservoir and Its Tributaries

The Muda Reservoir built for the purpose of irrigation and water supply for agricultural, domestic and industrial usage for some areas in Perlis, Kedah and Penang (Latifah & Les-Met, 2014). As reported by several researchers (Shah *et al.*, 2006; Lee *et al.*, 2013), Muda Reservoir and its tributaries houses more than 30 species of fishes. Such high diversity of fishes provides an important artisanal industry for local people. Lee *et al.* (2013) reported that the landing of fishes in Muda Reservoir increased from 24.68 metric tonnes in 2006 to 58.36 metric tonnes in 2010. The increase of this artisanal fishery in Muda Reservoir is believed will give some negative effects on fisheries resources and water pollution. Consequently, fisheries activities in Muda Reservoir and its tributaries need to be more ecologically friendly and sustainable in the future.

Although Muda Reservoir is not well known as Kenyir Lake and Temengor Lake, Muda Reservoir is a stupendous area for recreational anglers, researchers, wildlife conservation and nature tourism. Zalina (2014) reported that The Ulu Muda forest complex surrounding Muda Reservoir provide tranquil home to diverse wildlife including at least 112 species of mammals. The most unique feature of this place is the existence of natural saltlicks which is believed to supply important mineral supplement to the diets of wildlife. The common activities in Muda Reservoir and its tributaries were fisheries. It provides sources of employment and protein supply for the people that stay in vicinity to this reservoir. In general, most of the fishermen in Muda Reservoir applied artisanal fishery with low technology practices, limited manpower and moderate average daily income of RM 50 (*Personal communication*, 2015). The common fishing gears are seine net, cast net, portable trap, fishing line and long line. Some of the fishermen also have part time job as boatmen for tourists and researchers in Muda Reservoir. Other than that, the recreational fishing also performed in this area where the *Channa striata* (haruan) and *Hampala macrolepidota* (sebarau) were the most popular amongst the anglers (Lee *et al.*, 2013). Muda Reservoir also offers a tremendous landscaping of its pristine streams and forests where the eco-tourisms and research activities such as recreational camping, caving and wildlife sightseeing performed by various naturalists, researchers and groups of non-governmental organization.

1.3 Beardless barb (*Cyclocheilichthys apogon*)

The beardless barb or *Cyclocheilichthys apogon* is a freshwater fish species in the Family Cyprinidae and widespread all over Southeast Asia (Vidthayanon, 2012; Froese *et al.*, 2015). They inhabited freshwater environment living in benthopelagic area and distributed in tropical climate (30°N till 10°S) from Myanmar to Indonesia within temperature 24°C to 26°C (Riehl & Baensch, 1991). A study by Baird *et al*. (1999) investigated that *C. apogon* can reach maximum length of 25 cm in total length. As its name suggests, this species does not have a barbel and can be distinguished by having a black blotch at caudal fin base and rows of black spots along lateral scale (Kottelat, 2001) (Figure 1.1).

They commonly found in small rivers, lakes and reservoirs (Talwar & Jhingran, 1991), ditches, canals and slow moving or standing water area (Rainboth, 1996) and enters flooded areas during high water season (Vidthayanon, 2012; Froese *et al.*, 2015). They could also be found in medium to large sized rivers (Taki, 1978; Vidthayanon, 2002). Pantulu (1986) reported that *C. apogon* was found in the basin-wide tributary of the lower Mekong.

The stomach contents of *C. apogon* usually consist of insect remains (Kottelat & Widjanarti, 2005). Small plankton, crustaceans, fragments of plants, leaves, twigs and tree roots also found in their stomach. According to Rainboth (1996), *C. apogon* in Cambodia reproduce late during high-water or wet season from September to October when the water levels high and begin to decline. In term of fisheries, this species have an indigenous aquaculture and ornamental properties as well as common daily food (smoked or fermented) in Thailand and Mekong Grand Lake (Vidthayanon, 2012).

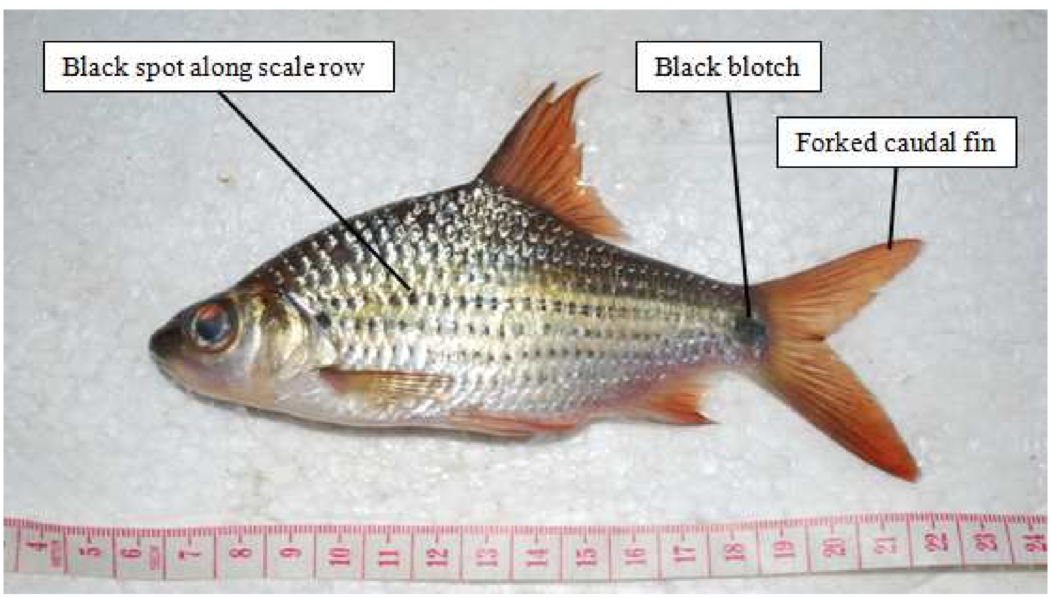

Figure 1.1. *Cyclocheilichthys apogon*

1.4 Problem statement

The Muda Reservoir and its tributaries are very important to local people because it is the main source of freshwater fishes, which is the main food for them due to its cheaper price and higher in protein source. This ecosystem can be considered as vulnerable to human alterations. Any changes to catchment areas will influence the presence of the existing aquatic organism biodiversity such as fishes and plankton (Cooke *et al.*, 1993). Present study was conducted in the tributaries or sub-catchment areas in Muda River (Labua River, Sira Jawa River, Nyeh River and Debu River) and Teliang River. It is noted that several water physical parameters such as temperature, pH and total suspended solid (TSS) in tributaries of Muda Reservoir had an increment in values and changes slightly as reported from the study by Mohd-Kamil *et al.* (2005) and Lee *et al.* (2013). The main purpose of this study was to identify the changes in physico-chemical parameters in these areas and comparing the results with the previous reports.

In addition, the growth of fisheries industry in Muda Reservoir is believed in jeopardy in the near future as the area of Ulu Muda Forest Reserve itself are heavily affected by human activities such as illegal logging, over-exploitation and over fishing, resource degradation and pollution (Sinar-Harian, 2017). The main threat for the Muda Reservoir fisheries industry are deforestation and unsustainable logging activities which will affect the quality of water catchment and it inhabitants. The clearing of forest patches until 200 m from the water mark may cause the run-off of soil into Muda Reservoir and its tributaries making raw water supply murky. Besides that, unsustainable fishing activities and illegal poaching by local fisherman such as the using cyanide and dynamite in fishing could harm the fish population and aquatic ecosystem. The over-exploitation or over fishing also contributes to the disruption of fish communities.

Apparently, the mixed fish or ‘ikan putih’ together with the snakehead (*Channa striata*), Asian redtail catfish (*Hemibagrus capitulum*) and marble-goby (*Oxyeleotris marmorata*) dominated the commercial fish trade and are the mostly consume by local people, as previously reported by Lee *et al*. (2013) and from the preliminary observation on fish landing at Pengkalan Gubir of Muda Reservoir. The ‘ikan putih’ is known from its white coloured of various cyprinid species of *Cyclocheilichthys apogon* (temperas), *Barbonymus schwanenfeldii* (lampam sungai), *Mystacoleucus obtusirostris* (sia), *Osteochilus vittatus* (terbul), *Oxygaster anomalura* (lalang) and *Rasbora dusonensis* (seluang). These fish are very abundant in Muda Reservoir and their market price as low as RM 6.00 per kilogram to the high price of RM 50.00 per kilogram (Lee *et al*., 2013). They also very popular amongst the local people which it is palatable as favourite dishes or consumed as grill fishes with the price may fetch RM 20.00 per dish. Some local people also made the ‘ikan putih’ as traditional fermented fish or ‘ikan pekasam’ and sell to the local market at the price of RM 20.00 to RM 30.00 per kilogram regarding to the species used and this would gave supplement income.

Most of the ‘ikan putih’ were caught in the tributaries of Muda Reservoir. *C. apogon*, as one of the species from ‘ikan putih’ was chosen for detailed biological studies. Previously, a few freshwater fish studies were carried out in tributaries of Muda Reservoir such as by Samat *et al*. (2005), focused on the freshwater fishes in the upstream of Muda River especially in Sg. Lasor, while Shah *et al*. (2012) investigated fish checklist distribution in Sg. Sira Batu, Sg. Surat, Sg. Air Hangat, Sg. Bahui and

Sg. Jawa. Whereas, Lee *et al*. (2013) explored the freshwater fish in riverine environment (Muda River, Teliang River, Charok Tera and Che-Song River) and lacustrine environment. No detailed biological studies of freshwater species in tributaries of Muda Reservoir were reported before. Present research concentrates more on biological studies of *C. apogon* regarding population parameters, feeding and reproductive biology. *C. apogon* or 'ikan temperas' had been chosen in this study as it is can be found in all sampling sites during preliminary sampling and important as artisanal wild capture for local people.

1.5 Objectives of the study

The objectives in this study were as follows;

1) To evaluate the physico-chemical water quality parameters in tributaries of Muda Reservoir (Labua River, Sira Jawa River, Nyeh River, Debu River and Teliang River).
2) To determine the length-weight relationships and relative condition factor of *C. apogon* between male and female, immature and mature, during dry and wet months, length size group and sampling stations.
3) To examine the population parameters of *C. apogon* through the estimation of growth parameters, mortality coefficients and recruitment patterns using FiSAT software.
4) To elucidate the feeding aspects of *C. apogon* regarding gut fullness index, relative gut length and the diet of *C. apogon* between male and female, immature and mature, during dry and wet months, length size group and sampling stations.

5) To investigate some aspects on reproductive biology of *C. apogon* concerning on the sex ratio, gonad maturity stages, length at first maturity, gonadosomatic index, fecundity and oocyte diameter.

CHAPTER 2

LITERATURE REVIEW

2.1 Physico-chemical water quality

Literally, water quality is useful tool for pollution monitoring (Maiti, 2004). Water quality is a fundamental aspect in determining the healthiness of aquatic ecosystem. The healthy aquatic ecosystem and good water quality are vital in order to sustain fish species and other aquatic organisms (Arimoro *et al.*, 2008). According to Venkatesharaju *et al.* (2010), healthy aquatic ecosystem also depends on the physico-chemical and biological characteristics. Boesch and Turner (1984) found that fish communities have strong physiological and behavioral responses to the changes in their environment. The deterioration on water quality may cause higher mortality rates of fishes, changes the fish assemblage of certain area and changes the physical behavior of fishes (Borja *et al.*, 2012).

In Malaysia, the water quality assessment in lakes and rivers commonly use the Interim National Water Quality Standard for Malaysia (INWQS) and water quality index (WQI) as suggested by the Department of Environment (DOE). The DOE has been monitored the status of river water quality of river in Malaysia. The purpose is to detect any changes in the water quality status and identify water pollution sources. The classification is based on annual basis by categorizing rivers in Class I, II, III, IV and V based on the INWQS. The classification guidelines of the INWQS is shown in Appendix A.

Besides that, the assessment for trophic status in lakes is estimated using the Carlson's trophic state index (TSI) as proposed by Carlson (1977). Carlson's trophic state index (TSI) has been largely used to assess the trophic status of lakes in almost all the countries (Sharma *et al*, 2010). This index is used to estimate the level of eutrophication during dry season using three indicators; transparency (SD), total phosphorus (TP) and Chlorophyll *a* concentrations (Chl-*a*). In this study, only INWQS was used to estimate the water quality status in tributaries of Muda Reservoir. The INWQS is applicable for both rivers and lakes environment. Yisa and Jimoh (2010) stated that INWQS is an important standardisation measurement that is most helpful in assessing and monitoring surface water.

Previous studies of water quality status in various tributaries of Muda Reservoir were conducted by Mohd-Kamil *et al*. (2005) and Lee *et al*. (2013). The water quality status regarding the physico-chemical parameters in tributaries of Muda Reservoir is expected to be changing over time. Accordingly, this study was conducted to access if there are differences in the physico-chemical parameters in tributaries of Muda Reservoir with the previous studies.

2.2 Diversity of freshwater fishes in tributaries of Muda Reservoir

Several studies on freshwater fish distribution in various tributaries of Muda Reservoir had been previously reported by Samat and Mazlan (2003), Samat *et al*. (2005), Shah *et al*. (2012) and Lee *et al*. (2013). They revealed that fish species diversity in tributaries of Muda Reservoir is moderate and could be increased by more intensive sampling. Samat and Mazlan (2003) studied the fish distribution in Weng River, Samat *et al*. (2005) in Lasor River, Shah *et al*. (2012) in Sira Batu River, Surat

River, Air Hangat River, Bahui River and Jawa River and Lee *et al*. (2013) in riverine (Muda River, Teliang River and Charok Tera River) and lacustrine environment. The continuous assessment on fish distribution is required for the better conservation planning in future. Hence, this study was conducted to promulgate and update the latest fish checklist distribution in various tributaries of Muda Reservoir.

2.3 Length-weight relationship (LWR)

The length-weight relationship (LWR) is a practical index appropriate for understanding their survival, growth, general well-being, maturity and reproduction (Le-Cren, 1951). Usually, the LWR is used to extract preliminary information on condition of fish and delineate whether growth of fish is positive allometric, negative allometric or isometric (Ricker, 1975). The length-weight relationship have been used to assess the relative wellbeing of a fish population (Bolger & Connoly, 1989) and ascertain a crucial pre-requisite in fishery biological investigations as it deals with the expected weight estimation of an individual fish of known length from length frequency distribution (Beyer, 1987; Froese, 1998; Koutrakis & Tsikliras, 2003).

In addition, length-weight relationship is used to estimate and compare life history and morphological aspects between populations from different regions in this world (Goncalves *et al*., 1997; Stergiou & Moutopoulus, 2001; Odat, 2003). Hence, length-weight relationship of fishes is vital in population assessment (Ricker 1968; Khaironizam & Norma-Rashid, 2002). Lizama *et al*. (2002) avowed that the knowledge of quantitative aspects such as length-weight relationship, condition factor, growth, mortality and recruitment of fishes have taken into consideration to become an important tool for the study of fish biology.

More to the point, the length-weight relationship has been used frequently to estimate weight from length because direct length-weight measurements can be time-consuming in the field sampling (Sinovcic *et al*., 2004). Likewise, the length-weight relationship parameters are important in fish biology as it can give information on stock condition (Bagenal & Tesch, 1978) and commonly used on commercial scales in population assessments (Steeby *et al*., 1991; Ali *et al*., 2000). Accordingly, length-weight relationship widely used in stock assessment models in fisheries management (Barthélemy *et al*., 2014; Alireza & Hashem, 2016).

The length-weight parameter of the fish may differ in fish population of the same species due to the different metabolism of each fish species and the environmental condition where fish live (Gonzalez-Ganadara *et al*., 2003) as well as due to fishing, feeding and reproduction activities (Egbal *et al*., 2011). According to Samat *et al*. (2008), the size of individual fish may vary because of competition for food, supply of nutrients and climatic parameters. In addition, environmental deterioration could reduce growth rates and decrease average age of the fish. However, in reality, the interactions between growth rates and environmental changes are believed to be complex and argumentative to explain.

Frequently, length-weight relationship has been used extensively for analyses of fisheries data worldwide (Mendes *et al*., 2004). For example; Mansor *et al*. (2010) scrutinize length-weight relationship for 12 freshwater fish species in Kerian River Basin and Pedu Lake, Malaysia; Esmaeili *et al*. (2014) estimate length-weight relationship for 37 freshwater fish species in Iran; Barthélemy *et al*. (2014) determine length-weight relationship of 30 fish species in Aby Lagoon, Africa; Ayyildiz *et al*. (2015) find out length-weight relationship of 8 freshwater fish species from Turkey;

Lee *et al*. (2015) establish length-weight relationship for 18 freshwater fish species from the Nakdong River in South Korea and last but not least, Erguden (2016) elucidate length-weight relationship for 6 freshwater fish species from the Seyhan Reservoir, Turkey. However, the length-weight relationship of freshwater fish in tributaries of Muda Reservoir was not previously reported yet. Hence, this study was conducted to fill this gap in tributaries of Muda Reservoir.

2.4 Condition factor

The condition factor is used to assess the condition or fitness of fish populations and helps to estimate the feeding conditions of the fish (Bagenal & Tesch, 1978; Froese, 2006). Condition of fish can be tremendously vital in fisheries management. The plump fish is an indicator of favorable environmental condition with ample prey availability and convenience habitat condition, while thin fish may become an indicator of less favorable environmental condition (Blackwell *et al*., 2000). Bagenal and Tesch (1978) also make a hypothesis that the heavier fish of a given length are in better condition. The same goes to a study by Ibrahim *et al*. (1980). They also found that fish with a high value of condition factor are heavy for its length, whereas fish with a low condition factor value are lighter.

Condition factor of same species in different fish population probably give information pertaining the timing and duration of breeding and food supply (Weatherley & Rogers, 1978). For that reason, condition factor become a useful estimation in order to monitor the growth rates in fish, their age and feeding intensity (Ndimele *et al*., 2010) and to evaluate the well-being of fish (Zamani-Faradonbe *et al*., 2015). The condition factor could also be used as an index to assess the status of the aquatic ecosystem in fish habitat, which is particularly influenced by both abiotic and biotic environmental conditions (Anene, 2005). Gomiero and Braga (2005) stated that the differences in condition factor value give an indication of the degree of food sources availability, state of gonadal maturity, age and sex and environmental condition. Therefore, the study of the condition factor is important to understanding the fish life cycle as well as contributes to the proper management of fish species and maintains the ecosystem in equilibrium (Lizama *et al*., 2002).

Generally, there were three universal equations in condition factor study; Fulton's condition factor (*K*), relative condition factor (K_n) and relative weight (*W*r) (Hadi-Raeisi *et al*., 2011). The Fulton's condition factor is calculated according to the formula by Htun Han (1978); $K = 100W/L^3$, where *W* is body weight (g) and *L* is length. According to Froese (2006), this formula is widely used in fish biology studies and fisheries. However, this equation is limited to the species with isometric growth and invalid for comparing *K* between species with allometric growth unless both species exhibit isometric growth (Ogle, 2013). The relative condition factor for individual fish is calculated using equation by Le-Cren (1951); $K_n = W/aL^b$, where *W* is the body weight (g), *L* length (cm) and *a* and *b* are specific parameters of length-weight relationship. Whereas the relative weight estimated using formula by Wege and Anderson (1978); $Wr = 100W/Ws$ where *W* is weight of a specimen and *W*s is a standard weight representing the 75th percentile of observed weights at that length. The details about these condition factors are investigated by Froese (2006).

The condition factors of various fish species were applied by some researchers all over the world, for examples; Moradinasab *et al*. (2012) determine condition factors for five Cyprinid species in Anzali wetland, southwest of the Caspian Sea; Mohd-

Shafiq *et al*. (2012) establish condition factors for six freshwater species in Kerian River, Malaysia; Seher and Suleyman (2012) estimate the condition factors for seven Cyprinid fish species from Camligoze Dam Lake, Turkey; Mozsar *et al.* (2015) resolve condition factors for three freshwater fish species in eutrophic oxbow lake connected to the River Tisza, Hungary and Radkhah and Eagderi (2015) find out condition factors for six Cyprinid fish species from Zarrineh River, Iran. Previously, there was no report on the condition factor of freshwater fish in tributaries of Muda Reservoir. Hence, this study was performed to investigate the condition factor of cyprinid fish (*C. apogon*) in tributaries of Muda Reservoir.

2.5 Population parameters

The estimation of population parameters is a popular method in fisheries biology. Some intensive research had been previously conducted by some researchers such as Ingles and Pauly (1984) and Dwiponggo *et al*. (1986), involving 24 years and 12 years data collection respectively. The population parameters such as growth, mortality and recruitment is commonly used by researchers (Smith *et al*., 1998) and important in fish stock assessment (Fakhri *et al*., 2011). The estimation of population parameters of *C. apogon* in tributaries (riverine environment) of Muda Reservoir was not conducted before. There were only two reported studies on population parameters of *C. apogon* in lacustrine environment by Mohd-Shafiq (2016) in Bukit Merah Reservoir and Moreau and Sricharoendham (1999) in Rajjaprabha Reservoir, Thailand. The following sections will briefly describe the population parameters regarding the growth, mortality and recruitment pattern.

2.5.1 Growth

Fishes exhibit indeterminate growth (Enberg *et al*., 2008). It means that fishes continue to grow throughout their lives even though after maturation. Their growth rates are determined by some factors like food supply, habitat, water quality and competition. According to Dutta (1994), slow-growing fish tend to live longer than fast-growing fish. Growth basically refers to an increase in physical size over time. The growth and age becomes an important tool to predict the potential yield of the fishery and to describe the status of a fish population as well as accelerates the assessment of stock size, production, mortalities and recruitment to adult stock (Lowe-McConnel, 1987).

The growth parameters ($L\infty$, K & t_0) have been estimated because these population parameters are important to describe the species and also are inputs in several fishery production models (Sparre & Venema, 1992; Hilborn & Walters, 1992). L_∞ is the largest theoretical mean length that a species could attain in its habitat, K is the growth rate or speed it grows towards their final size and and t_0 is age at time zero. Usually, the growth parameters differ from species to another species, from area to another area and may vary from stock to stock within the same species (Sparre & Venema, 1992).

Normally, the estimation of growth parameters is based on the length-frequency data. This data analyzed using special program package for length-based stock assessment called FiSAT II (FAO-ICLARM Stock Assessment Tools – Version 1.2.2). FiSAT II was developed for analysis of length frequency data and other related analyses such as catch at age, size at age, selection and data collected for tropical fish stock assessment (Gayanilo *et al.*, 1996).

FiSAT program consist of routines which were FILE, EDIT, ASSESS, SUPPORT, WINDOW and HELP. First step to use this program by clicking the FILE and entering the length frequency data. By clicking FILE, it allows data entry, file creation, editing and data manipulation. When the data set was entered and filed, routine of ASSESS were used to estimate growth and mortality parameters efficiently as recommended in the FiSAT Reference Manual (Gayanilo *et al.*, 1996). FiSAT computer program is used for the population parameter estimation which comprises of cohort separation, growth parameters of $L\infty$ (length infinity) and K (growth rate), growth performance index (Ø'), mortality coefficients namely total mortality (Z), natural mortality (M) and fishing mortality (F), length at first capture (Lc), yield per recruit and biomass per recruit and annual recruitment pattern.

2.5.2 Mortality

Fish mortality means the death of fish from fish stock. The mortality of fish mainly caused by several factors includes environmental stress (Chapman & Van-Well, 1978; Davis, 2002), parasites and diseases (Landau, 1979), fishing activity and age (King, 1991), and fish predation (Otobo, 1993). Generally, the mortality of fish is caused either natural mortality or fishing mortality (Sparre & Venema, 1992). Natural mortality relates to the natural causes such as competition, cannibalism, disease, old age, pollution or predation. Whereas fishing mortality relates to the physical injury of fish during capture. In fisheries population dynamics, natural mortality is denoted by

‘*M*’, fishing mortality denoted by ‘*F*’ (Sparre & Venema, 1992) and total mortality denoted by ‘*Z*’ (Gulland, 1969).

The total mortality is estimated by a length converted catch curve method, produced by the ELEFAN I routines in FiSAT (Pauly, 1984). The natural mortality rate is estimated using the empirical relationship of Pauly (1980): $\log_{10}M = -0.0066 - 0.279 \log_{10}L\infty + 0.6543 \log_{10}K + 0.4634 \log_{10}T$. Fishing mortality is estimated using the relationship, $F = Z - M$. The parameters *F*, *Z* and *M* are used for establishing the level of exploitation (*E*) by the equation, $E = F/Z$ (Gulland, 1971). The exploitation rate is an index for estimation of the utilization level of a fishery. It enables rough estimation whether fish stock is overfishing or not based on the assumption of the optimal value of *E* (E_{opt}) is equal to 0.5. According to Gulland (1971) and Pauly (1984), the use of 0.5 for E_{opt} is based on the assumption that the sustainable yield is optimized when fishing mortality is equal to natural mortality ($F = M$).

2.5.3 Recruitment pattern

Recruitment is the entrance of young fish into the exploited fishing area and became vulnerable to fishing gear (Gulland, 1983). It also refers to the number of new young fish that enter or join a fish population in a given year (Abowei *et al.*, 2010). Ricker (1975) stated that recruitment also means the addition of new fish to the vulnerable population by growth from among smaller size individuals. Thus, the recruitment becomes the major source of variability in fish population (Bankole, 1990). However, the mean age of fish at recruitment generally depends on the type of mesh size of the fishing gear. According to Moreau and Cuende (1991), the annual recruitment pattern is obtained by projecting length frequencies backward onto a one-year time scale in

FiSAT, which uses the growth parameters as inputs. This routine reconstructs the recruitment pulse from a time series of length-frequency data to determine how many pulses per year and the relative strength per pulse. Using this way, plots showing the seasonal patterns of recruitment will be attained (Moreau & Cuende, 1991).

2.6 Feeding biology of fish

2.6.1 Feeding habits

Feeding is the process of an organism obtaining the food. Feeding and searching for food are the factors that regulate the distribution, migration and growth of fish (Papaconstantinou & Caragitsou, 1992). The classification of fish according to the amount of food they consumed can be divided into monophagic, euryphagic and stenophagic (Nikolsky, 1963). Monophagic is the feeding on single types of food, euryphagic is the feeding on a few different types of food and stenophagic is the feeding on limited variety types of food. According to Biswas (1993), the fish food in natural habitat can be divided into four major groups. First group is plankton which includes phytoplankton and zooplankton that cannot swim against the water current (Lalli & Parsons, 1993). Second group is nekton which comprised of aquatic animals that can be found in any depth of water, swim and move independently of water currents. Third group is benthos which includes phytobenthos and zoobenthos that can be found in the bottom of water body. Last group is detritus which is described as organic material comes from dead aquatic organism or leaves, small wood and fine benthic organic matter (Findlay *et al*., 2002). Present study was performed to determine whether the *C. apogon* is monophagic, euryphagic or stenophagic as well as to verify the types of food they consume in their natural habitat in tributaries of Muda Reservoir.

Feeding habits of fish also can be classified into herbivores, omnivores, carnivores and detritivores. Herbivorous fish feed on plants such as plankton, periphyton, algae or detritus, omnivorous fish feed on plants and animal such as algae, worms, small crustacean and aquatic insects, carnivorous fish feed only on other animals such as zooplankton and aquatic insect (Gerking, 1994; Rainboth, 1996) and detritivorous fish feed on detritus (Amarasinghe *et al.*, 2008). Examples of herbivorous cyprinids are *Osteochilus*, *Barbodes* and *Puntius*, omnivorous cyprinids are *Mystacoleucus*, *Tor* and *Rasbora*, carnivorous cyprinids are *Channa*, *Cosmochilus* and *Hampala* and detrivorous cyprinid is *Labeo.* Recent study investigates the types of feeding habit of *C. apogon* in tributaries of Muda Reservoir whether they are herbivores, omnivores, carnivores or detritivores using stomach content analysis.

2.6.2 Stomach content analysis

Stomach content analysis and food preferences investigation is fundamental and important aspect in fish biology (Zacharia & Abdurahim, 2004). This analysis is widely used in order to exemplify the food and feeding habit of certain fish species (Sivadas & Bhaskaran, 2009). Hyslop (1980) investigated five popular method in analyzing stomach content namely frequency of occurrence, numerical, volumetric, gravimetric and subjective method. The frequency of occurrence is estimated by counting the number of stomach containing one or more individuals of each food item consumed and the total is expressed as a percentage of the total number of stomach examine. In numerical method, the number of each food item is enumerated as the percentage of the total number of food items found in the stomach. Whereas in volumetric method, the food items are squashed on a slide to a uniform depth and the area of squash for each category of food is expressed in percentage. Then, in gravimetric method, the weight of food is measured either when it is wet or dry. This method is concerned on the calorific intakes of fish. Finally, in subjective method, it concentrates on the percentage contribution by volume of each category of food to the total content estimated (Hyslop, 1980). The frequency of occurrence and numerical method were chosen in this study in order to analyze the oesophagiogastric gut content of *C. apogon*.

2.7 Reproductive biology

Reproductive biology is an important aspect in understanding the biology of fishes (Azadi, 1996). Reproductive biology of fish is defined as the combination of the species-specific reproductive mode and reproductive traits (Murua & Saborido-Ray, 2003). The reproductive biology investigates the reproductive aspects such as maturity stages, gonadosomatic index, length at first sexual maturity, egg diameter and fecundity (Allam, 1996; Abdallah & Faltas, 1998; Ibrahim, 1999). This study is important to understand a fish population because they provide insight into the estimation of the spawning season, reproductive potential over time as well as enabling survival and continuation of species by using some tactics and strategies (Cushion *et al*., 2008; Muchlisin, 2014).

2.7.1 Reproductive strategy

The reproductive strategies of fishes associated to the effort by female and male fishes in order to maximize the production of the offspring and their survival in relation to their environment, parental life expectancy and available energy (Roff, 1992; Pianka, 2000). According to Bone *et al*. (1996), there are no distinctive characters between eggs and larvae of freshwater fish compared to eggs and larvae of marine fish, even though they encounter different environment and osmotic problems. Via a research by Balon (1975 & 1984), spawning behaviors of fish can be categorized based on how the eggs are fertilized (internal or external), where the eggs are deposited (pelagic or benthic) and whether how parents look after the eggs after spawning (bearers, guarders and non-guarders). Bearers are fish that carry their embryos with them internally or externally. Guarders are fish that protect eggs and offspring after spawning by parental care or brood care. Whereas non-guarders are fish that do not protect their eggs and offspring after spawning. Accordingly, *C. apogon* lies in the family Cyprinidae. Nelson (2006) stated that Cyprinidae practicing external fertilization, egg-layers and categorized into non-guarders. However, a few species build nests, guard their eggs or deposit their eggs in bivalve mollusk, such as bitterlings of subfamily Acheilognathinae.

Lode (2012) classified reproductive strategies in term of development of zygote and relationship with their parent into five categories; ovuliparity, oviparity, ovo-viviparity, histotrophic viviparity and hemotrophic viviparity. Ovuliparity means that the female fish lays unfertilized egg into surrounding waters and their egg fertilized externally by male fish. Examples of fish that applies this strategy are cichlids, goldfish, salmon and tuna. Oviparity is when fertilization takes place internally and female sheds zygote covered by additional tissues into surrounding waters. Usually, male fish use intromittent organ (claspers-modified pelvic fins) to deliver sperm into female fish. Examples of fish that applies this strategy are horn shark and skates.

In ovo-viviparity, the fertilization occurs internally and fish eggs develop inside the mother's body, depending on nourishment directly by the mother and the yolk. Examples of ovoviviparous fish are angel sharks, coelacanths and guppies. Whereas in histotrophic viviparity (tissue eating), embryos develop inside the female's oviducts, gaining nutrients by consuming other tissues such as zygotes. This strategy also called intrauterine cannibalism, where the largest embryos eat weaker siblings. Examples of fish in this category are grey nurse shark and halfbeak, *Nomorhamphus ebrardtii* (Meisner & Burns, 1997). Last category is hemotrophic viviparity (blood eating), where embryos develop in the female's oviducts and obtaining nutrients directly by parent via specific structure like placenta in mammals (Lode, 2012). Examples are including lemon shark, surfperches, pipefish and seahorses.

2.7.2 Reproductive system

The development pattern of fish oocyte could be categorized into synchronous, asynchronous or group synchronous (Wallace & Selman, 1981; De-Vlamming *et al.*, 1982). Synchronous pattern is known as total spawner. It means that the development of oocyte is simultaneously and in unison. The egg and sperm of fish only will be produced and fertilized once in their lifetime, indicating that they only have one reproductive cycle and a single size distribution in ovary (West, 1990). Example of fish in this category is common carp, *Cyprinus carpio* (Vazirzadeh & Yelghi, 2015).

In asynchronous pattern, the development of oocyte is non-simultaneous. Fertilization and development of oocyte occurred continuously. Besides, the reproductive cycle could be repeated many times during their lifetime. Fish in this category are also known as batch spawners, where in each batch, only a portion of the yolked oocytes is spawned commonly through hydration process (Murua & Saborido-Ray, 2003). The examples of fish in this category are gudgeon, *Gobio gobio* (Rinchard *et al.*, 1993), peacock bass, *Cichla kelberi* (Normando *et al.*, 2009) and bulatmai barbel, *Luciobarbus capito* (Eagderi *et al.*, 2013).

Latter category is group synchronous pattern. This group is known as multiple spawner, where the development of oocyte occurred in groups and simultaneously. The egg and sperm form a few development cycles and fertilize a few times. Sometimes, this cycle only takes a few weeks with many fertilization times during particular season. According to Murua and Saborido-Ray (2003), at least two populations of oocyte at different developmental stages are observed in this category. The example of fish in this category is bleak, *Alburnus alburnus*, white bream, *Blicca bjoerkna* (Rinchard & Kestemont, 1996), *Rasbora tawarensis* (Muchlisin *et al.*, 2010), African carp, *Labeobarbus batesii* (Claudine *et al.*, 2013) and *Amblypharyngodon mola* (Azadi & Mamun, 2004). Present study was conducted to determine whether the development of oocyte of *C. apogon* is in synchronous, asynchronous or group synchronous pattern using the histological analysis.

On the other hand, fecundity is the spawning ability of fish and related to the number of ripe eggs produced by female fish prior to spawning (Bagenal, 1978). In simple words, it means the potential reproductive capacity of fish populations. Fecundity may increase with the increased body size, differ with species in a population, between populations of the same species, from year to year or season to season in a population (Lawson, 2011). Fecundity also can provide an objective measure of reproductive effort of certain species (Moyle & Cech, 2000) and can be used in estimating fish population in certain area (Lawson, 2011). Research study by Hunter *et al.* (1992) found seven categories of fecundity descriptions, which are annual fecundity, total or absolute fecundity, potential annual fecundity, determinate fecundity, indeterminate annual fecundity, relative fecundity and batch fecundity.

First category is annual fecundity. Annual fecundity is the total number of eggs spawned by a female per year and also called as annual realized fecundity. Second category is total or absolute fecundity. It means the standing stock of advanced yolked oocytes in the ovary. In other words, it means the total number of eggs in a female fish. Third category, potential annual fecundity; is the total advanced yolked oocytes matured per year and considered to be equivalent to the total fecundity prior to the onset of spawning in fish species with determinate fecundity. Fourth category is determinate fecundity. It happens when the potential annual fecundity becomes fixed prior to the onset of spawning. In fishes with determinate fecundity, total fecundity decreases with each spawning because the standing stock of advanced yolked oocytes is not replaced during the spawning season. Fifth category, indeterminate annual fecundity, occurs when the potential annual fecundity of a female is not fixed prior to the onset of spawning and unyolked oocytes continue to be matured and spawned during the spawning season. Sixth category, relative fecundity is the number of mature oocytes in a female fish divided by their total weight. Final category is batch fecundity. It is the number of hydrated oocytes released in one spawning or number of the viable eggs released by a serial spawner in a pulse of spawning and usually