SOME ECOLOGICAL ASPECTS OF Plicofollis argyropleuron (SILURIFORMES: ARIIDAE) IN THE MERBOK ESTUARY OF KEDAH

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By

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LIST OF ABBREVIATIONS

FISAT = FAO-ICLARM Stock Assessment Tools

GPS = Global Positioning System

SCT = Salinity,Conductivity, Temperature

vBGF = von Bertalanffy Growth Function

DATABASE ABBREVIATIONS AND SYMBOLS

CAO = Cortical Aveoli Ooocyte

CPUE = Catch Per Unit Effort

FO = Frequency of Occurrence

GSI = Gonadosomatic Index

LST = Late Spermatid

LWR = Length-Weight Relationship

Og = Oogonia

ol = Ovarian Lamellae

PS = Primary Spermatocyte

sc = sertoli cell

SG = Spermatogonia

SS = Secondary Spermatocyte

st = Seminiferous Tubules

ST = Spermatid

SZ = Spermatozoa

Stage I = Immature

Stage II = Maturing

Stage III = Matured

Stage IV = Ripe

Stage V = Spent

YG = Yolk Globule

YV = Yolk Vesicle

ZR = Zona Radiata

LIST OF PUBLICATIONS

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BEBERAPA ASPEK EKOLOGI *Plicofollis argyropleuron* (SILURIFORMES: ARIIDAE) DI SUNGAI MERBOK, KEDAH

ABSTRAK

Taburan dan kelimpahan, biologi pembiakan, corak pertumbuhan dan hubungan dengan parameter fizikokimia telah dikaji ke atas *Plicofollis argyropleuron* yang juga dikenali dengan nama tempatannya, Goh. Kajian ini dijalankan di Sungai Merbok, Kedah. Sampel ikan diambil daripada hasil tangkapan nelayan tempatan dari Jan-10 sehingga Jan-11 dan dianalisis. Taburan ikan dan kekerapan ikan muncul adalah paling tinggi pada Feb-10 dan hubungannya dengan parameter fizikokimia telah dikaji. Secara amnya, taburan hujan menjadi faktor utama dalam mempengaruhi taburan dan kekerapan kemunculan spesis ini. Sebanyak 30-50 ekor ikan diambil setiap bulan dan pelbagai saiz diperolehi dari 162mm hingga 336mm. Tahap kematangan ikan jantan dan betina dikategorikan kepada lima peringkat iaitu tidak matang, sedang matang, matang, matang sepenuhnya dan selepas matang mengikut ciri-ciri luaran gonad dan melalui kaedah histologi. Musim mengawan ikan ini ialah pada Jan-10 dan Apr-10 untuk ikan jantan dan bagi ikan betina ialah pada Mar-10 dan Aug-10. Ini menunjukkan spesis ini mempunyai kaedah pembiakan tidak serentak. Nilai relatif faktor keadaan, K setiap bulan ialah lebih dari 1 menunjukkan tahap kesihatan ikan, keadaan persekitaran dan bekalan makanan adalah dalam keadaan optimum untuk pembiakan spesis ini di Sungai Merbok. Corak pertumbuhan ikan ini adalah sama seperti corak pertumbuhan untuk ikan jenis tropika. Hasil kajian penyelidikan ini sangat berguna dalam mengenal pasti pengaruh dan kesan parameter persekitaran terhadap spesis ikan estuari.

SOME ECOLOGICAL ASPECTS OF *Plicofollis argyropleuron* (SILURIFORMES: ARIIDAE) IN THE MERBOK ESTUARY OF KEDAH

ABSTRACT

Distribution and abundance, reproductive biology, growth pattern and their relationship to physicochemical parameters have been studied on long snouted catfish, *Plicofollis argyropleuron*, locally known as Goh. This study was conducted in Merbok estuary, Kedah. The fish samples were analysed from the catches of artisanal fishermen collected from Jan-10 to Jan-11. Fish are most abundant and frequently occurred in Feb-10 and their relationship with physicochemical parameters were observed. Generally, rainfall tends to be the main factor that influences their abundance and occurrence. Monthly samples from 30 to 50 of *Plicofollis argyropleuron* were collected with the size varied from 162 mm to 336 mm. The maturity stages of male and female were classified into five different stages namely immature, maturing, mature, ripe and spent according to physical appearances of the gonad and histological method. Their spawning season is Jan-10 and Apr-10 (in males) and Mar-10 and Aug-10 (in females) which suggested that this species exhibit *asynchronous* reproductive behavior. Relative condition factor value, K for all months is more than 1 indicates the level of fish health, environmental conditions and nutrient supply are at the optimum level for this species reproduction in Merbok estuary. The growth pattern of this species is concurrent with the tropical fish growth pattern. The

findings of this study will be beneficial in inferring the affects of environmental parameters and their impacts to the estuarine fish species.

CHAPTER 1

GENERAL INTRODUCTION

1.1 INTRODUCTION

Recent investigations have shown that anthropogenic disturbances to natural ecosystems often results in the simplification of ecosystems and diversity loss which can have a significant effect on the ecosystem functioning. However, due to the lacking of baseline studies and habitat monitoring, the impacts of anthropogenic disturbances on the ecosystem functioning were often undocumented, resulting in little understanding on how the natural ecosystems respond to increasing losses of species (Naeem *et al*., 1994, 1996; Tilman *et al*., 1996; Symstad and Tilman, 2001).

Ecology or ecological science is the study related to the distribution and abundance of living organisms and how the distribution and abundance are affected by the interactions between organisms and their environment (Jody, 2005). The environment of an organism may include the physical surrounding which can be described as the sum of local abiotic factors such as insolation (light), climate and geology as well as the other organisms that share the habitat. Ecology is usually considered a branch of biology that studied living organisms. Organisms can be studied at many different levels from protein and nucleic acids (in biochemistry and molecular biology) to cells (in cellular biology) to individuals (in botany, zoology and other similar disciplines) and finally at the level of populations, communities and ecosystems to the biosphere as a whole; these latter strata are the primary subjects of ecological inquiries.

Estuary water functions as an important nursery habitat for many juvenile marine fishes that are often assumed to dwell in estuaries during their early life. This assumption is based on the occurrence of juveniles and also by the dogma of estuaries as vital nursery habitats (Able and Fahay, 1998; Able, 2005; Ray, 2005). However, the possibility of the juvenile's ability to recruit and utilize the environments as nursery remains largely unknown. Separate metrics such as occurrence, density, growth and mortality are often used as an index of juvenile production (nursery value) and often compared between putative nursery habitats to evaluate their relational values (Able, 1999). These surrogates (especially growth rate) have often been compared between microhabitats within and among the estuaries (Sogard, 1992; Gibson, 1994; Phelam *et al*., 2000; Ross, 2003). However, due to the lack of comparative data on habitat use by fishes in the estuary (Able, 2005), the overall value of a particular nursery habitat is intangible and difficult to measure (Wilson *et al*., 2005) although the theoretical foundation of the relative value of the nursery habitat is simple (Beck *et al*., 2001; Kraus and Secor, 2005).

Study on fish community or species assemblages includes species richness, diversity, morphological, physiological attributes and trophic structures (Zarul Hazrin, 2006). Fish assemblages represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores) tend to integrate effects of lower trophic levels (Garcia-Lopez *et al*., 2006) and depending on species and life stages (Gorman and Karr, 1978; Welcomme, 1985). Knowledge on the fish assemblages in estuary is essential to understand the functioning of these systems. The studies on the interactions between the fish and its habitat are determined by the relationship between aquatic and terrestrial habitats as fish usually consumed terrestrial sources such as insects and fruits provided useful information for conservation purposes (Lagler *et al*., 1977; Ponton and Copp, 1997; Fialho *et al*., 2007).

Fish distribution is a result of the interaction between fishes and their chemical, physical and biological surroundings (Lagler *et al*., 1977; Gordon *et al*., 1996; Bistoni and Hued, 2002). A number of factors affect the abundance, distribution and productivity of fish which include space competition, predation, water quality, nutrient supplies and flow variability (Gorman and Karr, 1978; Zakaria-Ismail and Sabariah, 1994; Gordon *et al*., 1996; Cassati *et al*., 2006; Andrus, 2008). In addition, the presence of riffles and in-stream woody debris that forms heterogeneous habitats influences the fish assemblages (Angermeier and Karr, 1983; Platts *et al*., 1983; Benke *et al*., 1985; Bisson *et al*., 1987). Short-term changes in fish abundance may also occur due to disturbances such as flash floods or droughts (Zarul Hazrin, 2006). Fish needs suitable water quality, migration routes, spawning grounds, feeding sites, shelter from predator and disturbances since they spend their entire life in the same habitat (Angermeier and Karr, 1983; Cowx and Welcomme, 1998).

Dudgeon (1992) pointed out that Asian river ecosystem degradations were related to human activities. Overfishing contributes more in mortality rate of marine species than freshwater species (Kottelat and Whitten, 1996; Coates *et al*., 2003). Human’s land activities will have direct or indirect impact on fish diversity (Nguyen and De Silva, 2006). The impacts were often measured by looking at fish assemblages, their presence or absence and their abundance (Bojsen and Barriga, 2002; Diana *et al*., 2006; Di Prinzio *et al*., 2009). In addition, the study of functional properties of fish such as feeding habit, reproductive biology and growth may provide details on the possible effects of deforestation (Vila-Gispert *et al*., 2000; Bojsen, 2005) especially in tropical ecosystem where terrestrial invertebrates are an important food sources for fish (Angermeier and Karr, 1983).

At present, very limited studies concerning fish ecology have been conducted in the estuaries and coastal areas of Malaysia. Thus, a precise identification and stock description on the fish is required. The information from the study would be very useful in determining and evaluating the degree of fish population changes in regard to human activities and environmental changes in an area. Such knowledge would be invaluable for the sustainable exploitation and management of fish resources in both estuary and coastal area ecosystems.

Therefore, this research was undertaken at Merbok estuary, Kedah with specific reference to *Plicofollis argyropleuron*. This study was separated into three different chapters and was mainly aimed to:

1) Study the distributions and abundances of the *Plicofollis argyropleuron* in a relationship with physical parameters.
2) Study the reproductive biology of the species.
3) Study the growth, mortality and recruitment patterns of the species.

CHAPTER 2

LITERATURE REVIEW

2.1 Estuary ecosystem

Estuary is one of the most important ecosystems in the world due to the existence of its diverse biological entities. Estuary is defined as a partially surrounded coastal body of water that has an open connection with the ocean at the lower parts where freshwater will be flushed off from inland and mixed with the saltwater that came from the open sea (Velaqzuez e*t al*., 2008). This unique ecosystem makes estuary more productive and abiotically variable yet a rigorous and stressful habitat for certain species.

There are three main processes in estuarine environment. One of the processes is the physical process by hydrological factors such as water quality modifications caused by climate changes (Roessig *et al*., 2004). This includes salinity, rainfall, pH, turbidity, conductivity, water depth and temperature. Identification of significant association between fish species and habitat conditions was the first step to incorporate the environmental information with fish abundance.

Beside physical and chemical aspects, biological factor such as fish assemblage make a good sense to perceive the health of the estuaries. The assemblage of estuarine fishes quickly respond to the fluctuation of environmental characteristics allowing them to be recognized as sensitive indicators of habitat degradation, environmental contamination and overall system productivity (Ecoutin *et al*., 2005; Qadir *et al*., 2005).

The study of estuaries has been split into two categories of climate, the tropical and temperate. Due to the complex scenario presented on tropical estuaries including the relationship between environmental factors within estuaries, spatial and temporal patterns in composition, abundance and distribution in fish assemblages, this ecosystem received considerable attentions (Pombo *et al*., 2005).

2.2 Merbok estuary

Merbok estuary is situated in the north-west Peninsular Malaysia at $5^{o}30'N$ $100^{o}25'E$. Here, the Merbok river flows through paddy field with alluvium soils to the mangrove area on its estuarine part into the Straits of Malacca. The length of the river is about 35 kilometres and 3 to 5 metres in depth with a few 20 metres deep holes in tributaries associate with Merbok river. The freshwater part of the river consist of only a few kilometres long as the seawater intrudes until 30 kilometres of its length (±86% of the river part) that tidal occurs at most part of the river (Ong *et al*., 1991).

Merbok river brings discharge water from the surrounding catchment area together with alluvium deposit and mudstone with a few scattered outcrops of granite and quartz. The catchment area around the Merbok estuary was estimated about 550 km^2. This estuary was connected with the

Sungai Muda through a channel at the south part of the river and covered by about 50 km^2 of mangrove vegetation on the estuarine part (Ong *et al*., 1991). According to Ong *et al*. (1980), the mangrove is dominated by *Rhizophora apiculata* and *Bruguiera plaviflora* that can grow up to 30 metres and high in productivity.

2.3 General information of fish

Fish are cold-blooded vertebrates with gills, fins as they depend on water as a medium to live (Lagler *et al*., 1977). Their feeding, digestion, assimilation, growth, responses to stimuli and reproduction depend on the water conditions (Lagler *et al*., 1977). Fishes are the most diverse among the vertebrate groups with 57 orders of living fishes and 482 families, contrast to number of orders and families of amphibians (8,27), reptiles (4,49), birds (29,165) and mammals (23,122) (Matthews, 1998). Lowe-McConnell (1987) reported that the Amazon river basin has the world's richest fish fauna with more than 1300 species. Froese *et al*. (1999) estimated that 7000 fish species that are consumed by humans for food, sports and the aquarium trade were threatened by environmental degradation. Only less than 2000 species were known for their life history parameters such as growth and length at first maturity which was important for fishery management.

2.4 Studied species

According to Marceniuk and Menezes (2007), there are 29 genera in the Ariidae family. Ariids are found worldwide in tropical to warm temperate zones. In Malaysia, there are 25 species from 11 genera recorded (Mansor *et al*., 2010). Ariids, live primarily in the sea unlike the majorities of catfish families that are restricted in the freshwater and have little tolerance for brackish or marine conditions. Ariids catfish are found in shallow temperate and tropical seas around the coastline of North and South America, Africa, Asia and Australia. They are absent in Europe and Antarctica (Velasco and Oddone, 2004). In general, members of Ariidae family attain large sizes, long living, slow growing, low fecundity and mouthbreed their eggs. The members of this family have a deeply forked caudal fin. There are usually three pairs of barbels. They possess some bony plates on their head and near their dorsal fins. Some species have venomous spines in their dorsal and pectoral fins (Mansor *et al*., 2010).

Kingdom **:** Animalia (C. Linnaeus, 1758)

Phylum **:** Chordata (Bateson, 1885)

Subphylum **:** Vertebrata (Cuvier, 1812)

Class **:** Osteichthyes (Huxley, 1880)

Order **:** Siluriformes

Family **:** Ariidae

Genus **:** *Plicofollis*

Species **:** *Plicofollis argyropleuron* (Valenciennes, 1840)

(Source: Global Biodiversity Information Facility (GBIF) Data Portal, 2008)

FAO/English name : Longsnouted catfish

Vernacular/Local name : Goh

Fish identifications : This species has a greyish-blue body. It has an adipose fin pale blotch, anal soft rays in between 14-21, a depressed and elongated head, 27-36% (mean 32%) of SL, low set eyes and a small mouth with width of 24-40% (mean 31%) of HL. Gill rakers are absent on hind aspect of first 2 gill arches.

Habitat, Biology and Fisheries : This species is a demersal-type fish. It lives in brackish and marine water. They usually occur in inshore waters over soft bottoms. They feed on detritus, prawns, soft-bodied organisms and mud. Commonly, they are marketed fresh, salted or dried.

Figure 2.1 Upper tooth patches of *Plicofollis argyropleuron*

Figure 2.2 Dorsal view of head (left side) and skull (right side) of *Plicofollis argyropleuron*

Conand *et al*. (1995) reported that sea catfish were caught throughout the year mostly near the coast during rainy season and in deeper water during dry season. Juveniles and small individuals are found in large numbers in area adjacent to the coast while larger fish occurs in deeper water. Most of the catch is made by boats with lines or gill nets and occasionally by trawlers. This fish is usually marketed fresh, dried or salted (Mansor *et al*., 1998). Some of the species are targeted by industrial and artisanal fisheries which significantly affecting the total regional production (Velasco and Oddone, 2004).

2.5 Fish as bioindicator

Markert *et al*. (2003) defined bioindicator as an organism that contains information on the quality of the environment where a sensitive species which lead to a change in biodiversity can be taken as surrogates for larger communities and act as an indicator for the condition of habitat or ecosystem thus providing a cost- and time-efficient mean to assess the impacts of environmental disturbances on an ecosystem. The use of bioindicator has evolved substantially and is frequently been incorporated into policies and regulations in order to monitor the ecological integrity of watersheds (Moyle and Randall, 1998), lakes (Karr, 1981; Harig and Bain, 1998), semi-natural pastures (Part and Soderstrom, 1999b), rangelands (Bradford *et al*., 1998) and forests (Brooks *et al*., 1998). Bioindicators are also use as the verification of the compliance of industries to specific anti-pollution laws (MacDonald and Smart, 1993) and as the assessment of habitat quality (Powell and Powell, 1986; Canterbury *et al*., 2000).

Diatoms and benthic invertebrates are among the organisms that have been used as a bioindicator. However, due to lack in the life-history information, specialized taxonomists, difficult and time consuming sampling, sorting and identifying, these organisms are less preferred as bioindicator (Karr, 1981). Simon (1999) proposed that fish is one of the best bioindicators and remained as an important part of aquatic study to evaluate water quality.

Many researcher in this field such as Karr (1981), Leonard and Orth (1986), Hughes and Noss (1992), Barbour *et al.* (1999) and Simon (1999) have listed the advantages of using fish as bioindicator. They mentioned that:

1) Fish are relatively long-lived and mobile so they will be a good indicator for long term effects (several years) and broad habitat conditions.
2) Fish tops the aquatic food web and is consumed by humans making them important for assessing contamination.
3) Fish are easy to collect, sort and identify to the species level even at the field allowing them to be released unharmed.
4) Environmental requirements of most fish are relatively well-known. Life history information is extensive for most fish species.
5) Fish is a migratory organism make them as suitable indicators for habitat connectivity.
6) Their economic and aesthetic values help to raise the awareness of the aquatic systems conservation.
7) While assessing the environmental quality by fish assemblages, the stock assessment can also be determined for a sustainable harvest resource.
8) Generally fish assemblages represent a variety of trophic levels (planktivores, herbivores, omnivores, insectivores, piscivores) which they tend to integrate effects of lower trophic levels.

2.6 Fish assemblages

The relationship of habitat structure and physiochemical quality of stream with the fish assemblages has been widely used (Casatti *et al*., 2006; Qadir *et al*., 2009). Akin *et al.* (2005) reported that abiotic factors (E.g. salinity, temperature, dissolved oxygen (DO), freshwater inflow, structural attributed of habitat, depth, geographic distance from the estuary mouth and hydrograph) affect the occurrence of fish within the estuaries. The large scale (in kilometres) patterns of fish distribution are the outcome of species response to their physical environment (Remmert, 1983). Abiotic factors operating over large spatial scale were believed to determine coarse community structure whereas biotic interactions define species abundance and distribution patterns within structure (Akin *et al*., 2005).

Fish species richness is one of the basic multimetric biological monitoring indices that frequently used to measure stream health (Karr and Chu, 1999; Daniel, 2006). Zaret and Rand's (1971) studied the fish assemblage in a small stream was perhaps the first to examine the effect of season on the patterns of niche segregation. They found that most fishes expanded their resources use during the wet seasons as most resources are abundant during this time while showed a trend to niche compression and segregation during dry season (Winemiller *et al*., 2000).

2.7 Factors influencing the distribution of fish

It is important to understand the relationship between the biotic community structure and the physical habitat (Martin-Smith, 1998) because every fish species has different habitat preferences (Fialho *et al*., 2007). Habitat diversity, the biomass, richness, mean fish size and density of fish were correlated with,

1) Water depth and velocity (Mendelson, 1975; Schlosser, 1985; Ali *et al*., 1988; Meffe and Sheldon, 1988; Sheldon and Meffe, 1995)
2) Substrate type, aquatic vegetation and bank cover (Gorman and Karr, 1978; Bishop and Harland, 1982; Schlosser, 1982; Rakocinski, 1988; Bishop and Forbes, 1991)

Sheldon (1968), Moyle and Vondracek (1985), Bain *et al*., (1988) and Koehn (1992) found that water depth and current velocity were the most important variables influencing fish distribution. The selection of fish in the physical habitat depends on the geological, morphological and hydrological processes (Cowx and Welcomme, 1998).

2.7.1 Water temperature

The presence of riparian vegetation influenced the water temperature. The vegetation shaded most of the water surfaces preventing excessive warming (Allan and Castillo, 2007) and provide inputs of allochthonous organic materials for the biological production in small stream ecosystems (Rohasliney and Jackson, 2009). Since fish are cold-blooded, the increase in water temperature will influence their body temperature, growth rate, food consumption and feed conversion (Gadowaski and Caddel, 1991; Kausar and Salim, 2006). Fish growth and liveability are optimum at certain temperature range (Gadowaski and Caddel, 1991). As for example, Afzal Khan *et al.* (2004) reported that the optimum growing temperature for warm water fish ranged from 25-30^{o}C. An increase in temperature may accelerate the digestion of nutrients due to the increase in enzyme activities (Shcherbina and Kazlauskene, 1971; Gordon *et al.*, 1996). High temperatures may lead to disease outbreaks inhibited the fish growth (Platts *et al*., 1983).

2.7.2 Salinity

Salinity is the concentration of ions dissolved in water consisting of sodium, magnesium, calcium, chloride, sulphate, carbonate and bicarbonate. Gordon *et al.*, (1996) stated that salts enter a stream through saline groundwater, sea salts dissolved in the rainwater and agricultural runoff. The gas solubility in water was reduced as salinity increased (Helfman, 2009).

The loss of water molecules during evaporation increased the conductivity, total dissolved solids (TDS) and salinity by leaving dissolved minerals in the water system (Jacobsen, 2008). TDS contains of all organic and inorganic substance in water including sodium, calcium, magnesium and chloride (Gordon *et al*., 1996). The ability of the ions to conduct an electrical current increased the conductivity. Since salinity and conductivity were positively correlated (Jacobsen, 2008), the increasing salinity will increase the conductivity as well.

2.7.3 Conductivity

Conductivity defined as a measure of dissolved salt in the water or the total amount of dissolved ions in the water (Michaud, 1991). As flowing water picks up salts from the sediment bed (rocks and soils), conductivity will increase in the downstream direction. When the water reaches the estuary, conductivity rises very sharply as freshwater mixed with the high salt content of sea water. During storms, a high water level will decrease the conductivity since rainwater has a low dissolved salt content. Any soluble salts on the ground at the beginning of a large storm are quickly picked-up in the surface flow and become diluted by the rain.

2.7.4 Water depth

Gordon *et al.* (1996) stated that the variations in water depth are created by variations in channel from pools and riffles. Water depth can be categorized as very shallow (0-5m), shallow (5-20m), moderate (20-50m) and deep (>50m) (Gorman and Karr, 1978). Compared to riffles, deeper pool and run habitats are generally more complex due to the presence of debris, roots or group of boulders with extensive space in between (Martin-Smith, 1998). Previous studies reported positive correlation between pool depth and the fish size (Power, 1987; Harvey and Stewart, 1991) and species richness (Mendelson, 1975; Meffe and Sheldon, 1988). Fish that lives in pools tend to be larger in size while small fish tends to live in shallow water (Gordon *et al*., 1996).

2.7.5 Turbidity

Turbidity is a measurement of water clarity and how easily light penetrates into the water. In a presence of other particles like sediments and suspended solid in the water, the amount of light that can pass through the water will be low. Thus, the cloudier the water, the greater the turbidity is. Aquatic organisms such as aquatic plants that carry out photosynthesis and some species of fish that use light for protection purpose can be affected by the changes in turbidity. Turbidity preference of fishes is a species-specific response and correlates with the age of the fish (Cyrus and Blaber, 1987; Blabber and Cyrus, 1983).

2.7.6 Rainfall

In most part of the world, the rain is the main source of freshwater that provides suitable conditions for diverse ecosystems as well as water for hydroelectric power plants and crop irrigations. Precipitation is a key component of water cycle and it is accountable for depositing most of the fresh water on the planet. An increase in temperature will lead to an increase in evaporation that induces extra precipitation. There has been an upsurge in the amount of heavy precipitation events in most areas during the past century as well as an increment since the 1970s in the prevalence of droughts especially in the tropics and subtropics (Climate Change Division, 2008).

2.7.7 pH

pH is a measure of how acidic or alkalic a solution is which range value from 0 to 14. Solution is acidic if pH < 7, alkalic if pH > 7 and neutral at pH >7<. pH can be used as a measure to verify estuary water quality. Normally, the pH of coastal waters vary from pH 7-8 while wetlands, swamps and other forested areas will have lower pH levels. Changes in water pH value can be caused by several factors such as photosynthetic uptake of carbon dioxide by aquatic plants, deficiency of oxygen in waters, high rainfall and inflow of contaminants. Most aquatic organisms are well-adapted living in solution with pH between 5 and 9. In estuary, the pH tends to remain constant because the chemical components in seawater act as buffer to resist large changes of pH. However, biological activity might significantly alter the pH in the estuary. For an example, an excess presence of algae (algal bloom) may results an increase in pH levels in the estuary and become potentially harmful to aquatic organisms (Huet, 1994).

2.8 Sex ratio

Sex ratio indicates the composition of males and females in a population. It is calculated by expressing the respective numbers of males and females as a percentage of adult examined. This method is said to be more preferable when involving a direct ratio between numbers of males and females as it does not consider data where all the specimens may be of one sex (Beumer, 1979). Klingbeil (1978) reported that sex ratios calculated for an entire commercial season are based on an estimated total numbers of males and females landed. These ratios require correction for any differences in average weight of the sexes.

2.9 Fish breeding strategy

Three key strategies in fish breeding pointed by Wallace and Selman (1981) and De Vlamming *et al.* (1982) are:

1) Development of oocyte simultaneously (synchronous)

This type of breeding strategy occurred when sperm and egg produced and fertilized once before the fish dies. Fish in this category will only be experiencing its breeding cycle once during its lifetime.

2) Development of oocyte in grouping and simultaneously (grouping synchronous)

Fish that experience this type of strategy release sperm and egg that will form a few development cycles and fertilized for a few times. This cycle occurs in one year period or only a few weeks with many fertilization times (during particular season).

3) Development of oocyte non-simultaneously (asynchronous)

The development of oocyte and fertilization occurred continuously and the reproductive cycle can be repeated during the fish lifetime. For some species, each individual are able to fertilize a few eggs every day during the breeding season.

A breeding strategy can be influenced by a lot of factors. In order to perform a perfect breeding cycle and ensure all eggs are produced safely before and after been fertilized, certain elements need to be taken into consideration such as environment suitability, the presence of an enough food supply, reduction of predator amount and water quality level.

2.10 Reproductive biology

Barr (1968) and Crim and Gleb (1991) pointed that ovary cycle can be divided into four levels. For testis cycle, Grier (1981) and Sukumasavin (2001) proposed that it can be divided into five levels. The levels are:

Ovary cycle:

1) Oogonium replication through mitosis division. Oogonium is small and round in shape and present either in single or in grouping.
2) Transformation of oogonium to oocyte through meiosis. Primary oocyte would develop into critical stage and will respond on stimulation of gonadtrophin hormone.
3) Development of oocyte and vitellogenic process occurs actively and correlated with gonadtrophin hormone.

4) Maturity of oocyte and ovulation occurs when fertile oocytes are released into the water.

Testis cycle:

1) Testosterone hormone stimulates spematogonia (2n) to undergo mitosis and become primary spermatocyte.
2) Primary spermatocyte will grow and reduce the number of chromosomes to half and become secondary spermatocyte.
3) At the end of meiosis, secondary spermatocyte will become spermatid.
4) Ketotestosteron hormone will stimulate spermatid to produce tail to become spermatozoa. This process is called spermatogenesis. Spermatozoa is a mature sperm in the testis lumen.
5) Spermatozoa will further dissolve in seminal liquid and produces semen. This process is called spermiation. Male fish is considered mature at this time (functional maturity). Testis lumen will be filled with sperm and semen will be released when the abdomen being pressed

2.11 Gonadosomatic Index (GSI)

Gonadosomatic index, abbreviated as GSI is a tool of measuring the sexual maturity of animals in relation to ovary and testis development (Barber and Blaker, 2006). The calculation for GSI is as follows,

$$GSI = \frac{\text{Wet gonad weight}}{\text{Wet body weight}} \times 100$$

Payne (1975), Htun-han (1978) and Delahunty and de Vlaming (1980) reported that reproductive cycle involving apparent changes to gonad weight, heart and somatic tissue. Changes in the gonad maturity can be observed during the changes of gonad weight in the reproductive cycle.

2.12 Spawning season

According to De Vlaming (1972), the right spawning time is very important for the species survival. Previous study has showed that tropical fish spawn year round (Aizam *et al.*, 1983) with peak period during rainy season. Either in sea or river, heavy rainfall would result in a rising of the water level in littoral zone and further improving the quantities of food such as phytoplankton and zooplankton (Bagenal, 1967). The presence of food would naturally stimulate the fish to spawn and would ensure the survival of larval and juvenile fish.

2.13 Fecundity

Fecundity is the actual reproductive rate of an organism or population measured by the number of gametes (eggs), seed set or asexual propagules (Etienne, 2010). Marked differences in fecundity among species often reflect different reproductive strategies (Pitcher and Hart, 1982;

Wootton, 1984; Helfman *et al*., 1997; Murua and Saborido-Rey, 2003). Within a given species, fecundity may vary as a result of different adaptations to environmental habitats (Witthames *et al*., 1995). Even within a stock, fecundity is known to vary annually, undergo long term changes (Horwood *et al*., 1986; Rijnsdorp, 1991; Kjesbu *et al*., 1998) and has been shown to be proportional to fish size, age and condition. Larger fish produces more eggs, both in absolute and in relative terms to body mass. For a given size, females are in better condition to exhibit higher fecundity (Kjesbu *et al*., 1991).

2.14 Length at first maturity

Fish becomes sexually mature for the first time at a size that is rather constant to the proportion for their final length. This value is given as close to 2/3 of the final body length. The length at which 50% of the population is found to be matured (M_{50}) is calculated by using a graph paper (Wooton, 1998).

2.15 Growth in fish

Growth can be defined as a gradual increase or development in term of size and number of the living organisms over time (Pauly, 1984; Sparre and Venema, 1998). According to Jobling (2002), the changes in either length or weight or both as the fish grows up defined growth. Growth is expressed in a growth curve with sigmoid form. The growth rates can be slow due to the competition for foods in a crowded situation within the fish population (Gulland and Holt, 1959).