CHAPTER 2

REVIEW OF LITERATURE
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REVIEW OF LITERATURE

Silverbellies have long been subjected to detailed biological studies including food and feeding, length-weight relationship, age, growth and reproductive biology. However, very few work on silverbellies from the Kerala coast is reported by Balan (1963) on biology, Kurup & Samual (1983) on taxonomy of leiognathids from Vembanad lake and Abraham (2001) on taxonomy, biology and population dynamics of silverbellies along the Kerala coast. It is with this background the present study was undertaken.

1. SYSTEMATICS

As a science, systematics encompasses both taxonomy and classification and precisely it is the study of the kinds and diversity of organisms, including their distinction, classification, investigation of phylogenetic relationships and evolution (Gill and Mooi, 2002). Other fields of fishery biology such as ecology, genetics, development, physiology and conservation are recognizing that, an understanding of the systematics of fishes can often be necessary for clarifying concepts and frequently crucial to forming coherent and complete hypotheses. Fisheries are one of the most important renewable resources. With increasing fishing pressure, the only option left for the sustainability of fisheries is their rational management. Proper management is possible with a thorough knowledge of the dynamics of the fish stocks. For a meaningful study of the dynamics, knowledge of natural history of the species is necessary and this in turn can be acquired by the correct identification of fish species. This assumes greater importance in tropical seas where, a multitude of closely related and
morphologically similar species occur. The role of taxonomy and proper identification cannot be overstressed in studies of population dynamics. The study is also a step towards understanding the bewildering biodiversity that characterizes the tropical seas.

1.1 Systematic review of the Family: Leiognathidae

Many taxonomists involved in the description of leiognathids from certain regions around the globe. Gilchrist and Thompson (1908) have adopted the genus name *Equula*. Work on systematics of silverbellies from seas around India was rather rare and scanty and the major contributors were Hora and Mukherji (1938), Munro (1955), Menon and Talwar (1972), Talwar (1973), Datta (1974), Kotthaus (1974), James (1975, 1984 a and 1984 b), Smith (1978), Sundararaj et al. (1982), Talwar and Kacker (1984) and Sudarsan (1986). James (1985a &b) reported relationship among the genera and species by a comparative osteology of 17 species by providing an osteological key to the genera and the species of Indian leiognathids.

Leiognathidae is in need of taxonomic revision. The superficial external similarity of leiognathids, the wide geographical distribution of the family, rudimentary original descriptions for many species, and propagation of misidentifications in the literature have all contributed to scores of taxonomic problems that plague the family which not only contribute to frequent misidentifications but also to the creation of “wastebasket” species (Sparks, 2006 a; Chakrabarty and Sparks, 2007). Leiognathids are reported to be difficult to diagnose and identify because these fish are morphologically conservative fishes across genera (Sparks et al., 2005). All earlier Indian authors referred to three
genera *Leiognathus*, *Gazza*, and *Secutor* in Leiognathidae. The validity of the species belonging to *Gazza* and *Secutor* largely has been resolved recently (Kimura *et al*., 2000). However, species in the genus *Leiognathus* still present considerable taxonomic difficulty, despite various family level revisions (James, 1975, 1984; Jones, 1985 and Woodland *et al*., 2001), because of the morphological similarity of many species. Several analyses of these fishes have been carried out focusing on morphology (Kimura *et al*., 2000, 2003 and 2005; Sparks, 2006a and 2006b). Advances in understanding the family level phylogenetic relationships of ponyfishes have provided a better understanding of the relationship of leiognathids at the generic and species levels (Chakrabarty and Sparks, 2007 & 2008). The genus *Leiognathus*, which formally contained majority of ponyfish species, was reported paraphyletic. Many taxonomic changes have taken place in recent years, including the discription of novel taxa; several new genera have been recently established and some subgenera have been resurrected from synonymy and elevated to generic rank including: *Equulites* Fowler, 1904 (elevated to generic rank by Chakrabarty and Sparks, 2008; Kimura *et al*., 2008a), and *Eubleekeria* Fowler, 1904 (elevated to generic rank by Chakrabarty and Sparks, 2008; Kimura *et al*., 2008b); *Nuchequula* Whitley, 1932 (elevated to generic rank by Chakrabarty and Sparks, 2007; Kimura *et al*., 2008c) and *Aurgiequula* Fowler, 1918 (elevated to generic rank by Chakrabarty *et al*., 2008). Sexually dimorphic light organ of leiognathids are found to be phylogenetically significant and out of such studies two new genera were recently described; *Photopectoralis* Sparks, Dunlap and Smith, 2005 and *Photoplagios* Sparks, Dunlap and Smith, 2005 (Currently a junior synonym of *Equalites*). *Karalla* Chakrabarty and Sparks, 2008 is another newly described
genus. In the present work, the systematics of leiognathids along the Kerala coast is studied and only the updated generic and species names considered as valid by the FAO (Fricke and Eschmeyer 2009, Eschmeyer and Fricke, 2010 (Fish base, online publications) are used throughout the study.

Leiognathidae is represented by a high diversity of species in the Seas around India. Of the 49 valid species reported world over and 26 species in the Western Indian Ocean (Fricke and Eschmeyer, 2009 and Eschmeyer and Fricke, 2010 - Fish base online pub.), a maximum of 21 species belonging to three traditional genera viz. Leiognathus, Gazza and Secutor were reported so far from the east and west coasts of India. Even though, the family has been revised recently by adding several new genera by the aforesaid authors; such work has not gained much momentum in the Indian region.

1.2 Morphometrics in Ichthyological Systematics

Morphometrics looks at measureable components of fish such as size of body parts which have been commonly used to measure discreteness and relationships among various taxonomic categories. Morphometrics and meristic analysis can be a first step in investigating the stock structure of species with large population sizes (Sawant and Raje, 2007).

For the past 50 years, morphometric investigations have been based on a set of traditional measurements described by Hubbs and Lagler (1947 and 2004). In the present study morphometric measurements are done based on the instructions proposed by Hubbs and Lagler (1947). The workers who used the system of Hubbs and Lagler (1947) for the morphometric analysis in leiognathids include Datta (1974) in Leiognathus splendens, Kotthaus (1974) in Gazza minuta and Leiognathus equulus, Dulcic and Pallaoro (2002) in Leiognathus
klunzingeri. In spite of the studies done by aforesaid authors, no systematic and conclusive attempt have been done on the morphometric studies of silverbellies from the Kerala coast.

The survey of literature on taxonomy of silverbellies from India clearly reveals that most of the work was carried out from the eastern and southeastern coasts. After the work of James (1975), who has done the last full revision of Leiognathidae, no attempt has been seriously made by any worker towards a comprehensive study on the systematics of this important demersal fish group based on morphological identification keys, morphometrics and meristics. Adequate biometric data is lacking for marine species from the west coast of India. The literature on species distribution in different regions in India suggested a great deal of variation in the distribution and abundance of species (James, 1975; Jayabalan and Ramamoorthi, 1977). The distribution of species along the west coast needs to be better understood. James (1969), Rani Singh and Talwar (1978a & 1978b), Jayabalan (1985) and James and Badrudeen (1990) added seven species to the known ponyfish species of India of which four were new to science and three were first reports from India. The most thorough and only comprehensive revision of the family Leiognathidae from the Indian seas was that of James (1975). Jayabalan and Ramamoorthi (1977) gave a synoptic key to the genera of Leiognathidae at Porto Novo and Talwar and Kacker (1984) described 15 species. James (1984 b) also described 17 species of ponyfish from the Western Indian Ocean including India. Recently Chakrabarty et al. (2008) redescribed the ponyfishes of Sri Lanka and resurrected Aurigequula Fowler, 1918.
Therefore, it was felt necessary to study the taxonomy of one of the most abundant and misidentified marine taxa found in the coastal waters of Kerala. In the backwaters of Kerala, Shetty (1963) reported 6 species and Kurup and Samuel (1983) reported nine species which brought the total known species from Kerala to 11. The last full of the taxonomy of silverbellies along the Kerala coast was limited to that work of Abraham (2001) who reported 16 species belonging to three traditional genera with varying abundance and stated that *Gazza achlamys* is of rare occurrence along the Kerala coast. Out of 16 species, *Nuchequula blochii* Valenciennes, 1835 (Syn. *Leiognathus blochii*), *Photoplagios elongates* (Syn. *Leiognathus elongates*) and *Aurigequula longispina* Valenciennes, 1835 (Syn. *Leiognathus smithurstii*) which were shown a rare occurrence along Kerala Coast as reported by Abraham (2001) did not encountered in the present study.

Hence first part of the present study is aimed at gathering information on the distribution of silverbellies along the Kerala coast and arranging them in a systematic way by observing the morphological characters and preparing keys to genera and species. Morphometric and metistic details were also analyzed which help to determine the degree of association of various characters and to establish proportions in total length facilitating the identification of the members of the family.

2. FOOD AND FEEDING

Food is basic to all vital functions of an individual fish as well as the population. The movement and migrations of fish population are primarily in search of favourable spawning and feeding ground. Food is one of the key factors that profoundly influence the shoaling behaviour, growth, conditioning and even
the fishery. Furthermore, feeding habit is one of the primary criterions deciding on transplantation of a species to new ecosystem with least possible damage to the native fauna (Bachok et al., 2004).

A variety of methods are available and commonly used for the gut content study in fishes. The occurrence method is the simplest way of recording the number of stomachs containing one or more individuals of each food category. This number is expressed as a percentage of all stomachs. In gravimetric/volumetric method, food contents in the stomach are measured either in weight or volume (displacement method). This may not be suitable for fishes feeding on smaller items like unicellular algae, diatoms etc., but found to be useful to quantify the diet of carnivorous as well as predatory fishes. Number method is relatively easy to carry out but is beset with distorted information on volume of the gut content components.

In numerical method, the number of individuals in each food category is recorded for all stomachs and the total is expressed as percentage of total individuals in all food categories (Berg, 1979). The number of organisms may be determined using a Sedgwick-Rafter counting cell (Brazo et al., 1978). Index of preponderance method (Natarajan and Jhingran, 1961) taken into account both the frequency of occurrence as well as bulk of the food item (volume) providing a definite and measureable basis for grading different food items. To estimate the importance of each food items among the forage, Index of Relative Importance - IRI of Pinkas et al. (1971), as modified by Hyslop (1980) is widely used by fishery biologists. Mohan and Sankaran (1988) reported two new indices, Simple Resultant Index (RS) and Weighted Resultant Index (RH) for the gut content analysis of fishes.

A review indicated that study on diet of leiognathids is scanty from Kerala coast. Brief description on the diet of *Leiognathus brevirostris, Gazza minuta* and *Secutor insidiator* from the South- East coast of India was given by Chacko (1944 a & 1944 b), Vijayaraghavan (1949), John (1951), Bapat and Bal
A review of food habit and food composition studies of Indian marine fishes reveals lack of consistent methodological approach and application of statistical tests to analyse results. Apart from the above mentioned studies along the east coast; none has attempted to access information on the food and feeding habits of silverbellies off Kerala coast. The present study therefore, aimed at contributing knowledge on the diet of three species of silverbellies; *Leiognathus brevirostris*, *Gazza minuta* and *Secutor insidiator* inhabit along Kerala coast and to examine the seasonal and ontogenetic variations in feeding intensity and types of prey consumed by the fish with a view to get information on the functional role of these fishes in their respective ecosystems.

2.1. Diet overlap study

Morphological comparisons of feeding apparatus among co-occurring species provide important information to ecologists searching for the mechanisms that determine resource utilization and animal community structure (Krebs, 1989; Wikramanayaka, 1990). Motta (1988), Humphries (1993) and Labropoulou and Eleftheriou (2005) require special mention who conducted a comparative study on the mouth morphology of ten species of Pacific butterfly fishes, three co-occurring species of atherinids and two pairs of congeneric demersal fish species respectively to examine the effect of the morphological differences in the feeding apparatus and resource partitioning among co-occurring fish species. Many authors stated that, slipmouths are benthic-pelagic (demersal) fishes usually found feeding in schools containing several other co-existing species on the
shallow coastal Sea beds (Anon, 1976 a& b; Liu Jing, 1997 and Seah et al., 2009). Hence, a study on the diet overlap in resource use and morphological peculiarities of the food gathering apparatus in three co-occurring species of silverbellies; Gazza minuta, Leiognathus brevirostris and Secutor insidiator which live in a community along Kerala coast is especially relevant in understanding the community organization. Various similarity indices or resource utilization indices or diet overlap indices have been used for diet overlap study (Loman, 1986) which includes Morisita’s (1959), Horn’s (1966), Schoener’s (1970) and Pianka’s (1973) and there is controversy as to which index is the best (Krebs, 1989).

In the present study the dietary overlap of each species pair is calculated by Simplified Morisita – Horn index (Horn, 1966). This index ranges from 0 to 1, values equal to or greater than 0.6 are considered as high food overlap (Zaret and Rand, 1971). Pony fishes are very specific in the nature of food intake. They are generally recognized by its protractle mouth either in direction upward, forward or downward (Sparks et al., 2005 and Woodland et al., 2001) and search for prey using the protruding pipette-like mouth or by sieving potential food through their gill rakers (Liu Jing, 1997). Eventhough, some authors studied the mechanism that makes the moth slips in slipmouths (Whitehead, 1986), only a few workers like Liu Jing (1997), worked on the morphological comparison of feeding apparatus among co-occurring leiognathids distributed in the South China sea. No such work was ever reported for silverbellies distributed in the seas around India.

The diet of most fishes change with growth, but the timing of these changes varies from species to species and is often associated with changes in
lifestyles or habitat (Blaber, 2000). Although, ontogenetic shift in feeding habits have been studied for a wide variety of fish species in recent years (Hajisamae et al., 2006; Roger et al., 2007; Kusuto et al., 2008), it is worth mentioning that there is a paucity of information on fishes from Southeast Asia, in despite of having diverse fish fauna in the coastal ecosystem (Hajisamae and Chou, 2003). A complete understanding of such ecological processes will have a bearing on the success of management and conservation practices (Gerking, 1994). Hence, it is attempted to investigate the seasonal and ontogenetic variation in diet and feeding intensity, comparative study of the feeding apparatus and diet overlap in 3 species of silverbellies from the Kerala coast.

3. LENGTH - WEIGHT RELATIONSHIP AND RELATIVE CONDITION FACTOR

Length - weight data provide statistics that are cornerstone in the foundation of fishery research and management. It is of prime importance in fish yield equations, estimation of biomass, stock assessments, estimating growth, mortality, in the prediction of weight of fish from a given length in yield assessment and production (tissue growth) of fish in natural waters as well as in hatcheries and laboratories (Ekelemu and Kesena, 2010 and Ghailen et al., 2010). Weight of the fish normally increases with increase in length. Hence these two parameters can be related and described by hypothetical cube law \( W = c L^3 \), where ‘\( W \)’ represents weight of fish, ‘\( L \)’ is the length and ‘\( c \)’ a constant. Thus, in general, the growth of fish in weight is directly proportional to the cube of the length (Lagler, 1956). Le Cren (1951) suggested a generalized parabolic equation, \( W = aL^b \), where \( W \) and \( L \) represent weight and length of fish respectively, ‘\( a \)’ and ‘\( b \)’ constants estimated empirically from the data. The exponential value of ‘\( b \)’ in
the parabolic equation has been found to vary from 2.5 to 4 (Hile, 1936 and Martin, 1949). Length weight relationship equation may help to determine whether somatic growth is isometric (b = 3; where the body form of fish remains constant at different lengths) or allometric (negative allometric; b<3, when fish becomes more slender as the length increases and positive allometric; b>3, where fish grows more wider and deep with increase in length (Spiegel, 1991 and Safran, 1992).

The equation, \( W = aL^b \) can be transformed into linear function by taking logarithmic value of the length and weight data and the values of ‘a’ and ‘b’ can be estimated by regression analysis. Then the parabolic equation, \( W = aL^b \) takes the form, \( \log W = \log a + b \log L \) or \( Y = A + bX \)

Where, ‘Y’ = \( \log W \), ‘X’ = \( \log L \), ‘A’ = \( \log a \), the intercept of the line on the ‘Y’ axis and ‘b’, the exponent.

Variation from the expected weight for length of individual fish or group can be detected by an analysis of the condition factor (K) and relative condition factor (Kn). Le Cren (1951) proposed the relative condition factor ‘Kn’ calculated by the following formula, \( Kn = \frac{W}{w} \), where, ‘W’ = observed weight of the fish and ‘w ’= the calculated weight obtainable from the length-weight relationship equation. Some published work on the length weight relationship and condition factor of leiognathids include that of Pearson and Malpas (1926), Balan (1963), James and Badrudeen (1981), Cinco (1982), Murty (1983), Pauly (1984), Bianchi (1985), James (1986) and Murty (1986b). Detailed account on the length weight relationship and relative condition of pony fish species distributed along the Kerala coast is still lacking. The objective of this chapter is to present information on the length-weight relationship (LWR) and relative condition factor of three
leiognathids, *Leiognathus brevirostris*, *Gazza minuta* and *Secutor insidiator* of Kerala coast.

**4. REPRODUCTIVE BIOLOGY**

Reproductive traits include aspects such as length at first maturity, maturation cycle, size dependent fecundity, sex ratio and spawning season. Identification of the breeding activity of an exploited fish species provides management options for the protection of its spawning stocks (McPherson, 1993). Information on the size and age at maturity is essential to ensure a sustained yield by regulating the mesh size of the net, to make sure that the smaller fish also gets an opportunity to spawn at least once in their life time. In addition, knowledge on maturation process and spawning frequency is reported to be useful for understanding the life history, stock structure, recruitment and fishery dynamics (Schaefer, 1987). Sex ratio study is important because males and females are of different sizes in majority of fishes, a displacement of the average size of fish in the commercial catches in either direction will also alter sex composition of the stock. Certain internal factors (hormones) and external factors (water temperature and salinity) reported to act as stimuli for inducing spawning in fishes (Qasim, 1973).

Scanty information is available on the reproductive aspects of leiognathids and no attention was so far paid to silverbellies distributed along the Kerala Coast. Previous work on the reproductive biology of the slipmouths from abroad included Kamohara (1967) on the spawning period of *Leiognathus equulus* from Japan, Wallace (1975) and Pauly (1977a) on the maturity data of *Leiognathus daura* from Philippines, Saetre and De Paula e Silva (1979) on spawning season of five species of silverbellies including *Gazza minuta* and *Secutor insidiator*,

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The maturation, fecundity and spawning habits of leiognathids have been described by earlier authors from Indian coast. Anon (1981, 1982 and 1985) and Arora (1951) reported the spawning and fecundity of *Leiognathus splendens*. Balan (1963) studied the breeding biology of *Leiognathus bindus* from Calicut coast, Jones (1967), Rao (1967a) on the reproductive cycle of *Leiognathus splendens*, Pillay (1972) and Jayabal and Ramamoorthy (1985b) on fecundity and spawning of *Secutor insidiator*, Qasim (1973), Kuthalingam et al. (1978) and Jayaseelan (1979) on the spawning frequency and fecundity of some species of silverbellies, James and Badrudeen (1975, 1981 and 1986) on the reproductive biology of *Leiognathus brevirostris* and *Leiognathus dussumieri* from the Palk Bay and Gulf of Mannar, Jayabal (1986a) on the spawning season and fecundity of *Leiognathus splendens*, *Secutor insidiator* and *Gazza minuta* at Porto Novo coast. Murty (1990) on the reproduction of *Secutor insidiator* from Kakinada, Murthy (1983) on the breeding biology of *Leiognathus bindus*, Dhulkhed and Annigeri (1988) on the size at first maturity and spawning season of *Leiognathus bindus* and *Leiognathus splendens* from Karwar and Murty et al. (1988) on the spawning season of *Leiognathus bindus*, *Leiognathus brevirostris* and *Gazza minuta* from Kakinada.

Review showed that, except for the spawning and fecundity studies of Balan (1963) on the *Leiognathus bindus* and Abraham (2001) on *Leiognathus*
splendens and Secutor insidiator, no study was sofar reported on the reproductive biology of siverbellies of Kerala coast. Hence, the present study was undertaken to get a comprehensive knowledge on the reproductive parameters of 3 leiognathids viz. Gazza minuta, Leiognthus brevirostris and Secutor insidiator from Kerala coast.

4.1 Quantification of ovaries into different stages of maturity

Fish exhibit periodic and cyclic reproductive behavior. For the determination of cycle of maturity of gonads, the most common method is to define the stages of sexual maturity and follow them at monthly, fortnightly or weekly intervals in a sample fairly representative of the population. A large number of keys for maturity have been reported by various workers; Qasim (1957) followed 4 to 5 maturity stages in Blennius pholis, Bal (1960) put forward as much as 14 stages for Polydactylus indicus, Michele et al. (1997) adopted five maturity stages while studying the reproductive biology of scad, Trachurus mediterraneus from the Gulf of Trieste and Sivakami et al. (2001) developed seven stage key for Priacanthus hamrur. In the present study, 5 stages of maturity was adopted.

4.2 Histological study of ovary in Secutor insidiator

Histological approach permits definition of the process of development and final maturation of the oocytes and allows the identification of the essential morphological parameters that can be used to monitor the sequence and the timing of the ovarian development. Except for the work of Fujito (1960) on the egg development of Leiognathus nuchalis, work in this regard on silverbellies is rather rare and scanty.
4.3 **Size at first maturity**

Greenwood (1976) reported that fish becomes sexually mature for the first time at a size which is a rather constant proportion of their final length. Variations in the lengths at first maturity may be related to ecological factors, food supply and assimilation (Keshava *et al.*, 1988). The length at which 50% of the fish attain maturity is regarded as the length at first maturity (Borah, 2001).

4.4 **Spawning frequency**

The frequency of reproduction is another characteristic of fish’s life history strategies that appears to reflect the predictability of the environment in which the fishes live. Grimes and Huntsman (1980) have demonstrated that by studying the intra-ovarian egg dimensions of fishes in the mature condition and changes in the gonadosomatic index, it is possible to elucidate the duration of spawning periods and individual spawning frequency.

4.5 **Fecundity**

Fecundity is the most common measure of reproductive potential in fishes because it is relatively easy measurement to make. Potential fecundity/absolute fecundity is usually defined as the number of ripening/ripe eggs available in the female in a single breeding season (Bagenal and Braum, 1968). Fecundity varies with seasons, climatic conditions, habitat, nutritional status and genetic potential (Bromage *et al.*, 1992). Murua *et al.* (2003) analyzed the merits and demerits of various methods employed to estimate the fecundity of marine fish species. Gravimetric method is the most common method used to estimate fecundity (Hunter *et al.*, 1989). In this method, fecundity (F) is determined as the product of gonad weight and oocyte density. In the volumetric method of fecundity estimation, ovary volume and subsample volume instead of ovary weight and
subsample weight was used (Simpson, 1951b). Absolute fecundity can usually be related to other variables of the fish such as total length, body weight and ovary weight by ordinary least square method (Bagenal and Braum, 1968).

4.6 Sex ratio

The sex-ratio distribution was studied to test whether the observed sex ratio in each month differed significantly from the expected ratio.

5. LIGHT ORGAN AND SEXUAL DIMORPHISM IN LEIOGNATHIDAE

Sexual dimorphism in overall size and appearance occurs throughout the animal kingdom and can be influenced by sex specific natural selection resulting from ecological differences between the sexes (Hedrick and Temeles, 1989; Reimchen and Nosil, 2004) and has thus far dominated research on sexual differences in morphology (Schulte-Hostedde et al., 2002). According to Andersson (1994), differences in the selective pressures experienced by the sexes can ultimately result in the evolution of sexual dimorphism of morphological traits. In 2004, Reimchen and Nosil opined that, contrasting life history pressures and temporal shift in ecology can exert a strong influence on the evolution of sexual dimorphism.

Many fish species show sexual dimorphism, a condition where males and females are different in colour and/or form thus sexes can be detected externally. Perhaps the ultimate in sexual dimorphism occurs in a deep sea ceratioid angler fish. Sexual dimorphism has been reported in many freshwater fish groups. Molly and Inasu (1997) in two inland catfishes, *Ompok bimaculatus* (Bloch) and *Horabagrus brachysoma* (Gunther) and Roychan (2005) in *Anabas testudineus*. However, reports on sexual dimorphism in marine and estuarine teleosts are rather scanty and the main contributors are Jayabalan and Ramamoorthi (1985a) in

However, aforesaid workers discussed the sexual dimorphism in fishes purely based on morphological differences including morphometrics, meristics and external colour differences between the sexes. In leiognathids, sexual dimorphism is rather distinct; because the intra-specific differences is not only based on external morphological structures or colour differences but a special symbiotic bioluminescent circumoesophagial light organ present in this group of fish. Hence all research work regarding the sexual dimorphism in leiognathids are centered around the sexual differences in the internal light organ and associated external modifications resulting in sexual dimorphism (McFall- Ngai and Dunlap, 1984; Dunlap and McFall- Ngai, 1987 and McFall- Ngai and Morin, 1991).

5.1 Symbiotic bioluminescence in Leiognathids

In the order Perciformes, only three families are reported to have representatives with luminous bacterial light organs; Percichthyidae, Apogonidae, and Leiognathidae (Bond, 1996). Family Leiognathidae is the most specious of all the Perciform families with luminous bacterial associations. Approximately 21 species of this family; all have circumoesophagial light organ which harbor the luminescent bacterium, *Photobacterium leiognathi*, extracellularly and open to the alimentary tract. This allows the fish to acquire the bacteria early on its life cycle and to maintain its bacterial population (McFall- Ngai and Morin 1991).
The hypothesized functions of the bacterial light emitted by the leiognathids include camouflage illumination as ventrally directed luminescence compensates for the silhouette of the organism and effectively camouflaging against bottom-dwelling piscivorous fishes (McFall- Ngai and Morin, 1991), schooling (Hastings and Morin, 1991 and Woodland et al., 2002), attracting prey, spacing of individuals in a school and sex-specific signaling - intra specific communication (McFall-Ngai and Dunlap, 1983 and 1984; Dunlap and McFall-Ngai, 1987; McFall- Ngai and Morin, 1991 and Sparks and Dunlap, 2004). To substantiate the above speculations of the functional role of the leiognathid light organ system, McFall-Ngai and Dunlap (1983) have reported three modes of luminescence based on observations in live \textit{Gazza minuta}, held in 1.5 t aquarium. The bioluminescent behavior of \textit{Leiognathus elongates} in their natural habitat and the ecological relevance in terms of intraspecific communication was reported for the first time by Sasaki \textit{et al.} (2003).

5.2 Leiognathid light organ system [LOS]

The general organization of leiognathid light organ system has been well described by several authors (Herring, 1978a and 1978b, 1983; McFall-Ngai, 1983; McFall-Ngai and Dunlap, 1983 and Dunlap and McFall- Ngai, 1987). The circumoesophageal light organ is reported to be consisted of a highly vascularized gland of an oesophageal diverticulam which supplies oxygen and nutrients to the bioluminescent bacteria. This is unknown in other fish groups, including those traditionally hypothesized to be closely related to leiognathids - gerreids and carangoids (James, 1975 and Jones, 1985). The evolution of symbiosis has involved great anatomical changes in the host to form the light organ housing the
bacterial symbionts and accessory structures to control light emission. The surface of the light organ is covered by muscular shutters rich in chromatophores.

Leiognathids were reported to control the intensity and duration of the bacterial luminescence by coordinating both the light organ and the surrounding tissues [The Light Organ System (LOS)], including chromatophore rich muscular shutters, reflecting and transmitting elements in the gas bladder, musculature, bone and transparent skin of either the anteroventral or flank surface - all of which serve to produce an emission which occurs almost exclusively and evenly from the ventral surface (Woodland et al., 2002 and Dunlap, 2007). It is reported that, light from the internally located light organ reaches the outside (ventral) surface via indirect and somewhat sophisticated optics. The gut tract makes a loop into the wall of the swim bladder at the site of the light organ. The organ thus faces directly into the swim bladder and is provided with an eyelid-like flap (muscular shutter) which can control the amount of light shining into the air filled bladder. Some of the light is initially directed into the air bladder, which is internally reflecting, being lined with guanine crystals – the same material which is responsible for the silvery skin of many fish (Denton, 1970 and 1971) from whence it passes to the entire posterior ventral surface by means of reflective and light – conducting muscle fibers and tissues. Many variations were reported on this theme in Leiognathidae (Nealson and Hastings, 1979).

In leiognathids, the sexual dimorphism reported so far was based on its internal light organ and associated external modifications. Most leiognathid species possessed a dimorphic light organ in males and females (Dunlap and McFall-Ngai, 1984; McFall-Ngai and Dunlap, 1984; Sasaki et al., 2003; Sparks et al., 2005 and Ikejima et al., 2008). According to Ikejima (2008), some leiognathid
males possessed enlarged light organs compared to females and in some species, the morphological differences in light organ were so extreme that not only the light organ size, but also the area of the transparent skin patch or stripe become distinct in males.

However, research in this field from the Indian waters is limited to the work in pony fishes collected from the east coast of peninsular India. Jayabal et al. (1978) reported the occurrence of symbiotic bioluminescent bacteria in the silverbelly light organ for the first time from Indian waters. Jayabalan and Ramamoorthi (1979, 1982a, 1982b and 1985a) reported the significance of ventral luminescence and its functions in pony fishes. Jayabalan (1980, 1986b and 1989) worked on the light organ of several silverbelly species from the Porto Novo waters. Jayabalan and Shanbhogue (1984) described the light organ in many pony fish species and its role in the vertical migration undertaken by the fish. Jayabalan and Ramamoorthy (1985a) and Jayabalan (1986b), studied sexual dimorphism in *Leiognathus bindus* (Val) based on light organ characters. Lakshmanaperumal et al. (1981), Ramamoorthy and Jayabalan (1982), Remesh (1989 and 1990), Venugopalan and Remesh (1985) and Remesh and Venugopalan (1987) also deserved special mention for their research in leiognathid light organ.

Review showed that, limited work is done on the internal light organ characters and associated external modifications in leiognathids from India generally and Kerala coast specifically. From the above details, it is obvious that leiognathids provided an extraordinary and unmatched biological system that combines dramatic sexual dimorphism and photic signaling. The light organ system in these fishes differs greatly between species and sexes but is seldom studied and not very well understood. Hence the present study was undertaken to
prove the hypothesis that the light organ in leiognathids are dimorphic in males and females and fish exhibit some external modifications in association with the internal light organ. The species selected for the study included *Secutor insidiator* and *Photopectoralis bindus* distributed along the coastal and estuarine waters along Kerala coast. The research also aimed to test the possible coupling between sexual maturity and secondary development of the light organ in these species.