Chapter 1

GENERAL INTRODUCTION

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1.1 Introduction

Life evolved in the oceans and consequently, the diversity of taxa that live there is enormous. Among these, fishes have been ecological dominants in aquatic habitats through much of the history of complex life. They are excellent showcases of the evolutionary process, exemplifying the intimate relationship between form and function, between habitat and adaptation. By any measure, fishes are among the world’s most important natural resources. Additionally, with over 25,000 known species, the biodiversity and ecological roles of fishes are being increasingly recognized in aquatic conservation, ecosystem management, restoration and aquatic environmental regulation (Ormerod, 2003).

Cochin estuary, a part of the extensive estuarine system of backwaters on the south west coast of India, is a tropical positive estuarine system which is situated at the tip of the northern Vembanad Lake, and is the largest estuary in the state of Kerala, extending between 9º 40’ and 10º 12’ N and 76º 10’ and 76º 30’E with its northern boundary at Azheekode and southern boundary at
Thannirmukkam bund. The salinity gradient in the Cochin Backwaters supports diverse species of flora and fauna, according to their tolerance for saline environment. This tropical estuary with high productivity acts as nursery ground for many species of marine and estuarine fin fishes and molluscs and crustaceans. Low lying swamps and tidal creeks, dominated by sparse patches of mangroves with their nutrient rich physical environment, support larvae and juveniles of many commercially important species. The areas of backwaters with fine sediments and rich organic matter supports abundant and diverse benthic fauna. According to the influence of the southwest monsoon and other associated meteorological conditions, the year may be conveniently split into three well-defined periods with characteristic hydrographic conditions i.e., monsoon (June – September), post-monsoon (October - January) and pre-monsoon (February – May). The changes in the hydrology of backwaters controlled by the seasons play an important role in regulating the migrant fauna of the estuary (Menon et al., 2000). The fishes of tropical estuaries are subject to a range of interactions of physical-chemical and biological processes that determine their patterns of occurrence, distribution and movement (Blaber, 2000). Hence it is desirable to study the various aspects of its biology.

The biology of fish, and in particular its growth and reproductive biology, has been the subject of vast study for many decades. In recent years, 4000-5000 original research papers have been published annually in over 400 journals covering all aspects of fish biology (Cvancara, 1992). Knowledge of fish biology, and the principal factors which determine growth and body composition, is important when considering the role of fish as a source of nutrition.

The Batrachoidiformes commonly referred to as toadfishes (or frogfishes in Australia), are a group of small to medium-sized bottom
dwelling fishes which inhabit the warmer waters of coastal regions of America, Europe, Africa and India. They are found worldwide between about 51°N and 45°S along continents in marine and brackish waters, occasionally entering rivers, with several freshwater species in South America. They are found from the shoreline down to a depth of at least 366 m, often lying buried in the sand or mud, under rocks or coral heads and debris, hiding in crevices and burrows, where they function as ambush predators feeding on crabs, shrimps, molluscs, sea urchins and fishes. Toadfishes are hardy and are able to survive for hours after being removed from the water. They are also experts in camouflage. Their ability to change colour to lighter or darker shades at will and their mottled pattern makes them difficult to see. Toadfishes are said to be quiet vicious and will snap at almost anything upon the slightest provocation. Toadfishes do not school, but they are gregarious and tend to congregate together (Halstead, 1970). They have limited dispersal ability because of their demersal eggs which lack pelagic larvae. Compared to other fishes, they are sluggish in nature.

Though toadfish are not commercially exploited, they are consumed on a small scale by local fishermen but usually end up as a source of fishmeal and oil. A few smaller toadfishes from brackish-water habitats have been exported as fresh-water aquarium fishes. Some batrachoids are venomous. However, the greatest interest of these fishes to biotoxicologists is their unique and highly developed venom organs (Halstead, 1970). Some Batrachoid species have traditionally been used as laboratory animals in the field of physiology (Hopkins et al., 1997; Gilmour et al., 1998; Perry et al., 1998; Paert et al., 1999), toxicology (Gutierrez et al., 1978; Sinovcic et al., 1980; Sarasquete et al., 1982), ethology (Ament et al., 1997; Bass, 1998),
neurobiology (Rabbitt et al., 1995; Fine et al., 1996; Hirsch et al., 1998),
cardiology (Benitez et al., 1994a, b; Coucelo et al., 1996), biomedicine
(Lopes-Ferreira et al., 2000, 2004; Smith and Wheeler, 2006) and
endocrinology (Fine et al., 1996; Knapp et al., 1999). Toadfishes are one of
the best-studied groups for understanding vocal communication in fishes
(Rice and Bass, 2009). The scientific demand for toadfish has spawned to
what may be the world’s smallest fishery (Mensinger and Tubbs, 2006).

The flat toadfish, *Colletteichthys dussumieri* (Valenciennes, 1837) is
a sedentary and solitary species that lives partly buried in soft sand and
mud or concealed in rock crevices, in coral reefs or in sea grass or weedy
bottoms and in tidal pools (Randall, 1995). They are found in the Persian
Gulf and along the coasts of Pakistan, India and Srilanka (Greenfield,
2006). They prefer high saline waters (Kurup and Samuel, 1985). Though
they have no commercial importance in fisheries, but significantly sound
management of vegetated coastal resources relies on the basic knowledge
on the biology of the species, including information on population
structure. Such information influences the development of management
strategies and strategies for conserving biodiversity. Moreover, the flesh of
*C. dussumieri* is said to have ethno-medicinal uses for the cure of asthma
(personal information). Aim of the present study is to provide the first
detailed information on various aspects of biology of the species,
*Colletteichthys dussumieri* of Cochin estuary.

1.2 Literature review

Till recently most of the publications on the toadfishes refers to
taxonomy and systematics and few reports on biological aspects of some
species. Aside from references to *Colletteichthys dussumieri* in purely
systematic papers (Greenfield, 2006; Greenfield et al., 2008) and another regarding morphometrics (Roja et al., 2010), no information is available on any of the aspects of the species. The natural history of only four species has been studied in any detail: *Opsanus tau* (Gudger, 1910; Gray and Winn, 1961; Wilson et al., 1982), *Opsanus beta* (Breder, 1941; Tavolga, 1958, Serafy et al., 1997, Malca et al., 2009), *Porichthys notatus* (Hubbs, 1920; Arora, 1948) and *Halobatrachus didactylus* (Palazon-Fernandez et al., 2001; Pereira et al., 2011), the biology of *C. dussumieri* remains unknown.

Taxonomy forms the very basis of all biological research. Taxonomic documentation is only the first step in understanding our biodiversity. In fact, it is the step without which other research is impossible. Most information about toadfishes refers to taxonomy and systematics and some of the representative publications are those of: Collette, 1966; Greenfield and Greenfield, 1973; Collette and Russo, 1981; Greenfield et al., 1994; Collette, 1995; Randall, 1995; Greenfield, 1996; Greenfield, 1997; Greenfield, 1998; Greenfield, 1999 and Collette et al., 2006.

Biometric studies are useful for the identification of a fish species and for detecting variations in the fish population. Biometry reflects the proportionate growth of different body parts and the influence of environmental factors in a particular habitat. Roja et al. (2010) observed discrepancies in meristic and morphological characters of *C. dussumieri* from estuarine waters of India. Dove (1960) studied the variation in size and morphological changes that take place during the prolarval growing period and metamorphosis to the young stage of *Opsanus tau*. Costa et al. (2003), analysed the Lusitanian toadfish, *Halobatrachus didactylus* from six different localities in terms of morphometric and meristic characters in order to investigate the hypothesis of population fragmentation on the
Portuguese coast. Marques et al. (2005) studied the variation in bilateral asymmetry of the Lusitanian toadfish along the Portuguese coast. Argyriou et al. (2006) recorded the morphometric characters of *H. didactylus* from waters of the Ionian Sea, Western Greece. Marques et al. (2006) assessed the differentiation of *H. didactylus* along the Portuguese coast considering morphological characters (20 morphometric and 16 meristic) and genetic markers (10 allozymes, 11 loci).

Food and feeding habit of the fish in the estuary is of great importance to understand their niche, behavioral patterns, life history, growth and management of commercially important fisheries (Bal and Rao, 1984). A few scientists have dealt with the aspect of food composition and feeding habits of toadfishes. Hubbs (1920) reported that the nocturnally active toadfish, *Porichthys notatus* feed on small crustacean larvae, other zooplankton and small fishes. Linton (1901) noted that alimentary canal of *Opsanus tau* was chiefly filled with crustacean and molluscan remains and the bones and scales of fishes. Gudger (1910) reported that *O. tau* had more preference for blue crab. The food and feeding habits of oyster toadfish near Solomons was assessed by Schwartz and Dutcher (1963). Food habits of *O. tau* in New Jersey waters were studied by McDermott (1965). Feeding and growth by the sessile larvae of *Porichthys notatus* was investigated by Crane (1981). Wilson et al. (1982) analyzed the feeding habits of the oyster toadfish, *Opsanus tau* in South Carolina. Hoffman and Robertson (1983) studied food and feeding habits of two Caribbean reef toadfishes namely, *Amphichthys cryptocentrus* and *Sanopus barbatus*. Granado and Gonzalez (1988) studied the dietary habits of *Amphichthys cryptocentrus*. Mensinger and Tubbs (2006) examined the effects of temperature and diet on the growth of captive year 0 specimens of *Opsanus tau*. 
Detailed investigations on the reproductive biology of a few species of toadfishes are available from different geographical localities. The functions and histology of the yolk-sac of the young toadfish, *Batrachus tau* was studied by Ryder (1890). Gudger (1910) gave a detailed description on the fertilization and embryonic development of oyster toadfish, *Opsanus tau*. Observations on the habits and early life history of plain midshipman (Batrachoididae), *Porichthys notatus* was made by Arora (1948). Hoffman (1963) gave a detailed investigation of the gross and microscopic anatomy and seasonal changes of the reproductive system of male toadfish, *Opsanus tau*. While studying the reproductive ecology and sound production of the toadfish, *Opsanus tau*, Gray and Winn (1961) found a protracted spawning season of the species in the Chesapeake Bay. Hoffman (1963) also analysed the accessory glands and their ducts in the reproductive system of the male toad fish, *O. tau*. Hoffman and Robertson (1983) studied the foraging and reproduction of the two Caribbean Reef toadfishes, *Amphichthys cryptocentrus* and *Sanopus barbatus*. According to them, egg size and number of eggs in the ovaries of the species were similar to those of other toadfishes. Granado and Gonzalez (1988) studied the reproduction and larval development of *Amphichthys cryptocentrus* from the islands of Margarita and Cubagua, Venezuela. Their study was focused on sex ratio, maturity stages, and minimum length at first maturation and fecundity. They identified 5 maturity scale for the species. Annual variations in fecundity, egg size and condition of the plainfin midshipman (*Porichthys notatus*) were evaluated by DeMartini (1990). Gonzalez De Canales et al. (1992) studied histological and histochemical characteristics in *Halobatrachus didactylus* (Schneider, 1801) during oogenesis. Rosety et al. (1992) analysed the biochemical parameters during reproduction of the toadfish, *Halobatrachus didactylus* (Schneider, 1801).
Palazon-Fernandez et al. (2001) worked on some basic reproductive traits (sex ratio, size at sexual maturity, spawning period and fecundity) of *Halobatrachus didactylus*. The morphology of the genital apparatus of two batrachoid species, *Opsanus tau* and *Porichthys notatus*, was studied by Barni *et al.* (2001). The anatomical organization of the female reproductive apparatus was similar in both species but differences were observed in the rhythm of gametogenesis with individual oocyte production asynchronous in *O. tau* and group synchronous in *P. notatus*. Fine *et al.* (2004) studied the seasonal variation in androgen levels in the oyster toadfish. This study quantified gonad development and plasma androgens in males and females throughout a seasonal cycle to relate them to the prolonged reproductive cycle and to quantitative changes in boatwhistle parameters. Habitat, abundance and size at maturity of scarecrow toadfish, *Opsanus phobertron* at Bimini, Bahamas were studied by Newman *et al.* (2004). The presence of large numbers of scarecrow toadfish including mature females, when the water temperature was $>22^\circ$ C, suggests that the species is a successful breeding tropical population and not a glacial relict. Barimo *et al.* (2007) conducted field studies in Florida Bay to examine physiological, ecological and behavioural characteristics of the gulf toadfish, *Opsanus beta*, in relation to nitrogen metabolism, habitat usage, and spawning. Sisneros *et al.* (2009) investigated the morphometric changes associated with the reproductive cycle and behaviour of the intertidal –nesting, male plainfin midshipman *Porichthys notatus*.

Age information forms the basis for calculations of growth rate, mortality rate and productivity, ranking it among the most influential of biological variables. Calculations as simple as that of growth rate, or as complex as that of virtual population analysis, all require age data, since any rate calculation requires an age or elapsed time term (Campana, 2001).
Age and growth in the batrachoididae family have been studied using various methods. Schwartz and Dutcher (1963) employed vertebrae to estimate age in Maryland population of toadfish (*O. tau*) and discerned 12 age groups with sexual difference in growth. Wilson et al. (1982) used otoliths to assess the age structure of a south Carolina population and found most of the toadfish (*O. tau*) were <6 year old with no sexual difference in growth. Radtke et al. (1985) determined somatic and otolith growth in the oyster toadfish (*O. tau*). Serafy et al. (1997) used the length frequency distribution to ascertain the growth of *Opsanus beta* in Biscayne Bay, Florida. Vianna et al. (2000) estimated the growth and mortality of *Porichthys porosissimus* employing length frequency analysis. Malca et al. (2009) determined the age and growth of Gulf toadfish, *Opsanus beta* based on otolith increment analysis. The estimated ages of males and females ranged from <1 year to 6 and 5 years, respectively. Age, growth and mortality of *Halobatrachus didactylus* was investigated by Palazon-Fernandez et al. (2010) using otoliths.

The condition factor (K) (Le Cren, 1951) is a quantitative parameter of the well-being state of the fish and reflects recent feeding conditions. This factor varies according to influences of physiologic factors, fluctuating according to different stages of the development. Anderson and Neumann (1996) refer to length/weight data of population, as basic parameters for any monitoring study of fisheries, since it provides important information concerning the structure and function of populations. Wilbur and Robinson (1960) presented linear regression equations for length, weight and girth relations of *Opsanus tau*. Organ – body weight relationship in *O. tau* was studied by Robinson et al. (1960). Swartz and Van Engel (1968) re-examined the mathematical relations between length, weight and girth in the toadfish,
Wilson et al. (1982) observed no detectable differences in the growth rate or size of age classes of *O. tau* in South Carolina. Similar observations were made by Radtke et al. (1985) for *O. tau*. Muto et al. (2000) reported a positive allometric growth for *Porichthys porosissimus*. Vianna et al. (2000) investigated the length-weight relationship and relative condition factor of *Porichthys porosissimus*. Palazon-Fernandez et al. (2001) assessed the length-weight relationship and condition factor of *Halobatrachus didactylus*.

For better utilization and processing of new resources analysis for proximate chemical composition and nutritional components becomes a prerequisite, especially in case of new varieties of sea food hitherto not analyzed. An understanding of the composition is vital to evaluate each species of fish in terms of quality. Histochemical and biochemical aspects of the lipids of the female toadfish, *Halobatrachus didactylus*, during its annual reproductive cycle were studied by Munoz-Cueto et al. (1996). Investigation on chemical composition of fish from Indian waters has been reported by many workers. Some of the recent studies are as follows. John and Hameed (1995) studied the biochemical composition of *Nemipterus japonicus* and *Nemipterus mesoprion* in relation to maturity cycle. Mohanty and Samantaray (1996) studied the biochemical composition of juvenile *Channa striatus* and associated the data with the reproductive cycle and water temperature. Shendge and Mane (2007) correlated seasonal variation in the biochemical composition of cyprinid fish, *Cirrhinus reba* (Hamilton) with the reproductive cycle. Changes in biochemical composition of muscles of an Indian major carp, *Labeo rohita* in influence of age was investigated by Gangwar et al. (2007). Nutritive value of *Botia berdmorei* and *Lepidocephalus guntea*, endemic in the water bodies of Manipur (India) has been studied by Sarojnalini (2010). The nutritive value of six important
commercial fishes from India was validated by Ravichandran et al. (2011) and the nutritive parameters included protein, fatty acid, carbohydrate and moisture.

From the foregoing account it is seen that so far no attempt has been made to study the various aspects of biology of flat toadfish, *Colletteichthys dussumieri*. Though not important as a food fish, the species is an interesting batrachoid on account of its peculiar mode of life, habitat and parental care. Therefore, it was thought worthwhile to scrutinize in detail the various aspects of its biology.

1.3 **Objectives of the study**

- To study the systematics of the fish, *Colletteichthys dussumieri*
- To study the growth of morphometric variables in relation to total length
- To analyse the food and feeding habits
- To determine the fecundity and factors influencing reproduction
- To calculate the age and growth of the fish by otolith analysis
- To determine length – weight relationship and condition factor
- To analyse the proximate biochemical constituent to elucidate its nutritional status

1.4 **General organization of the thesis**

The thesis is organized into nine chapters.

**First chapter** comprises of general introduction, importance of the present study, review of works done on family Batrachoididae, the objectives of present study and the general organization of thesis.
The salient features of *C. dussumieri* together with its systematic position are described in the **second chapter**. A key for identification of species is also included.

The **third chapter** examines the morphometric characters in order to determine changes with growth and differences between sexes.

Information on the qualitative and quantitative aspects of food composition in relation to sex and season, relative length of gut, seasonal variation in feeding intensity and gasto-somatic index are presented in the **fourth chapter**.

The **fifth chapter** incorporates various aspects of reproduction. The dynamics of spermatogenesis and oogenesis of the fish species are illustrated with the help of the histological studies of ovary and testis in different stages of maturity. Maturity stages of males and females, monthly percentage occurrence of fish with gonads in different stages of maturity, pattern of progression of ova during different months, gonado-somatic index, minimum length at first maturity, sex ratio and fecundity and its relationship to various body parameters are the various reproductive and biological aspects discussed in this chapter.

Estimation of age and growth characteristics, worked out separately for male and female populations by otolith analysis are dealt in **chapter six**. Validating the annual periodicity of growth zone formation by performing a marginal increment analysis, determination of growth parameters, natural mortality, longevity and growth performance index are also presented.

The **seventh chapter** put forth the relationship between total length (mm) and body weight (g) in both the sexes. This chapter also describes the
seasonal and size-wise variation of relative condition factor (Kn) and Ponderal index (K) of the fish.

The **eighth chapter** evaluates the nutritive value of the species by analyzing the proximate composition. Seasonal variations in protein, lipid, carbohydrate and moisture contents were estimated.

Finally, in **ninth chapter** results from the whole study are summarized.

In general, each chapter is subdivided into brief introduction, materials and methods, results and discussion. Table, graphs and photographs are inserted at appropriate places. The relevant references pertaining to the above chapters have been given at the end.